Australian Government
Department of Infrastructure and Regional Development

WESTERN SYDNEY AIRPORT



DRAFT ENVIRONMENTAL IMPACT STATEMENT

VOLUME 4
TECHNICAL REPORTS

VOLUME 4

Appendix A
Proponent details and environment record

Proponent information

Title of the action	Proposed Western Sydney Airport
EPBC Referral Number	2014-7391
Designated proponent	Department of Infrastructure and Regional Development
ABN	86 267 354 017
Postal address	GPO Box 594, Canberra ACT 2601

Environmental record of the responsible party

		Yes	No
1	**Does the party taking the action have a satisfactory record of responsible environmental management?** The Commonwealth Government, as represented by the Department of Infrastructure and Regional Development, has demonstrated commitment to responsible environmental management.	**X**	
2	**Has either (a) the party proposing to take the action, or (b) if a permit has been applied for in relation to the action, the person making the application - ever been subject to any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources?** The Commonwealth Government, through its various departments and agencies, has been subject to proceedings various jurisdictions in relation to the protection of the environment and the conservation and sustainable use of natural resources.	**X**	
3	**If the party taking the action is a corporation, will the action be taken in accordance with the corporation's environmental policy and planning framework?** The Commonwealth Government is not a corporation.		**X**
4	**Has the party taking the action previously referred an action under the EPBC Act, or been responsible for undertaking an action referred under the EPBC Act?** The Commonwealth Government, through its various departments and agencies, has undertaken numerous activities which have been the subject of referral and approval under the EPBC Act.	**X**	

VOLUME 4

Appendix B
EIS study team

Names of persons involved in preparing the EIS

Name	Organisation	Role in the EIS
Project leadership team		
Brendan McRandle	Department of Infrastructure and Regional Development	Executive Director, Western Sydney Unit
Peter Robertson	Department of Infrastructure and Regional Development	General Manager, Western Sydney Unit
Lisa Webber Corr	Department of Infrastructure and Regional Development	Director, Western Sydney Unit
Phil Hambly	Department of Infrastructure and Regional Development	Assistant Director, Western Sydney Unit
Mitchell Neto	Department of Infrastructure and Regional Development	Assistant Director, Western Sydney Unit
Charlene Liau	Department of Infrastructure and Regional Development	Policy Officer, Western Sydney Unit
Scott Maxwell	Department of Infrastructure and Regional Development	Policy Officer, Western Sydney Unit
Alexander Dallwitz	Department of Infrastructure and Regional Development	Graduate, Western Sydney Unit
David Chubb	GHD Pty Ltd	Project manager
Greg Marshall	GHD Pty Ltd	Technical study manager
Tom Ryan	GHD Pty Ltd	PMO interface manager
Michael Goodall	GHD Pty Ltd	Project co-ordinator
Helen Weston	Environmental Affairs Pty Ltd	Strategic advisor
EIS documentation		
Jon Williamson	RPS Manidis Roberts Pty Ltd	EIS documentation lead
Stuart Hill	RPS Manidis Roberts Pty Ltd	EIS documentation team
Nick Johnson	RPS Manidis Roberts Pty Ltd	EIS documentation team
Aaron Bowden	RPS Manidis Roberts Pty Ltd	EIS documentation team
Karl Rosen	GHD Pty Ltd	EIS documentation lead
Sophy Townsend	GHD Pty Ltd	EIS documentation team
Kate Panayotou	GHD Pty Ltd	EIS documentation team
Goulan Kaddour	GHD Pty Ltd	Word processing

Name	Organisation	Role in the EIS
Isabel Workman	Big Picture Communications Pty Ltd	Editor
Geospatial and graphics		
Brook Hambly	GHD Pty Ltd	Lead geospatial analyst
Andrew Foddy	GHD Pty Ltd	Geospatial support
Adrian Miller	GHD Pty Ltd	Geospatial support
Jade Richardson	GHD Pty Ltd	Geospatial support
Michelle Vergis	RPS Manidis Roberts Pty Ltd	Creative Design lead
Tabatha Redreau	RPS Manidis Roberts Pty Ltd	Creative Design consultant
Community and stakeholder		
Meegan Sullivan	RPS Manidis Roberts Pty Ltd	Community and stakeholder manager
Romina Cavallo	RPS Manidis Roberts Pty Ltd	Community and stakeholder specialist
Michael Robertson	GHD Pty Ltd	Community and stakeholder specialist
Allen Rodwell	GHD Pty Ltd	Community and stakeholder specialist
Biodiversity		
Jayne Tipping	GHD Pty Ltd	Biodiversity assessment team lead
Dan Williams	GHD Pty Ltd	Biodiversity offset team lead
Ben Harrington	GHD Pty Ltd	Biodiversity documentation lead
Kirsten Crosby	GHD Pty Ltd	Biodiversity documentation team
Malith Weerakoon	GHD Pty Ltd	Biodiversity documentation team
Air quality and greenhouse gas		
Damon Roddis	Pacific Environment Operations Pty Ltd	Local air quality and greenhouse gas lead
Paul Boulter	Pacific Environment Operations Pty Ltd	Technical advisor
Justine Firth	Pacific Environment Operations Pty Ltd	Local air quality lead
Calum Philips	Pacific Environment Operations Pty Ltd	Technical assistant
Liza McDonough	Pacific Environment Operations Pty Ltd	Technical assistant
Noise and vibration		
Barry Murray	Wilkinson Murray Pty Ltd	Noise and vibration lead
John Wasserman	Wilkinson Murray Pty Ltd	Project co-ordinator
Rob Bullen	Wilkinson Murray Pty Ltd	Aircraft noise lead

Name	Organisation	Role in the EIS
Ben Lawrence	Wilkinson Murray Pty Ltd	Ground-based noise lead
Brian Clarke	Wilkinson Murray Pty Ltd	Aircraft noise coordinator
Adam Bioletti	Wilkinson Murray Pty Ltd	Aircraft noise modeller
Tim Collins	Wilkinson Murray Pty Ltd	Ground-based noise modeller
Hazard and risk		
Richard Robinson	R2A Pty Ltd	Hazard and risk team lead
Gaye Francis	R2A Pty Ltd	Technical advisor
Janelle Adrain	Health and Safety Essentials Pty Ltd	Dangerous goods
Captain Sandy Robinson	R2A Pty Ltd	Aviation advisor
Dr Tony Enright	Enright Consulting	Fire modelling
James Robinson	R2A Pty Ltd	Mathematical modelling
Surface water, groundwater and water quality		
Nicola Bailey	GHD Pty Ltd	Surface water hydrology lead
Laura Thomas	GHD Pty Ltd	Hydrologist
Robin Connolly	GHD Pty Ltd	Hydraulic modeller
Guy Lampert	GHD Pty Ltd	Geomorphologist
Stefan Charteris	GHD Pty Ltd	Hydrogeologist
Ricky Kwan	GHD Pty Ltd	Surface water quality lead
Sam Douglas	GHD Pty Ltd	Water quality modeller
Community health		
Lyn Denison	Pacific Environment Operations Pty Ltd	Community health lead
Dr Andrew Buroni	RPS Group UK	Community health technical specialist
European and other heritage		
Erin Williams	RPS Manidis Roberts Pty Ltd	European heritage lead
Deborah Farina	RPS Manidis Roberts Pty Ltd	European heritage team
Georgia Wright	RPS Manidis Roberts Pty Ltd	European heritage team
Alexandra Byrne	RPS Manidis Roberts Pty Ltd	European heritage team
Joshua Madden	RPS Manidis Roberts Pty Ltd	European heritage team
Jakob Ruhl	RPS Manidis Roberts Pty Ltd	European heritage team

Name	Organisation	Role in the EIS
Planning and land use		
Liz Coker	RPS Manidis Roberts Pty Ltd	Planning and land use lead
Jaime Bohm	RPS Manidis Roberts Pty Ltd	Planning and land use team
Aaron Bowden	RPS Manidis Roberts Pty Ltd	Planning and land use team
Visual and landscape		
Kris Peterson	RPS Manidis Roberts Pty Ltd	Visual and landscape lead
Peter McLean	Lighting, Art and Science	Lighting assessment
Regional air quality		
Greg Yarwood	Environ Australia Pty Ltd	Technical director
Ronan Kellaghan	Environ Australia Pty Ltd	Project manager
Prakash Karamchandani	Environ Australia Pty Ltd	Modelling manager
Gary Wilson	Environ Australia Pty Ltd	Lead emissions modeller
Yoann Long	Environ Australia Pty Ltd	Emissions modeller
Megan Neiderhiser	Environ Australia Pty Ltd	Emissions modeller
Traffic and access		
Graham McCabe	GHD Pty Ltd	Traffic and access lead
Tony Frodsham	GHD Pty Ltd	Traffic technical reviewer
Simon Payne	GHD Pty Ltd	Traffic modelling
Keith Varga	GHD Pty Ltd	Traffic engineering
Karen McNatty	GHD Pty Ltd	Construction traffic assessment
Caitlyn Tretheway	GHD Pty Ltd	Trip generation support
Owen Peel	GHD Pty Ltd	Traffic impact assessment specialist
Matthew Thompson	GHD Pty Ltd	Transport planning
Sergio Garcia	GHD Pty Ltd	Transport planning support
Bird and bat strike		
Phil Shaw	Avisure Pty Ltd	Bird and bat strike risk assessment lead
Kylie Patrick	Avisure Pty Ltd	Bird and bat strike risk assessment team
Jeff Follett	Avisure Pty Ltd	Bird and bat strike risk assessment team
Matt Smyth	Avisure Pty Ltd	Bird and bat strike risk assessment team

Name	Organisation	Role in the EIS
Sharon Worthing	Avisure Pty Ltd	Bird and bat strike risk assessment team
Social impact		
Dr Pallavi Mandke	GHD Pty Ltd	Socio-economic assessment team lead
Lauren Harding	GHD Pty Ltd	Socio-economic assessment specialist
Jayne Mooney	GHD Pty Ltd	Socio-economic assessment researcher
Elle Davidson	GHD Pty Ltd	Socio-economic assessment researcher
Tamsin Fisher	GHD Pty Ltd	Socio-economic assessment researcher
Aboriginal cultural heritage		
Kelvin Officer	Navin Officer Heritage Consultants	European and Aboriginal heritage study manager
Kerry Navin	Navin Officer Heritage Consultants	Report editing
Nicola Hayes	Navin Officer Heritage Consultants	Survey manager
Jo Dibden	Navin Officer Heritage Consultants	Survey archaeologist
Oliver MacGregor	Navin Officer Heritage Consultants	Stone artefact analysis
Jill Huntley	Navin Officer Heritage Consultants	Supplementary artefact analysis
Economics		
Oliver Jones	Ernst & Young	Economics specialist lead
Lars Rognlien	Ernst & Young	Economics specialist
Filipe Barros	Ernst & Young	Economics specialist
Property values		
Tim Brown	Jones Lang Lasalle	Real estate lead
Graham Coutts	Jones Lang Lasalle	Real estate specialist
Daniel Turini	Jones Lang Lasalle	Real estate specialist
Thomas While	Jones Lang Lasalle	Real estate specialist
Waste and resources		
David Gamble	GHD	Waste and resources lead
Andrew Quinn	GHD	Waste management lead
Utilities and services		
Garry Taylor	GHD Pty Ltd	Infrastructure team lead

Name	Organisation	Role in the EIS
David Williamson	GHD Pty Ltd	Infrastructure team member
Contamination		
Helen Milne	GHD Pty Ltd	Contamination technical reviewer
Matthew Clutterham	GHD Pty Ltd	Contamination lead
Melissa Weber	GHD Pty Ltd	Contamination specialist
Bianca Iverson	GHD Pty Ltd	Contamination specialist
Vaughan Wilton	GHD Pty Ltd	Contamination specialist
Bushfire		
Paul De Mar	GHD Pty Ltd	Bushfire technical reviewer
Dominic Adshead	GHD Pty Ltd	Bushfire lead
Paul Dellow	GHD Pty Ltd	Bushfire specialist

VOLUME 4

Appendix C
Western Sydney Airport EIS Guidelines



GUIDELINES FOR THE CONTENT OF A DRAFT ENVIRONMENTAL IMPACT STATEMENT

Western Sydney Airport

Environment Protection and Biodiversity Conservation Act 1999

(Reference: EPBC 2014/7391)

GUIDELINES FOR A DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR

Western Sydney Airport

Department of Infrastructure and Regional Development

PREAMBLE

The proposal is to construct and operate a Western Sydney Airport at Badgerys Creek, New South Wales. Development of the proposed airport would be staged in response to demand, with an initial stage including one runway and an ultimate airport layout of two parallel runways on a broadly north-east/south-west orientation of up to 4,000 metres in length, with supporting airside and landside facilities capable of handling up to about 70 million passengers movements per year. The proposed airport would operate on a 24-hour basis.

Construction of the proposed action is scheduled for possible commencement in 2016 with airport operations commencing in the mid-2020s. The proposed airport could reach its full operational scale with parallel runways and terminal capacity to handle a minimum of approximately 54 million passenger movements annually from 2060.

The proposal was referred by the Department of Infrastructure and Regional Development under the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) to the Minister for the Environment and Heritage on 4 December 2014. The delegate of the Minister determined on 23 December 2014 that approval is required as the action has the potential to have a significant impact on the following matters of national environmental significance (NES) and other matters that are protected under Part 3 of the EPBC Act:

- Listed threatened species and ecological communities (section 18 & section18A);
- The heritage values of a National Heritage place (section15B & section15C);
- The world heritage values of a declared World Heritage property (section12 & section15A);
- The environment because the proposal is a Commonwealth action (section 28).

The delegate of the Minister determined on 23 December 2014 that the proposed activity be assessed by Environmental Impact Statement (EIS).

Information about the action and its relevant impacts, as outlined below, is to be provided in the EIS. This information should be sufficient to allow the Minister to make an informed decision on whether or not to approve, under Part 9 of the EPBC Act, the taking of the action for the purposes of each controlling provision.

GENERAL ADVICE ON GUIDELINES

1 GENERAL CONTENT

The EIS should be a stand-alone document that primarily focuses on the matters of NES and other matters listed above. It should contain sufficient information to avoid the need to search out previous or supplementary reports. The EIS should take into consideration the EPBC Act Significant Impact Guidelines that can be downloaded from the following web site: http://www.environment.gov.au/epbc/guidelines-policies.html.

The EIS should enable interested stakeholders and the Minister to understand the environmental consequences of the proposed development. Information provided in the EIS should be objective, clear, and succinct and, where appropriate, be supported by maps, plans, diagrams or other descriptive detail. The body of the EIS is to be written in a clear and concise style that is easily understood by the general reader. Technical jargon should be avoided wherever possible. Cross-referencing should be used to avoid unnecessary duplication of text.

Detailed technical information, studies or investigations necessary to support the main text should be included as appendices to the EIS. It is recommended that any additional supporting documentation and studies, reports or literature not normally available to the public from which information has been extracted be made available at appropriate locations during the period of public display of the EIS.

After receiving the Minister's approval to publish the report, the Proponent is required to make the draft EIS available for a period of public comment. Specific instructions regarding publication requirements will be provided as part of the Minister's direction to publish.

If it is necessary to make use of material that is considered to be of a confidential nature, the Proponent should consult with the Department on the preferred presentation of that material, before submitting it to the Minister for approval for publication.

The level of analysis and detail in the EIS should reflect the level of significance of the expected impacts on the environment. Any and all unknown variables or assumptions made in the assessment must be clearly stated and discussed. The extent to which the limitations, if any, of available information may influence the conclusions of the environmental assessment should be discussed.

The Proponent should ensure that the EIS assesses compliance of the action with the principles of Ecologically Sustainable Development as set out in the EPBC Act, and the objects of the Act at Attachment 1. A copy of Schedule 4 of the EPBC Regulations, - *Matters to be addressed by draft public environment report and environmental impact statement* is at Attachment 2.

2 FORMAT AND STYLE

The EIS should comprise three elements, namely:

- the executive summary;
- the main text of the document, and
- appendices containing detailed technical information and other information that can be made publicly available.

These guidelines are set out in a manner that may be adopted as the format for the EIS. This format need not be followed where the required information can be more effectively presented in an alternative way. However, each of the elements must be addressed to meet the requirements of the EPBC Act and Regulations.

The EIS should be written so that any conclusions reached can be independently assessed. To this end all sources must be appropriately referenced using the Harvard standard. The reference list should include the address of any Internet "web" pages used as data sources.

The main text of the EIS should include a list of abbreviations, a glossary of terms and appendices containing:

- a copy of these guidelines;
- a list of persons and agencies consulted during the EIS;
- contact details for the Proponent; and
- the names of the persons involved in preparing the EIS and work done by each of these persons.

Maps, diagrams and other illustrative material should be included in the EIS. The EIS should be produced on A4 size paper capable of being photocopied, with maps and diagrams on A4 or A3 size and in colour where possible.

The Proponent should consider the format and style of the document appropriate for publication on the Internet. The capacity of the website to store data and display the material may have some bearing on how the document is constructed.

SPECIFIC CONTENT

1 GENERAL INFORMATION

This should provide the background and context of the action including:

(a) the title of the action;

(b) the full name and postal address of the designated Proponent;

(c) a clear outline of the objective of the action;

(d) the location of the action;

(e) the background to the development of the action;

(f) how the action relates to any other actions (of which the Proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action;

(g) the current status of the action; and

(h) the consequences of not proceeding with the action.

2 DESCRIPTION OF THE ACTION

All construction, operational and (if relevant) decommissioning components of the action should be described in detail. This should include the precise location (including coordinates) of all works to be undertaken, structures to be built or elements of the action that may have impacts on matters of National Environmental Significance.

The description of the action must also include details on how the works are to be undertaken (including stages of development and their timing) and design parameters for those aspects of the structures or elements of the action that may have relevant impacts.

3 FEASIBLE ALTERNATIVES

Any feasible alternatives to the action to the extent reasonably practicable, including:

(a) if relevant, the alternative of taking no action;

(b) a comparative description of the impacts of each alternative on the matters of national environmental significance and other matters protected by controlling provisions of Part 3 of the EPBC Act for the action; and

(c) sufficient detail to make clear why any alternative is preferred to another.

Short, medium and long-term advantages and disadvantages of the options should be discussed.

4 DESCRIPTION OF THE ENVIRONMENT

The EIS must include a description of the environment, land uses and character of the proposal site and the surrounding areas that may be affected by the action. It is recommended that this include the following information:

(a) Listed threatened species (including suitable habitat) and ecological communities that are or are likely to be present in all areas of potential impact. To satisfy this requirement details must be presented on the scope, timing/effort (survey season/s) and methodology for studies and surveys used to provide information on the relevant listed threatened species/ecological community/habitat (as identified in Attachment 3). This includes details of:

- how best practice survey guidelines have been applied
- how surveys are consistent with (or a justification for divergence from) published Australian Government guidelines and policy statements.

(b) A description of the World Heritage/National Heritage values of the Greater Blue Mountains Area World Heritage property/National Heritage Place, as described in the Statement of Outstanding Universal Value and including reference to the World Heritage criteria the area is listed for as well as the integrity of the property.

(c) A description of the environment[1] in all areas of potential impact, including all components of the environment as defined in Section 528 of the EPBC Act:

- *ecosystems and their constituent parts, including people and communities*
- *natural and physical resources*
- *the qualities and characteristics of locations, places and areas*
- *Heritage values of places*
- *the social, economic and cultural aspects of a thing mentioned in preceding dot points.*[2]

5 RELEVANT IMPACTS

(a) The EIS must include a description of all of the relevant impacts of the action. Relevant impacts are impacts that the action will have or is likely to have on a matter protected by a controlling provision (as listed in the preamble of this document). Impacts during both the construction, operational and (if relevant) the

[1] See *EPBC Act Policy Statement - Definition of 'Environment' under section 528 of the EPBC Act* http://www.environment.gov.au/resource/epbc-act-policy-statement-definition-environment-under-section-528-epbc-act

[2] The social, economic and cultural 'aspects' of the environment are different to the economic and social 'matters' which must be considered under paragraph 136(1)(b) when the decision-maker decides whether or not to approve the taking of an action.
Paragraph 136 (1)(b) relates to economic and social matters associated with the taking of the action overall, whereas section 528(e) provides that social, economic and cultural aspects of, particular ecosystems and natural resources constitute the environment.

decommissioning phases of the project should be addressed, and the following information provided:

- a detailed assessment of the nature and extent of the likely short-term and long-term relevant impacts (detailing direct and indirect impacts);
- a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible;
- analysis of the significance of the relevant impacts; and
- any technical data and other information used or needed to make a detailed assessment of the relevant impacts.

(b) The EIS should identify and address cumulative impacts, where potential project impacts are in addition to existing impacts of other activities (including known potential future expansions or developments by the proponent and other proponents in the region and vicinity).

The EIS should address the potential cumulative impact of the proposal on ecosystem resilience. The cumulative effects of climate change impacts on the environment must also be considered in the assessment of ecosystem resilience. Where relevant to the potential impact, a risk assessment should be conducted and documented.

(c) The EIS should address the potential for facilitated impacts upon MNES at the local, regional, state, national and international scale.

(d) If the conclusion is made that any relevant controlling provision or element of a relevant controlling provision will not be impacted by the proposed action, then justification must be provided for how this conclusion has been reached. This includes any threatened species or ecological communities that are likely to be present on site, heritage items/places likely to be on site and other relevant elements of the environment that may be impacted by the proposed action.

(e) To support the assessment of local historic and indigenous heritage values, the EIS must include a full heritage impact assessment and the findings of the further program of archaeological survey that was foreshadowed in the referral for this project.

(f) Further details of threatened species and ecological communities protected by the controlling provisions of Part 3 of the EPBC Act are provided at Attachment 3.

(g) Impacts to the environment (as defined in section 528) should include but not be limited to the following[3]:

- changes to water quality on site and downstream of the site

[3] Note that the Greater Blue Mountains World Heritage Area and National Heritage Place is part of the environment and must be considered when describing the relevant impacts.

- changes to siltation
- hydrological changes
- removal and degradation of heritage items/places (historic, natural and indigenous)
- native flora and fauna habitat removal and degradation (on site and in surrounding areas that may be affected by the action)
- aircraft noise and vibration impacts on everyday activities and on sensitive environmental receptors (all sensitive receptors within the community and natural environment). Discussion and quantification/modelling of aircraft noise impacts should include consideration of all potential flight paths, height of flights, noise exposure patterns, noise contours, the range of frequencies of the noise, cumulative exposure, peak noise, frequency of overflights and temporal variability of this (including long term trends), varying aircraft types, varying aircraft operating procedures, and variations in noise patterns due to seasonal and meteorological factors
- noise and vibration from construction activities and machinery
- changes to air quality during construction and operation (including consideration of seasonal and meteorological variations that influence local air quality)
- potential fuel dumping impacts
- changes in traffic movements during construction and operation (associated with both passenger movements and workers)
- bird or bat airstrike
- lighting impacts on everyday activities and on sensitive environmental receptors (all sensitive receptors within the community and natural environment)
- changes in recreational use and amenity of natural areas
- change in qualities and characteristics of the surrounding areas and associated impacts to local communities (including land values and other economic impacts)
- creation of any risks or hazards to people or property that may be associated with any component of the action.

Quantification and assessment of impacts should:

- be against appropriate background/baseline levels
- be prepared according to best practice guidelines and compared to best practice standards

- consider seasonal and temporal variations where appropriate (including temporal changes in the sensitivity of the receptor)
- be supported by maps, graphs and diagrams as appropriate to ensure information is readily understandable

Guidelines and standards used to quantify baselines and impacts should be explained and justified.

6 AVOIDANCE AND MITIGATION MEASURES

(a) The EIS must provide information on proposed avoidance and mitigation measures to manage the relevant impact of the action on a matter protected by a controlling provision (as listed in the preamble of this document).

(b) The EIS must take into account relevant agreements and plans that cover impacts or known threats to a matter protected by a controlling provision (including but not necessarily limited to):

(a) any recovery plan and/or conservation advice for the affected species or ecological community

(b) any threat abatement plan for a process that threatens an affected species or ecological community

(c) any wildlife conservation plan for the affected species

(d) any relevant strategic assessment undertaken in accordance with an agreement under Part 10 of the EPBC Act.

(e) For the *Greater Blue Mountains Area World Heritage property,* the World Heritage Convention; the Australian World Heritage Management Principles; the *Greater Blue Mountains Area World Heritage Area Strategic Plan*[4]*, and relevant NSW National Parks and Wildlife Service/Office of Environment and Heritage Plans of Management.*

(c) The EIS must include specific and detailed descriptions of the proposed avoidance and mitigation measures based on best available practices. This must include the following elements :

i. A consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or compensate for the relevant impacts of the action, including:

- a detailed description of proposed measures;
- assessment of the expected or predicted effectiveness of the mitigation measures;
- any statutory or policy basis for the mitigation measures; and

[4] Refer to EPBC Act s322 Commonwealth Responsibilities

- the likely cost of the mitigation measures.

ii. A detailed outline of a plan for the continuing management, mitigation and monitoring of relevant matters protected by a controlling provision, including a description of the outcomes that will be achieved and any provisions for independent environmental auditing.

iii. Where appropriate, each project phase (construction and operation) must be addressed separately. It must state the environmental outcomes, performance criteria, monitoring, reporting, corrective action, contingencies, responsibility and timing for each environmental issue.

iv. The name of the agency responsible for endorsing or approving each mitigation measure or monitoring program.

7 RESIDUAL IMPACTS AND OFFSETS

Residual impacts

a) The EIS must provide details of the likely residual impacts upon a matter protected by a controlling provision after the proposed avoidance and mitigation measures have been taken into account. This includes:

   i the reasons why avoidance or mitigation of impacts may not be reasonably achieved

   ii quantification of the extent and scope of significant residual impacts.

Offset Package

a) The EIS must include details of an offset package to be implemented to compensate for residual significant impacts associated with the project, as well as an analysis of how the offset meets the requirements of the Department's *Environment Protection and Biodiversity Conservation Act 1999* Environmental Offsets Policy October 2012 (EPBC Act Offset Policy).

b) The offset package can comprise a combination of direct offsets and other compensatory measures, as long as it meets the requirements of the EPBC Act Offset Policy. Offsets should align with conservation priorities for the impacted protected matter and be tailored specifically to the attribute of the protected matter that is impacted in order to deliver a conservation gain.

c) Offsets should compensate for an impact for the full duration of the impact.

d) Offsets must directly contribute to the ongoing viability of the protected matter impacted by the project and deliver an overall conservation outcome that maintains or improves the viability of the protected matter, compared to what is likely to have occurred under the 'status quo' (i.e. if the action and associated offset had not taken place).

e) Note: offsets do not make an unacceptable impact acceptable and do not reduce the likely impacts of a proposed action. Instead, offsets compensate for any residual significant impact.

f) The EIS must provide:

   i details of the offset package to compensate for significant residual impacts on a protected matter; and

   ii an analysis of how the offset package meets the requirements of the EPBC Act Offsets Policy.

Further details of information requirements for EPBC Act offset proposals are provided at Attachment 4.

8 ENVIRONMENTAL RECORD OF PERSON(S) PROPOSING TO TAKE THE ACTION

a) The information provided must include details of any past or current proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:

   i the person proposing to take the action

   ii the person making the application for any related permits.

b) If the person proposing to take the action is a corporation, details of the corporation's environmental policy and planning framework must also be included.

9 OTHER APPROVALS AND CONDITIONS

The EIS must include information on any other requirements for approval or conditions that apply, or that the proponent reasonably believes are likely to apply, to the proposed action. This must include:

(a) details of any local or State Government planning scheme, or plan or policy under any local or State Government planning system that deals with the proposed action, including:

- what environmental assessment of the proposed action has been, or is being, carried out under the scheme, plan or policy; and
- how the scheme provides for the prevention, minimisation and management of any relevant impacts;

(b) a description of any approval that has been obtained from a State, Territory or Commonwealth agency or authority (other than an approval under the Act), including any conditions that apply to the action;

(c) a statement identifying any additional approval that is required; and

(d) a description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action.

10 ECONOMIC AND SOCIAL MATTERS

a) The economic and social impacts of the action, both positive and negative, must be analysed. Matters of interest may include:

i details of any public consultation activities undertaken, and their outcomes

ii details of any consultation with Indigenous stakeholders

iii projected economic costs and benefits of the project, including the basis for their estimation through cost/benefit analysis or similar studies

iv employment opportunities expected to be generated by the project (including construction and operational phases).

b) The economic and social impacts must include impacts at the local, regional and national level.

c) Details of the relevant cost and benefits of alternative options to the proposed action, as identified in Section 3, should also be included.

11 INFORMATION SOURCES PROVIDED IN THE EIS

For information given in the EIS, the EIS must state:

(a) the source of the information

(b) how recent the information is

(c) how the reliability of the information was tested

(d) what uncertainties (if any) are in the information

(e) what guidelines, plans and/or policies have been considered during preparation of the EIS.

12 CONCLUSION

An overall conclusion as to the environmental acceptability of the proposal on protected matters must be provided, which includes:

a) a discussion on how consideration has been given to the objects of the EPBC Act, the principles of ecologically sustainable development, and the precautionary principle (as detailed at Attachment 1)

b) justification for undertaking the proposal in the manner proposed, including the acceptability of the avoidance and mitigation measures

c) if relevant, a discussion of residual impacts and any offsets and compensatory measures proposed or required for significant residual impacts on protected matters, and the relative degree of compensation and acceptability.

ATTACHMENT 1

THE OBJECTS AND PRINCIPLES OF THE

ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999

SECTIONS 3 AND 3A

3 Objects of the Act

(a) to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance;

(b) to promote ecologically sustainable development through the conservation and ecologically sustainable use of natural resources;

(c) to promote the conservation of biodiversity;

(d) to promote a co-operative approach to the protection and management of the environment involving governments, the community, land-holders and indigenous peoples;

(e) to assist in the co-operative implementation of Australia's international environmental responsibilities;

(f) to recognise the role of indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity; and

(g) to promote the use of indigenous peoples' knowledge of biodiversity with the involvement of, and in co-operation with, the owners of the knowledge.

3A Principles of Ecologically Sustainable Development

The following principles are principles of ecologically sustainable development.

(a) Decision-making processes should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.

(b) If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

(c) The principle of inter-generational equity – that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.

(d) The conservation of biological diversity and ecological integrity should be a fundamental consideration in decision-making.

(e) Improved valuation, pricing and incentive mechanisms should be promoted.

ATTACHMENT 2

MATTERS THAT MUST BE ADDRESSED IN A PER AND EIS

(SCHEDULE 4 OF THE EPBC REGULATIONS 2000)

1 General information

1.01 The background of the action including:

(a) the title of the action;

(b) the full name and postal address of the designated Proponent;

(c) a clear outline of the objective of the action;

(d) the location of the action;

(e) the background to the development of the action;

(f) how the action relates to any other actions (of which the Proponent should reasonably be aware) that have been, or are being, taken or that have been approved in the region affected by the action;

(g) the current status of the action; and

(h) the consequences of not proceeding with the action.

2 Description

2.01 A description of the action, including:

(a) all the components of the action;

(b) the precise location of any works to be undertaken, structures to be built or elements of the action that may have relevant impacts;

(c) how the works are to be undertaken and design parameters for those aspects of the structures or elements of the action that may have relevant impacts;

(d) relevant impacts of the action;

(e) proposed safeguards and mitigation measures to deal with relevant impacts of the action;

(f) any other requirements for approval or conditions that apply, or that the Proponent reasonably believes are likely to apply, to the proposed action;

(g) to the extent reasonably practicable, any feasible alternatives to the action, including:

(i) if relevant, the alternative of taking no action;

(ii) a comparative description of the impacts of each alternative on the matters protected by the controlling provisions for the action; and

(iii) sufficient detail to make clear why any alternative is preferred to another;

(h) any consultation about the action, including:

(i) any consultation that has already taken place;

(ii) proposed consultation about relevant impacts of the action; and

(iii) if there has been consultation about the proposed action — any documented response to, or result of, the consultation; and

(i) identification of affected parties, including a statement mentioning any communities that may be affected and describing their views.

3 Relevant impacts

3.01 Information given under paragraph 2.01(d) must include

(a) a description of the relevant impacts of the action;

(b) a detailed assessment of the nature and extent of the likely short term and long term relevant impacts;

(c) a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible;

(d) analysis of the significance of the relevant impacts; and

(e) any technical data and other information used or needed to make a detailed assessment of the relevant impacts.

4 Proposed safeguards and mitigation measures

4.01 Information given under paragraph 2.01(e) must include:

(a) a description, and an assessment of the expected or predicted effectiveness of, the mitigation measures;

(b) any statutory or policy basis for the mitigation measures;

(c) the cost of the mitigation measures;

(d) an outline of an environmental management plan that sets out the framework for continuing management, mitigation and monitoring programs for the relevant impacts of the action, including any provisions for independent environmental auditing;

(e) the name of the agency responsible for endorsing or approving each mitigation measure or monitoring program; and

(f) a consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or compensate for the relevant impacts of the action, including mitigation measures proposed to be taken by State governments, local governments or the Proponent.

5 Other Approvals and Conditions

5.01 Information given under paragraph 2.01(f) must include:

(a) details of any local or State government planning scheme, or plan or policy under any local or State government planning system that deals with the proposed action, including:

(i) what environmental assessment of the proposed action has been, or is being carried out under the scheme, plan or policy; and

(ii) how the scheme provides for the prevention, minimisation and management of any relevant impacts;

(b) a description of any approval that has been obtained from a State, Territory or Commonwealth agency or authority (other than an approval under the Act), including any conditions that apply to the action;

(c) a statement identifying any additional approval that is required; and

(d) a description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action.

6 Environmental record of person proposing to take the action

6.01 Details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:

(a) the person proposing to take the action; and

(b) for an action for which a person has applied for a permit, the person making the application.

6.02 If the person proposing to take the action is a corporation — details of the corporation's environmental policy and planning framework.

7 Information sources

7.01 For information given the PER/EIS must state:

(a) the source of the information; and

(b) how recent the information is; and

(c) how the reliability of the information was tested; and

(d) what uncertainties (if any) are in the information.

ATTACHMENT 3

SUMMARY OF RELEVANT THREATENED FLORA, FAUNA AND ECOLOGICAL COMMUNITIES

The controlled action is considered likely to have a significant impact on the following EPBC listed threatened species and ecological communities:

- Critically endangered - *Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest* (Cumberland Plain Woodlands)
- Critically endangered - *Western Sydney Dry Rainforest and Moist Woodland on Shale* (Western Sydney Dry Rainforest)
- Vulnerable – *Pultenaea parviflora.*

A significant impact could not be ruled out for the following protected matters:

- Endangered - *Cynanchum elegans* (White-flowered Wax Plant)
- Endangered – *Pimelea spicata* (Spiked Rice-flower)
- Vulnerable – *Acacia pubescens* (Downy Wattle)
- Vulnerable – *Grevillea parviflora subsp. Parviflora* (Small-flower Grevialliea)
- Vulnerable - *Thesium australe* (Austral Toadflax, Toadflax)
- Vulnerable - *Heleioporus australiacus* (Giant Burrowing Frog)
- Vulnerable - *Litoria aurea* (Green and Golden Bell Frog)
- Vulnerable - *Chalinolobus dwyeri* (Large-eared Pied Bat)
- Vulnerable - *Pteropus poliocephalus* (Grey-headed Flying-fox).

ATTACHMENT 4

INFORMATION REQUIREMENTS FOR EPBC ACT OFFSET PROPOSALS

a) Details in relation to the proposed offsets package, including:

   i the location and size, in hectares, of any offset site(s)

   ii maps for each offset site that clearly show:

      o the relevant ecological features

      o the landscape context

      o the cadastre boundary.

   iii the current tenure arrangements (including zoning and ownership) of any proposed offset sites

   iv confirmed records of presence (or otherwise) of relevant protected matter(s) on the offset site(s)

   v details of studies and surveys used to confirm the presence of individuals and or likely habitat within offset site(s), including the scope, timing/effort (survey season/s) and methodologies employed

   vi detailed information regarding the extent (in hectares) and quality of habitat for relevant protected matter(s) on the offset site. The quality of habitat should be assessed in a manner consistent with the approach outlined in the document titled *How to use the offset assessment guide* available at: *http://www.environment.gov.au/epbc/publications/environmental-offsets-policy.html*.

b) Provide information and justification regarding how the offsets package will deliver a conservation outcome that will maintain or improve the viability of the protected matter(s) consistent with the *EPBC Act environmental offsets policy* (October 2012) including:

   i management actions that will be undertaken to improve or maintain the quality of the proposed offset site(s) for the relevant protected matter(s). Management actions must be clearly described, planned and resourced as to justify any proposed improvements in quality for the protected matter(s) over time

ii the time over which management actions will deliver any proposed improvement or maintenance of habitat quality for the relevant protected matter(s)

iii the risk of damage, degradation or destruction to any proposed offset site(s) in the absence of any formal protection and/or management over a foreseeable time period (20 years). Such risk assessments may be based on:

- presence of pending development applications, mining leases or other activities on or near the proposed offset site(s) that indicate development intent
- average risk of loss for similar sites
- presence and strength of formal protection mechanisms currently in place.

iv the legal mechanism(s) that are proposed to protect offset site(s) into the future and avert any risk of damage, degradation or destruction.

c) Provide information regarding how the proposed offsets package is additional to what is already required, as determined by law or planning regulations, agreed to under other schemes or programs or required under an existing duty-of-care.

d) The overall cost of the proposed offsets package; including costs associated with, but not necessarily limited to:

i acquisition and transfer of lands/property

ii implementation of all related management actions

iii monitoring, reporting and auditing of offset performance.

VOLUME 4

Appendix D
Western Sydney Airport
Usability Report

Australian Government
Bureau of Meteorology

Western Sydney Airport Usability Report

Meteorological Impacts


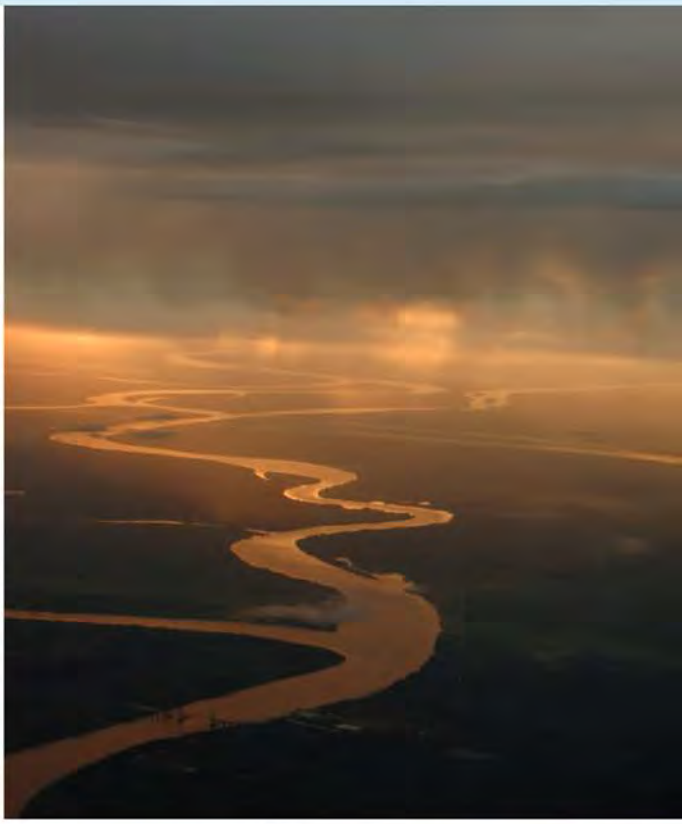



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Table of contents

Executive summary viii
1 Introduction 1
1.1 Bureau of Meteorology Aviation Weather Services 1
1.2 Badgerys Creek automatic weather station 1
1.3 Department of Infrastructure and Regional Development 2
1.4 Liability 3
2 Wind 4
2.1 Topographic wind effects 4
2.1.1 Anabatic wind 4
2.1.2 Katabatic wind 4
2.1.3 Valley flows 4
2.2 Wind speed and direction 5
2.2.1 Summer and autumn 6
2.2.2 Winter and spring 6
2.3 Percentage wind frequency table 6
2.4 Wind gusts 8
2.4.1 Summer and autumn 9
2.4.2 Winter and spring 9
2.5 Runway nomination 9
2.5.1 Crosswind 9
2.5.2 Headwind 13
2.6 Discussion 15
3 Temperature 16
3.1 Mesoscale effects 16
3.1.1 Coastal effects 16
3.1.2 Foehn effect 16
3.2 Temperature climatology 16
3.3 Temperature extremes 17
3.4 High temperatures 17
3.4.1 Temperatures exceeding 30ºC 18
3.4.2 Temperatures exceeding 35ºC 19
3.4.3 Temperatures exceeding 40ºC 20
3.5 Low temperatures 21
3.5.1 Temperatures below 0ºC 21
3.5.2 Frost 22
3.6 Freezing fog 24
3.7 Temperature inversions 25
3.8 Discussion 26
4 Rainfall 27
4.1 Rainfall climatology 27
4.1.1 Mean monthly rainfall comparison 28
4.1.2 Highest monthly rainfall comparison 29
4.1.3 Lowest monthly rainfall comparison 29
4.1.4 Highest daily rainfall comparison 30
4.2 Monthly rain day climatology 30
4.2.1 Mean monthly rain day comparison 31
4.2.2 Highest monthly rain day comparison 32
4.2.3 Lowest monthly rain day comparison 32
4.3 Discussion 33
5 Fog and low cloud 34

5.1 Fog types 34
5.1.1 Radiation fog 34
5.1.2 Advection fog 35
5.1.3 Valley fog 35
5.1.4 Sea fog 35
5.1.5 Advected fog 35
5.1.6 Freezing fog 36
5.2 Fog climatology 36
5.2.1 Fog days with visibility below 1000m 36
5.2.2 Fog days with visibility below 500m 38
5.2.3 Hourly visibility statistics below 1500m 40
5.2.4 Hourly visibility statistics below 800m 44
5.3 Low cloud 46
5.3.1 Low cloud at Badgerys Creek 47
5.3.2 Low cloud at Camden Airport 48
5.4 Discussion 50
6 Turbulence 51
6.1 Turbulence types 51
6.1.1 Mechanical turbulence 51
6.1.2 Rotors 51
6.1.3 Thermals 52
6.1.4 Convective turbulence 52
6.1.5 Frontal turbulence 52
6.1.6 Wake turbulence 53
6.1.7 Low-level vertical wind shear 53
6.2 Numerical modelling of turbulence 53
6.3 Severe turbulence 54
6.4 Moderate turbulence 55
6.5 Low-level vertical wind shear 56
6.6 Discussion 57
7 Thunderstorms 58
7.1 Thunderstorm properties 58
7.2 Lightning data 58
7.3 Lightning within 5nm 59
7.3.1 Monthly climatology 59
7.3.2 Hourly climatology 60
7.3.3 Lightning days within 5nm 60
7.4 Lightning within 10nm 61
7.4.1 Monthly climatology 61
7.4.2 Hourly climatology 62
7.4.3 Lightning days within 10nm 63
7.5 Lightning within 45nm 64
7.5.1 Monthly climatology 64
7.5.2 Hourly climatology 64
7.5.3 Lightning days within 45nm 65
7.6 Discussion 66
8 Conclusion 67
9 References 68

List of acronyms and abbreviations

Airservices	Airservices Australia
AWS	Automatic Weather Station
Bureau	Bureau of Meteorology
CASA	Civil Aviation Safety Authority
CCN	Cloud Condensation Nuclei
DIRD	Department of Infrastructure and Regional Development
LIDAR	Laser Imaging, Detection And Radar
Sydney KSA	Sydney Kingsford Smith Airport
Richmond	RAAF Base Richmond
RVR	Runway Visual Range
WSA	Western Sydney Airport

List of tables

Table 2-1 Table of percentage occurrence for selected wind direction and speed categories 7
Table 2-2 Table of historical percentage direction of crosswind >20kts 10
Table 2-3 Table of historical percentage direction of crosswind >25kts 11
Table 2-4 Table of percentage direction of crosswind >30kts 12
Table 2-5 Table of percentage direction of headwind >25kts 13
Table 2-6 Table of percentage direction of headwind >30kts 14
Table 3-1 Temperature climatology for Badgerys Creek 17
Table 3-2 Temperature climatology extremes for Badgerys Creek 17
Table 4-1 Rainfall climatology for Badgerys Creek 27
Table 4-2 Rain day climatology for Badgerys Creek 30
Table 5-1 Summary table of calculated statistics for visibility <1000m 38
Table 5-2 Summary table of calculated statistics for visibility <500m 39
Table 5-3 Table of monthly percentage occurrence of visibility <1500m for each hour of the day at Camden Airport 41
Table 5-4 Comparison table of percentage occurrence of visibility <1500m for each hour of the day in June and July 42
Table 5-5 Table of percentage monthly occurrence of visibility <800m for each hour of the day at Camden Airport 44
Table 5-6 Comparison table of percentage likelihood of visibility <800m for each hour of the day in June and July 45
Table 5-7 Aircraft category and corresponding alternate cloud minima 47

List of figures

Figure 1 Depiction of preliminary report findings for WSA in comparison with Sydney KSA viii
Figure 1.1 Site photograph of Badgerys Creek AWS 1
Figure 1.2 Topographical map of Sydney Basin 2
Figure 1.3 1997-99 EIS Master plan option A for WSA The white balloon shows the current location of the Badgerys Creek AWS 3
Figure 2.1 Seasonal wind rose for Badgerys Creek 5
Figure 2.2 Seasonal wind gust rose for Badgerys Creek 8
Figure 2.3 Average number of days per month of crosswind >20kts expected at WSA on runway 05/23 and Sydney KSA on runway 16/34 10
Figure 2.4 Average number of days per month of crosswind >25kts expected at WSA on runway 05/23 and Sydney KSA on runway 16/34 11
Figure 2.5 Average number of days per month of crosswind >30kts expected at WSA on runway 05/23 and Sydney KSA on runway 16/34 12
Figure 2.6 Average number of days per month of headwind >25kts expected at WSA on runway 05/23 and Sydney KSA on runway 16/34 13

Figure 2.7 Average no. of days per month of headwind >30kts on WSA runway 05/23 and Sydney KSA runway 16/34 14
Figure 3.1 Average hours of temperature ≥ 30ºC at Badgerys Creek....18
Figure 3.2 Boxplot of average hourly occurrence of temperature exceeding 30ºC at Badgerys Creek....18
Figure 3.3 Average hours of temperature ≥ 35ºC at Badgerys Creek....19
Figure 3.4 Boxplot of average hourly occurrence of temperature ≥ 35º at Badgerys Creek....19
Figure 3.5 Average hours of temperature ≥40ºC at Badgerys Creek....20
Figure 3.6 Boxplot of average hourly occurrence of temperature ≥ 40º at Badgerys Creek....20
Figure 3.7 Average hours of temperature ≤ 0º at Badgerys Creek 21
Figure 3.8 Hourly occurrence of temperatures ≤ 0º at Badgerys Creek....21
Figure 3.9 Average hourly inferred frost occurrence at Badgerys Creek 22
Figure 3.10 Average hourly inferred frost occurrence at Canberra Airport....22
Figure 3.11 Hourly inferred frost occurrence at Badgerys Creek....23
Figure 3.12 Hourly inferred frost occurrence at Canberra Airport 23
Figure 3.13 Average hours of inferred freezing fog occurrence at Badgerys Creek....24
Figure 3.14 Average hours of inferred freezing fog occurrence at Canberra Airport....24
Figure 3.15 Hourly inferred freezing fog occurrence at Badgerys Creek 25
Figure 3.16 Hourly inferred freezing fog occurrence at Canberra Airport....25
Figure 4.1 Monthly rainfall climatology at Badgerys Creek....28
Figure 4.2 Comparison graph of mean monthly rainfall....28
Figure 4.3 Comparison graph of highest monthly rainfall 29
Figure 4.4 Comparison graph of lowest monthly rainfall....29
Figure 4.5 Comparison graph of highest daily rainfall....30
Figure 4.6 Mean monthly rain days at Badgerys Creek....31
Figure 4.7 Comparison graph of mean monthly rain days....31
Figure 4.8 Comparison graph of highest monthly rain days....32
Figure 4.9 Comparison graph of lowest monthly rain days....32
Figure 5.1 Illustration of Radiation Fog and Post Rain Fog Formation Processes (Bureau 2014)....34
Figure 5.2 Illustration of Advection Fog Formation Processes (Bureau 2014) 35
Figure 5.3 Illustration of Advection Fog Formation Processes (Bureau 2014) 35
Figure 5.4 Monthly bar graph of number of days with visibility <1000m at Camden Airport....37
Figure 5.5 Monthly bar graph of number of days with fog events at Camden Airport....37
Figure 5.6 Monthly bar graph of number of days with visibility <500m at Camden Airport....38
Figure 5.7 Monthly bar graph of number of days with fog events at Camden Airport....39
Figure 5.8 Line graph of percentage occurrence of visibility <1500m for each hour of the day in June 43
Figure 5.9 Line graph of percentage occurrence of visibility <1500m for each hour of the day in July....43

Figure 5.10 Line graph of percentage occurrence of visibility <800m for each hour of the day in June 46
Figure 5.11 Line graph of percentage occurrence of visibility <800m for each hour of the day in July....46
Figure 5.12 Histogram of monthly average dewpoint depression at Badgerys Creek....47
Figure 5.13 Histogram of hourly average dewpoint depression at Badgerys Creek....48
Figure 5.14 Percentage hourly occurrence of cloud base <1500ft....49
Figure 5.15 Percentage hourly occurrence of cloud base <1000ft....49
Figure 5.16 Percentage hourly occurrence of cloud base <500ft....50
Figure 6.1 Example of effects of obstacle on fluid flow (Bureau, 2014) 51
Figure 6.2 Turbulence in lee mountain environment (Bureau, 2014) 52
Figure 6.3 Vertical wind shear configurations (Bureau 2014) 53
Figure 6.4 Monthly occurrence of severe turbulence....54
Figure 6.5 Hourly occurrence of severe turbulence....55
Figure 6.6 Monthly occurrence of moderate turbulence 55
Figure 6.7 Hourly occurrence of moderate turbulence....56
Figure 6.8 Comparison graph of monthly occurrence rates of severe wind shear 56
Figure 6.9 Comparison graph of hourly occurrence rates of severe wind shear 57
Figure 7.1 Monthly graph of lightning strikes within 5NM of Sydney KSA, WSA and Brisbane Airport....59
Figure 7.2 Hourly graph of lightning strikes within 5nm of Sydney KSA, WSA and Brisbane Airport....60
Figure 7.3 Monthly graph of lightning days within 5NM of WSA since Feb 2008 60
Figure 7.4 Monthly graph of lightning days within 5NM of Sydney KSA since Feb 2008 61
Figure 7.5 Monthly graph of lightning strikes within 10NM of Sydney KSA, WSA and Brisbane Airport....62
Figure 7.6 Hourly graph of lightning strikes within 10NM of Sydney KSA, WSA and Brisbane Airport....62
Figure 7.7 Monthly graph of lightning days within 10NM of WSA since Feb 2008 63
Figure 7.8 Monthly graph of lightning days within 10NM of Sydney KSA since Feb 2008 63
Figure 7.9 Monthly graph of lightning strikes within 45NM of Sydney KSA, WSA and Brisbane Airport....64
Figure 7.10 Hourly graph of lightning strikes within 45NM of Sydney KSA, WSA and Brisbane Airport....65
Figure 7.11 Monthly graph of lightning days within 45NM of WSA since Feb 2008 65
Figure 7.12 Monthly graph of lightning days within 45NM of Sydney KSA since Feb 2008 66

Executive summary

In 2014 the Bureau of Meteorology was engaged by the Australian Government Department of Infrastructure and Regional Development (DIRD) to provide a preliminary report on the meteorological parameters affecting the usability of the Badgerys Creek site for the development of the Western Sydney Airport (WSA).

With respect to the planned nomination of runways at Badgerys creek, it is expected that the current runway configuration proposed will be usable approximately 99.5% of the time based on crosswinds alone. Other weather phenomena such as fog, low cloud and low visibility conditions may lower the usability of the airport; however mitigation is obtainable through navigational systems and aids.

The major outcomes of the preliminary report have been summarised in Figure 1.

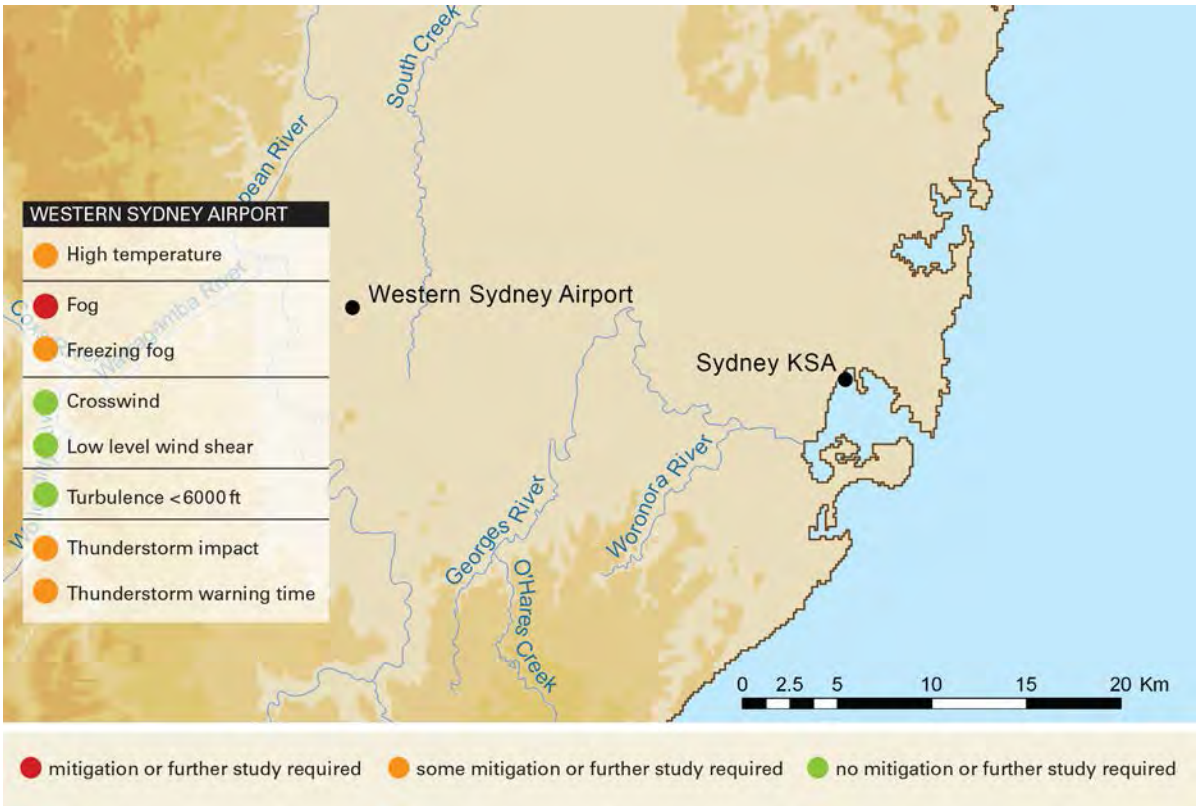

Figure 1 Depiction of preliminary report findings for WSA in comparison with Sydney KSA

Wind

- WSA experiences crosswind effects in the 05/23 direction on average half as often as Sydney KSA does in the 16/34 direction. The months of August to October are the most probable times to experience a crosswind exceeding 20kts at WSA in the 05/23 direction.
- Headwinds in excess of 25kts would be rare at WSA. Sydney KSA is approximately 4 times more likely to experience headwinds on the 16/34 parallel runways than WSA is on the proposed 05/23 runway.
- Headwinds in excess of 25kts are not expected to occur on average more than 0.4 days per month for any month of the year at WSA; whereas headwinds in excess of 25kts occur at Sydney KSA more than 0.8 days per month from September to March.

Temperature

- High temperatures (≥35ºC) at WSA can occur from October to March but would be more prevalent in the months of November to February with more than 7 hours per month expected on average. High temperatures (≥35ºC) at WSA would be most likely in the period from middle to late afternoon. Although temperatures above 35ºC do not occur frequently, they have the ability to restrict jet fuel loading.
- Low temperatures (≤ 0ºC) occur frequently in the months June to August at Badgerys Creek where on average. Temperatures are most likely to drop below 0ºC in July, where there is in average of more than 75 hours a month. On the days that the temperature is recorded below 0ºC, it is the early morning before sunrise when this is most likely to occur.
- Low temperature including conditions conducive to the formation of freezing fog occurs at Badgerys Creek from May to September with an average maximum of 3.5 hours in July. Canberra Airport experiences on average 10 times more hours a month in winter where freezing fog has the potential to form than would be expected at WSA
- The presence of a temperature inversion has a significant influence on the ability of the atmosphere to disperse pollutants. Further study into inversion levels would be necessary for the calculation of pollution parameters.

Rainfall

- Badgerys Creek receives slightly less rainfall per month than Camden Airport, and significantly less than Sydney KSA outside of thunderstorm season (October – March).

Turbulence

- Little to no low level severe wind shear is expected at WSA in comparison to Sydney KSA which experiences on average one hour per day in the months of August to December.
- Numerical modelling of atmospheric winds at Badgerys Creek shows that turbulence at WSA is predominantly expected to be caused by mechanical turbulence due to the Great Dividing Range.
- Moderate turbulence at WSA would be most likely in the months from June to August with on average five hours per day expected. Moderate turbulence at WSA would be most likely during the evening and overnight periods. In comparison, Sydney KSA could experience moderate turbulence at any time of the day but is most likely in the months from June to August.

- Over the 5yrs (2010-2014) of model data analysed WSA would have been expected to experience 1140 hours of moderate turbulence per year, whereas Sydney KSA would have been expected to have on average 1520 hours.
- Severe turbulence at WSA would be most likely in the months from June to August with on average three hours per day expected. Severe turbulence at WSA would be most likely during the evening and overnight periods. Moreover, Sydney KSA could experience severe turbulence at any time of the day but is most likely in the months from June to August.
- Over the 5yrs (2010-2014) of model data analysed WSA would have been expected to experience 545hrs of severe turbulence per year; whereas Sydney KSA would have been expected to have on average 735 hours.
- With the current wind analysis it is not possible to determine whether rotors would affect WSA.

Thunderstorms

- Thunderstorms and associated lightning is generally expected to form earlier in the day at WSA than Sydney KSA. Also, the thunderstorm season appears to both start and finish earlier at WSA than Sydney KSA.
- Overall, WSA would have experienced 632 less lightning strikes within 5nm, 1095 less lightning strikes within 10nm, and 2161 less lightning strikes within 45nm than Sydney KSA since February 2008.

The following outcomes have been found for Camden Airport. Camden Airport has been chosen as a representative site for WSA with regards to fog and low cloud data analysis:

Fog

- Fog at Camden Airport occurring for a period of an hour or more averaged 23% of days per year. The percentage increased to 40% of days per month during winter. Fog occurring for periods of four hours or more averaged 5% of days per year, increasing to 12% of days per month during winter.
- Fog occurs approximately 30 times more often at Camden Airport than at Sydney KSA during June and July; and approximately twice more likely at Camden Airport than at Canberra Airport, during June and July.

Low Cloud

- A cloud ceiling with broken or overcast cloud below 1500ft is approximately twice more likely at Camden Airport than Canberra Airport for all months except those in winter where both Camden and Canberra Airport experience a similar frequency of cloud with ceilings below 1500ft.
- A cloud ceiling with broken or overcast cloud below 1000ft is approximately 5 times more common at Camden Airport than Canberra Airport for all months except those in winter where Camden Airport only slightly exceeds Canberra Airport for the frequency of cloud with ceilings below 1000ft.
- A cloud ceiling with broken or overcast cloud below 500ft is approximately 3 times more likely at Camden Airport than at Canberra Airport for all months of the year.

Recommendations:

1. Clearance of vegetation to the west and south-west direction of the airport should be avoided as reducing drag may cause increases in wind speeds from downslope winds. (Page 15)
2. Orientation of buildings containing large surface areas should avoid the direction of strongest wind (westerly sector) as much as possible to avoid creating turbulent effects. (Page 15)
3. The effect of high temperatures may need to be considered during the construction of jet fuel facilities at WSA. (Page 26)
4. De-icing equipment may need to be considered in order to optimise operations at WSA during periods of low temperature. (Page 26)
5. Changes in land surface coverage will need to be accounted for in hydrological studies to ensure appropriate control measures and engineering can mitigate surface runoff. (Page 33)
6. Automatic instrumentation for cloud and visibility should be installed for the collection of climatological information and for the production of forecast products in future. (Page 50)
7. Appropriate low visibility landing equipment, such as runway visual range (RVR) needs to be considered in order to optimise operations at WSA. (Page 50)
8. A Doppler LIDAR system at Badgerys Creek can provide the necessary information for observing wind movement in the lower atmosphere including detection of wind shear and rotors. The Doppler LIDAR system is costly and a cost-benefit analysis would be recommended. (Page 57)
9. The Bureau implements an Automated Thunderstorm Alert Service (ATSAS) at WSA to improve the accuracy of thunderstorm forecasting for the airport whilst increasing the operational safety of ground staff and aircraft.

1 Introduction

1.1 Bureau of Meteorology Aviation Weather Services

The Bureau of Meteorology's (Bureau's) role in providing services for civil aviation is established through the Meteorology Act. Under the Convention for International Civil Aviation (the Chicago Convention) the Bureau is the designated Meteorological Authority for Australia and also provides meteorological services for civil aviation in Australia in accordance with the standards and practices set out in Annex 3 to the Convention.

In fulfilling this mandate it works closely with Airservices Australia (Airservices), which is responsible for air traffic services, and the Civil Aviation Safety Authority (CASA), which is responsible for the safety regulation of civil aviation in Australia.

1.2 Badgerys Creek automatic weather station

In 1995 the Bureau installed an Automatic Weather Station (AWS) at Badgerys Creek, (Lat 33.9S, Long 150.7E) which sits at an elevation of 81.2m (Figure 1.1). Since this time, a continuous supply of meteorological information including wind, temperature, dewpoint temperature, pressure and rainfall has been collected in order to build climatology of the local area. Owing to the location of the future Western Sydney Airport (WSA) site in the western Sydney Basin, the climate and weather phenomena that affect Badgerys Creek can be significantly different to those experienced at Sydney Kingsford Smith Airport (Sydney KSA).



Figure 1.1 Site photograph of Badgerys Creek AWS

Topographical differences across the Sydney Basin are the primary cause of weather variations in eastern New South Wales (NSW). Topography is likely to cause local disparities in temperature, moisture, pressure, rainfall and wind. Any combination of these factors will indirectly affect the frequency and severity of weather phenomena such as fog, thunderstorms, turbulence, wind shear and low cloud. A topographical map of the Sydney Basin annotating specific locations used in this report has been provided in Figure 1.2.

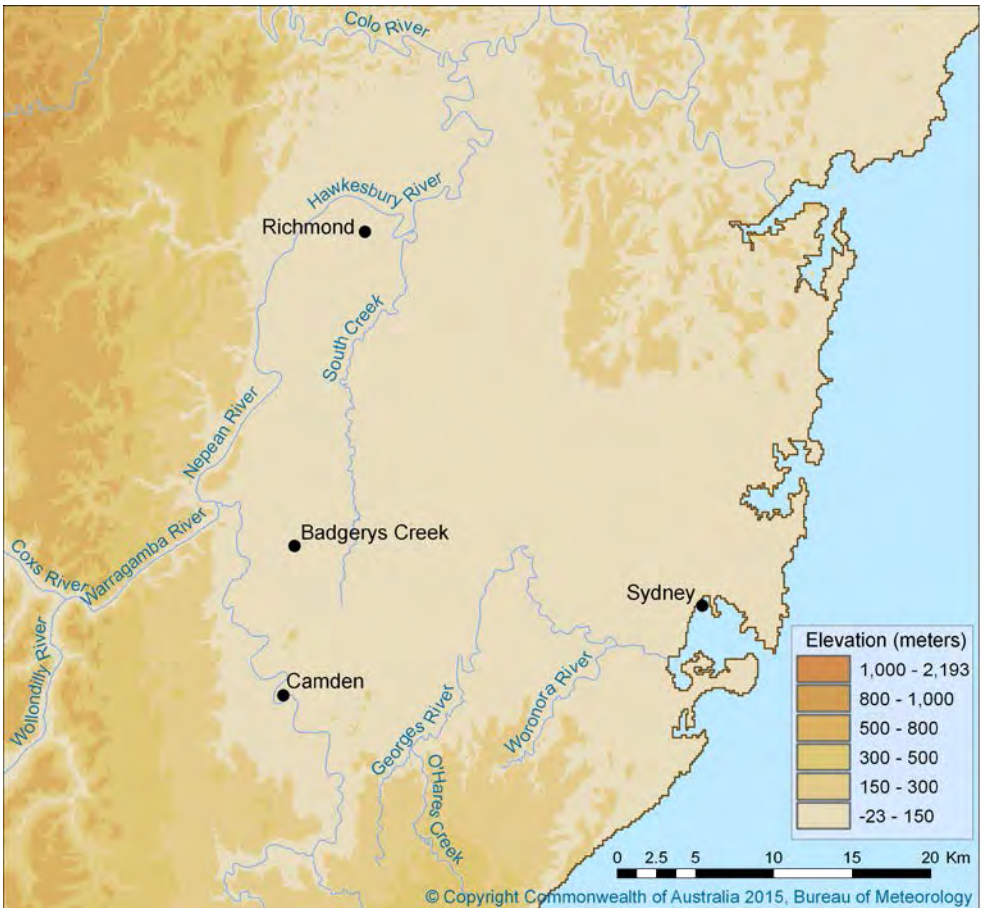

Figure 1.2 Topographical map of Sydney Basin

1.3 Department of Infrastructure and Regional Development

In 2014 the Bureau was engaged by the Australian Government Department of Infrastructure and Regional Development (DIRD) to provide a preliminary report surrounding the usability of the Badgerys Creek site for airport development on the basis of meteorology. The following report has been based on the proposed Option A airport master plan developed for the 1997-99 Second Sydney Airport Environmental Impact Statement provided in Figure 1.3.

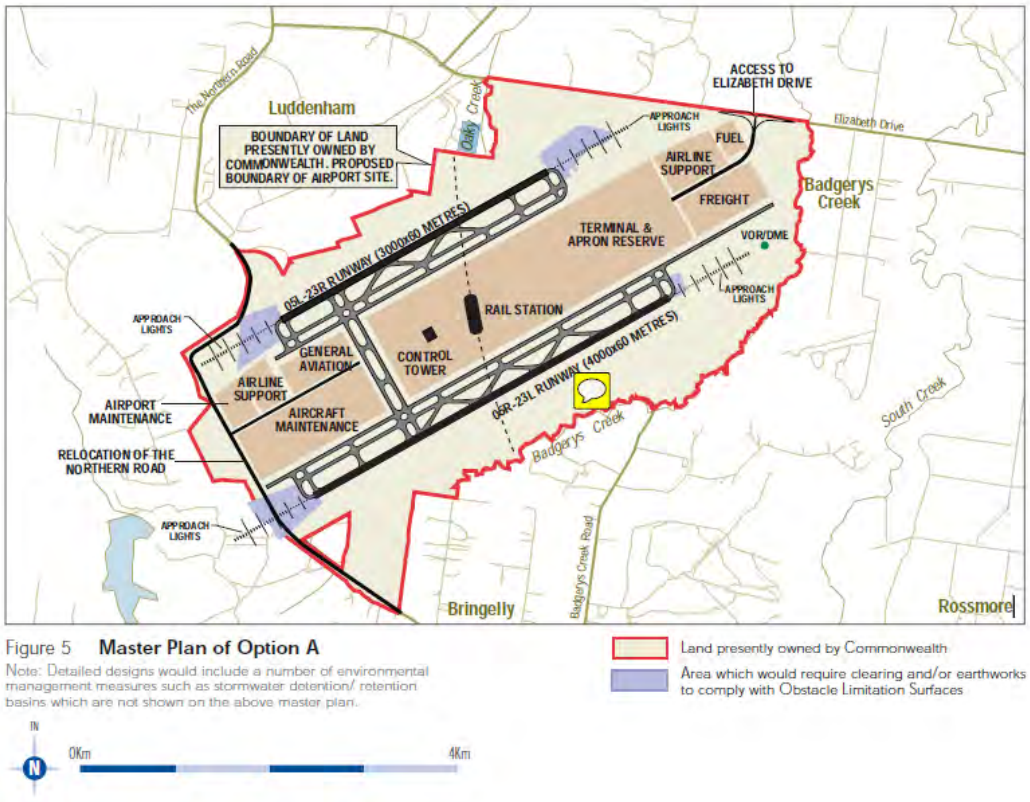

Figure 5 **Master Plan of Option A**

Note: Detailed designs would include a number of environmental management measures such as stormwater detention/ retention basins which are not shown on the above master plan.

Figure 1.3 1997-99 EIS Master plan option A for WSA. The white balloon shows the current location of the Badgerys Creek AWS

The aim of the preliminary report is to provide a broad climatology of the area together with an analysis of weather effects on the usability of WSA; this will also provide DIRD with sufficient information for the determination of areas which may require further directed research.

1.4 Liability

While every effort is made to supply the best data available, this may not be possible in all cases. We do not give any warranty, nor accept any liability in relation to the information given, except that liability (if any), that is required by law.

2 Wind

Wind is the movement of air in the atmosphere. Wind speed and direction can directly affect the usability of an airport and the optimisation of air traffic services at that airport. Strong winds perpendicular to a runway can affect the ability of an aircraft to land safely. Strong winds parallel to a runway can also affect the landing of an aircraft by impacting their ability to use aviation navigational aids or by reducing air speed sufficiently to cause the aircraft to stall.

The AWS at Badgerys Creek which measures wind speed, wind direction and wind gust strength has been used for wind analysis in this section of the report.

2.1 Topographic wind effects

The local topography interacts with the flow of air and movement of air pollutants in numerous ways. Topography has the ability to influence wind by channelling flows through valleys and creating air movement due to air density imbalances and pressure gradients in otherwise calm conditions. Wind direction analysis confirms that local topography influences both wind speed and direction at Badgerys Creek.

2.1.1 Anabatic wind

During the daytime in calm sunny weather a mountain top may receive more warming from the sun than the land below. In this instance, the parcel of warm air rises and creates an area of low pressure at the top of the mountain. Wind from the bottom of the mountain will move upslope into the area of low pressure, called an upslope wind. This process is known as an anabatic effect. The anabatic effect at Badgerys Creek would have the effect of producing light easterly winds when otherwise calm conditions would have prevailed.

2.1.2 Katabatic wind

A katabatic wind, also called a drainage wind, occurs when air of higher density at higher elevation moves down slope under the force of gravity. Katabatic winds in the western Sydney basin often occur in the overnight period and into the early morning. The katabatic effect from the surrounding mountains at Badgerys Creek produces a wind which blows from the south-westerly direction. A more detailed wind study could be conducted to determine the source of the katabatic wind, however the katabatic wind at WSA would be expected to be light and therefore cause little operational impact.

2.1.3 Valley flows

Mountain and valley winds occur locally as a result of the differences in the heating and cooling of the air over the mountains and valleys. In the daytime valley winds blow up the valleys and mountain slopes and at night the mountain winds blow in the opposite direction. It is unclear at this stage whether valley flows affect the AWS site at Badgerys Creek. A more detailed wind study could be conducted to determine the occurrence of valley flows, however valley flows would be expected to be light and therefore cause little operational impact to WSA.

2.2 Wind speed and direction

Wind directions are measured relative to true north such that the wind blows from the specified direction, and are measured in knots. The wind data analysed for Badgerys Creek[1] was a 10 minute average wind speed and direction.

Data has been displayed using a wind rose. The wind rose illustrates the main 8 wind directions and attributes a percentage occurrence of winds within a set speed range. The addition of the different speed ranges in one direction makes up one 'arm' of the wind rose. Figure 2.1 illustrates the four seasonal wind roses for Badgerys Creek.

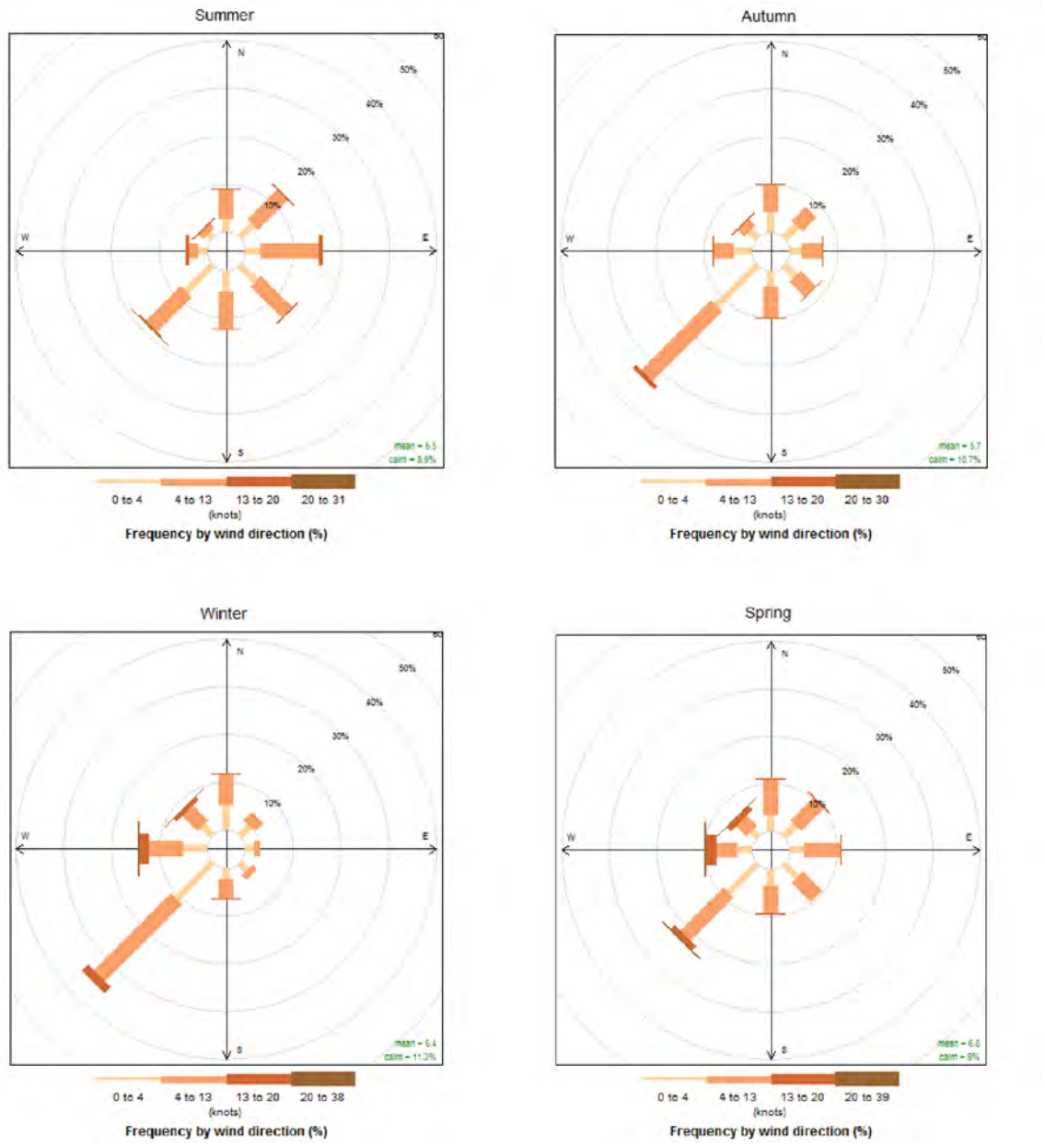

Figure 2.1 Seasonal wind rose for Badgerys Creek

[1] Unless otherwise stated the 10 minute data for Badgerys Creek was extracted from 4 Dec 1998 to 18 Nov 2014.

2.2.1 Summer and autumn

With a belt of high pressure to the south of the continent easterly winds prevail for much of the summer period. The Sydney Basin usually experiences an afternoon north-easterly sea-breeze along the coast tending more easterly as it moves further inland. As the heat of the day dissipates a south-westerly katabatic develops at Badgerys Creek overnight. The progression of a trough through the area can produce a more northerly or southerly component to the wind depending on the location of the associated area of low pressure. Furthermore, thunderstorms can create localised fluctuations in wind from any direction.

During summer the winds from the south-west are most common at Badgerys Creek. Yet winds from the eastern sector are also frequent and at their strongest during summer.

Winds in autumn are weaker from all directions except for the southwest. South-westerly winds predominate in autumn occurring more than 20% of the time. From summer to autumn there is a shift in frequency of winds from the easterly quadrant to the westerly quadrant.

2.2.2 Winter and spring

In winter the belt of high pressure is over the middle of the continent producing light and variable winds and fog conditions in the western Sydney Basin. The approach of cold fronts and associated troughs from the west brings synoptic westerly conditions. It is common for surface frontal troughs to be affected by the Great Dividing Range, modifying their trajectory and causing a southerly change to propagate along the NSW coastline.

During winter winds are infrequent from the easterly quadrant. Instead more than 30% of wind is expected to occur from the south-westerly direction. Winter into spring shows a shift back from a westerly wind regime into more easterly winds.

In spring winds from the south-west begin to weaken and an increase in wind strength occurs from the eastern sector. Additionally easterly winds become more frequent.

The wind rose in all seasons shows that winds from west to north-westerly directions are effectively blocked due to topography.

2.3 Percentage wind frequency table

30-minute data[2] has been analysed for all months of the year to determine the percentage occurrence for wind speed and direction at Badgerys Creek (refer to Table 2-1).

[2] Data range for Table 2-1 encompasses 10 Jan 1996 to 10 Dec 2014.

Table 2-1 Table of percentage occurrence for selected wind direction and speed categories

Wind	Wind Speed (knots)											
	Calm	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	>50	Total (%)
Calm	**10.0**												**10.0**
360		1.4	1.2	0.2	*[3]	*	0.0	0.0	0.0	0.0	0.0	0.0	2.8
010		1.3	1.3	0.2	*	*	0.0	0.0	0.0	0.0	0.0	*	2.9
020		1.2	1.2	0.2	*	*	0.0	0.0	0.0	0.0	0.0	0.0	2.7
030		1.2	1.0	0.1	*	*	0.0	0.0	0.0	0.0	0.0	0.0	2.3
040		1.0	0.7	0.1	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8
050		1.1	0.8	0.1	*	*	0.0	0.0	0.0	0.0	0.0	0.0	2.0
060		0.9	0.8	0.2	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
070		0.9	0.9	0.3	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
080		0.7	0.8	0.4	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
090		0.7	0.9	0.5	*	*	0.0	0.0	0.0	0.0	0.0	0.0	2.2
100		0.8	0.9	0.4	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
110		1.0	0.9	0.3	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
120		0.9	0.8	0.2	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0
130		1.1	0.8	0.2	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
140		1.0	0.7	0.2	*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
150		1.0	0.6	0.2	*	*	0.0	0.0	0.0	0.0	0.0	0.0	1.9
160		0.9	0.6	0.2	*	*	*	0.0	0.0	0.0	0.0	0.0	1.7
170		1.1	0.8	0.2	*	*	*	0.0	0.0	0.0	0.0	0.0	2.2
180		1.0	0.9	0.2	*	*	0.0	0.0	0.0	0.0	0.0	0.0	2.1
190		1.1	1.0	0.3	*	*	0.0	0.0	0.0	0.0	0.0	0.0	2.4
200		1.2	1.1	0.3	0.1	*	0.0	0.0	0.0	0.0	0.0	0.0	2.6
210		1.6	1.3	0.4	0.1	*	0.0	0.0	0.0	0.0	0.0	0.0	3.4
220		2.6	2.1	0.6	0.1	*	*	*	0.0	0.0	0.0	0.0	5.5
230		4.9	3.6	0.7	0.1	*	*	*	0.0	0.0	0.0	0.0	9.3
240		4.4	2.4	0.6	0.2	*	*	0.0	*	0.0	0.0	0.0	7.5
250		2.3	1.1	0.6	0.2	*	*	*	*	0.0	0.0	0.0	4.3
260		1.0	0.6	0.4	0.2	*	*	*	0.0	0.0	0.0	0.0	2.2
270		0.8	0.4	0.3	0.2	*	*	0.0	0.0	0.0	0.0	0.0	1.7
280		0.6	0.3	0.3	0.2	*	*	*	0.0	0.0	0.0	0.0	1.4
290		0.5	0.4	0.3	0.2	*	*	*	0.0	0.0	0.0	0.0	1.4
300		0.5	0.4	0.2	0.1	*	*	0.0	0.0	0.0	0.0	0.0	1.3
310		0.6	0.4	0.2	0.1	*	*	*	0.0	0.0	0.0	0.0	1.3
320		0.5	0.3	0.1	*	*	*	0.0	0.0	0.0	0.0	0.0	1.1
330		0.7	0.4	0.1	*	*	*	0.0	0.0	0.0	0.0	0.0	1.1
340		0.7	0.4	0.1	*	*	*	0.0	0.0	0.0	0.0	0.0	1.2
350		0.9	0.6	0.1	*	*	*	0.0	0.0	*	0.0	0.0	1.7
Total (%)	**10.0**	44.4	33.5	9.8	2.0	0.3	*	*	*	*	0.0	*	

[3] An asterisk indicates the event has occurred but with a frequency less than 0.05%.

Table 2-1 provides the ability to estimate the percentage chance of obtaining a specific direction above a certain speed based on climatology. It can be seen from the table that the wind at Badgerys Creek is calm[4] 10% of the time; Winds from the north and east almost never exceed 25kts; Winds exceeding 30kts from the south and west can be expected infrequently.

2.4 Wind gusts

Wind gusts are noted as the highest maximum 3 second gust in the last 10 minutes. The direction associated with a recorded wind gust is the average 10 minute wind direction which may not be indicative of the direction from which the gust came from. Nevertheless, anecdotal evidence suggests that the majority of wind gusts come from the recorded wind direction. A wind rose[5] of gusts has been created in Figure 2.2.

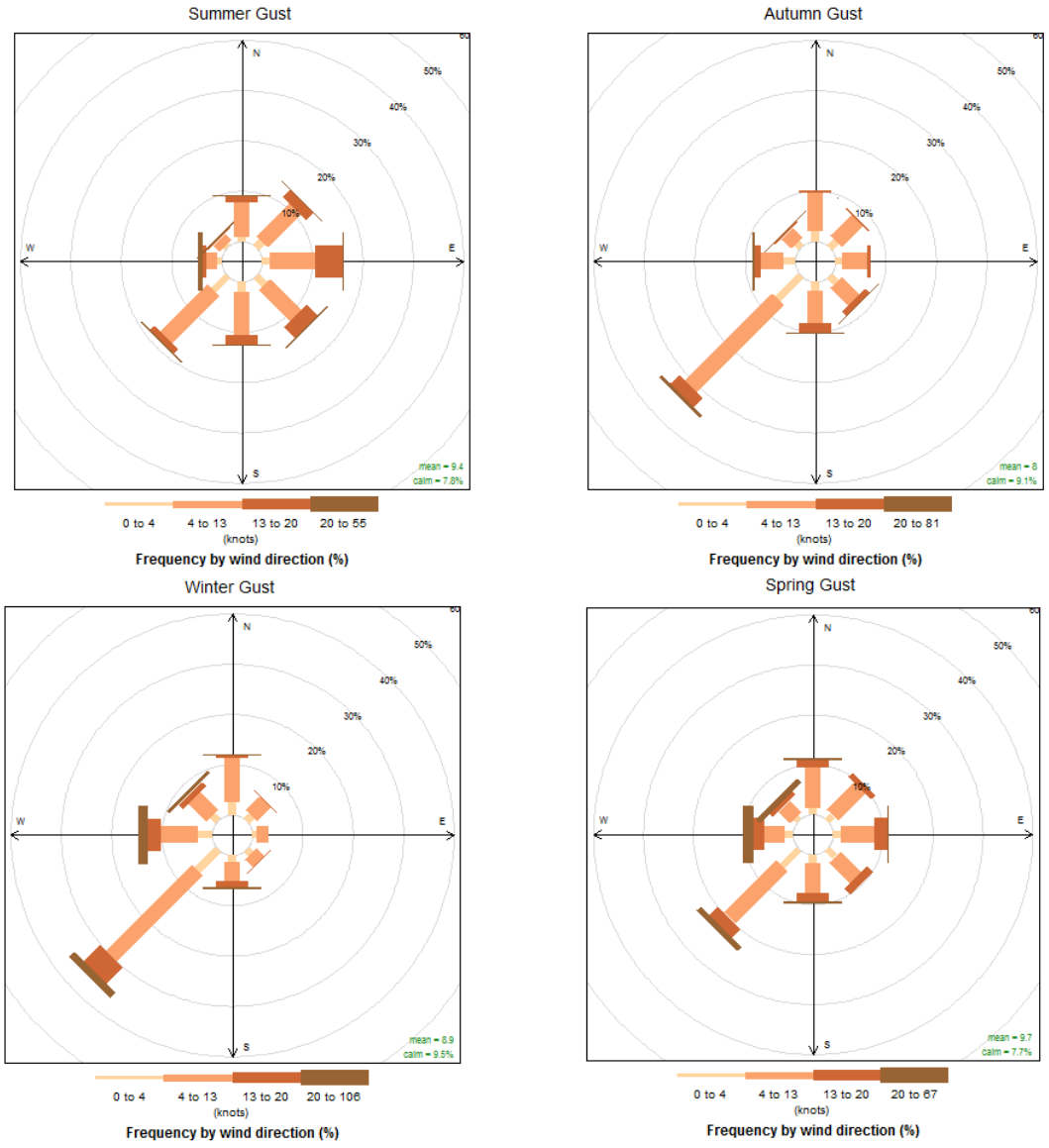

Figure 2.2 Seasonal wind gust rose for Badgerys Creek

[4] Calm has been defined as 0kts for this report.
[5] Refer to section 2.2 for instructions on how a wind rose is constructed.

2.4.1 Summer and autumn

Gusts in summer and autumn often occur from thunderstorms and synoptically reinforced sea breezes. The wind roses show that wind gusts in summer and autumn can occur from any direction, although wind gusts from west and north-west is not very common. Due to the blocking effect of the Great Dividing Range it could be assumed that thunderstorms are typically responsible for the gusts from the west and northwest directions.

The predominant gust direction appears to be south-westerly with more than 20% of gusts coming from this direction. However gusts equal to or greater than 12kts occur most frequently from the east.

2.4.2 Winter and spring

Wind gusts in winter and spring occur in a similar direction and frequency as those in summer and autumn, however to a lesser magnitude.

2.5 Runway nomination

CASA rules covering the maximum cross-wind and downwind limits for runway selections state:

> '*CASA determined that air traffic control should not nominate runways for use if an alternative runway is available when:*
>
> - *For runways that are completely dry, the cross-wind component, including gusts, exceeds 20 knots; and the downwind[6] component, including gusts, exceeds 5 knots.*
> - *For runways that are not completely dry, the cross-wind[7] component, including gusts, exceeds 20 knots; and there is any downwind component.'*

Thus, wind strength and direction can directly influence the availability of different runway configurations.

10-minute data was extracted from both Badgerys Creek and Sydney KSA[8] to complete the crosswind and headwind analysis. It is important to note that the data set for Badgerys Creek is not as extensive as that for Sydney KSA and may not be truly representative of climatic conditions.

2.5.1 Crosswind

A crosswind is a wind perpendicular to the direction of runway orientation. Generally, lighter aircraft find it more difficult to compensate for a crosswind on landing and take-off.

Calculations have been based on initial information detailing a runway in the direction of 05/23 true. Calculations can be reconfigured as required. Runway 16/34 at Sydney

---

[6] Downwind is defined as the wind's force on an aircraft in the same direction with which the wind is blowing, also known as a tailwind.
[7] Crosswind is defined as the wind's force perpendicular to the course of an aircraft.
[8] Unless otherwise stated the 10 minute data for Sydney KSA was extracted from 10 Oct 1948 to 18 Nov 2014.

KSA has been converted to degrees true for wind calculations. The mean 10-minute wind speed has been used for cross-wind calculations.

The number of days per month in which the crosswind would be expected to exceed 20kts at WSA and Sydney KSA has been graphed in Figure 2.3.

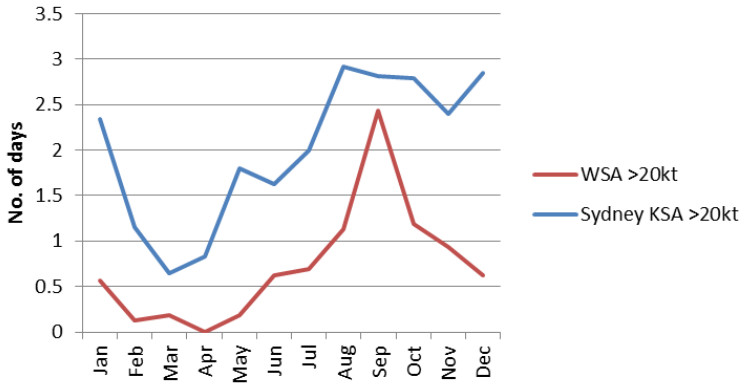

Figure 2.3 Average number of days per month of crosswind >20kts expected at WSA on runway 05/23 and Sydney KSA on runway 16/34

Crosswind of >20kts would occur on average on more than one day per month in August, September and October at WSA. In comparison, on average Sydney KSA would experience crosswinds of >20kts in all months except March and April.

A climatology of available data has recorded 9 in 722 cases in which a crosswind of >20kts would have occurred from the southeast at WSA. The potential for a south-easterly wind to cause a crosswind on runway 05/23 would be very rare; however a longer climatic record at Badgerys Creek would provide greater detail. Synoptic situations in which this event could occur would likely be restricted to gusts eventuating from a thunderstorm, or the positioning of an East Coast Low off the NSW coast. A summary table of historical crosswind direction has been supplied in Table 2-2.

Table 2-2 Table of historical percentage direction of crosswind >20kts

	WSA	Sydney KSA
	>20kts	>20kts
South-easterly crosswind	1.2%	14.8%
North-westerly crosswind	98.8%	85.2%

The number of days per month in which the crosswind would be expected to exceed 25kts at WSA and Sydney KSA has been graphed in Figure 2.4.

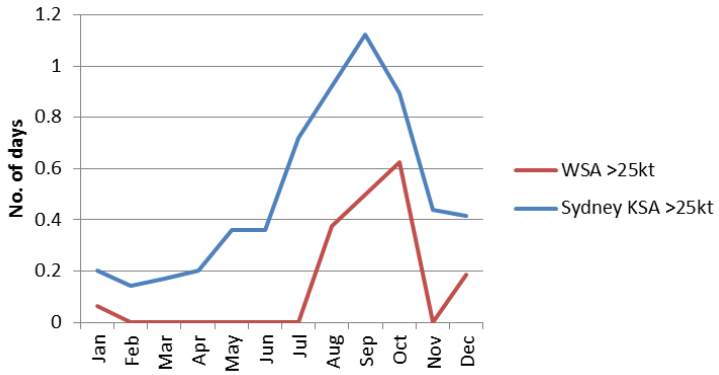

Figure 2.4 Average number of days per month of crosswind >25kts expected at WSA on runway 05/23 and Sydney KSA on runway 16/34

Crosswind of >25kts is expected to occur on average on more than 0.5 days per month in October at WSA. In comparison, Sydney KSA experiences crosswinds on runway 16/34 of >25kts on more than 0.5 days per month from July to October.

There are no historical cases to date in which a crosswind of >25kts would have occurred from the southeast at WSA; however a longer climatic record at Badgerys Creek would provide greater detail. A summary table of crosswind direction has been supplied below (refer to Table 2-3).

Table 2-3 Table of historical percentage direction of crosswind >25kts

	WSA	Sydney KSA
	>25kts	>25kts
South-easterly crosswind	0.0%	6.3%
North-westerly crosswind	100.0%	93.7%

The number of days per month in which the crosswind would be expected to exceed 30kts at WSA and Sydney KSA has been graphed in Figure 2.5.

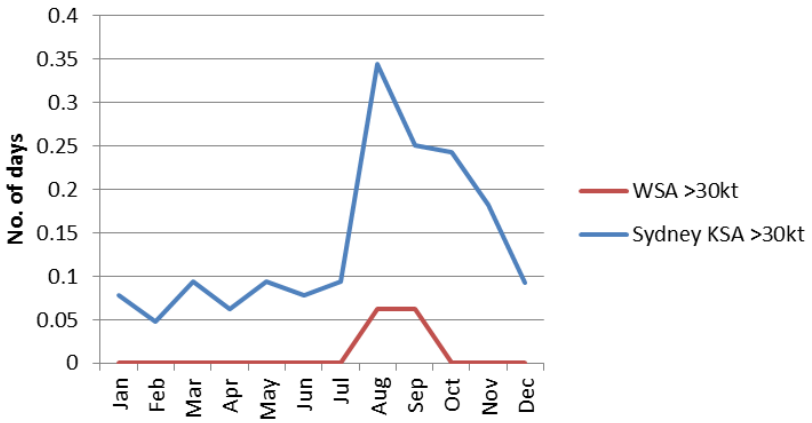

Figure 2.5 Average number of days per month of crosswind >30kts expected at WSA on runway 05/23 and Sydney KSA on runway 16/34

Crosswind of >30kts would be rare at WSA but are possible from the north-westerly wind direction. In comparison, Sydney KSA experiences crosswinds on runway 16/34 of >30kts on average on more than 0.5 days per month from August to November.

Historically there is yet to be an instance in which a crosswind of >30kts from the south-east that would impact on the 05/23 runway at WSA; however a longer climatic record at Badgerys Creek would provide greater detail. A summary table of crosswind direction has been supplied below (refer to Table 2-4)

Table 2-4 Table of percentage direction of crosswind >30kts

	WSA	Sydney KSA
	>30kts	>30kts
South-easterly crosswind	0.0%	13.2%
North-westerly crosswind	100.0%	86.8%

2.5.2 Headwind

A head-wind is a wind parallel but in the opposing direction to an aircraft landing or taking-off on the runway. At lower speeds a headwind is most beneficial for aircraft both landing and taking-off. Strong headwinds can impact an aircraft's use of approach instrumentation, or in extreme cases can cause the aircraft to lose sufficient air speed resulting in an engine stall.

The number of days per month in which the headwind would be expected to exceed 25kts at WSA and Sydney KSA has been graphed in Figure 2.6.

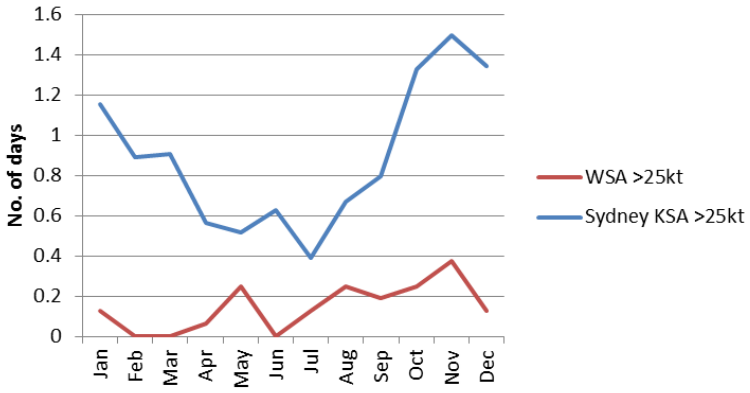

Figure 2.6 Average number of days per month of headwind >25kts expected at WSA on runway 05/23 and Sydney KSA on runway 16/34

Headwind of >25kts could occur in almost any month of the year at WSA, but would be rare. Headwinds in excess of 25kts are commonly seen at Sydney KSA where they occur approximately one day per month from October to January.

There is not historical data to date where a headwind exceeding 25kts would have impacted WSA on Runway 23; however a longer climatic record at Badgerys Creek would provide greater detail. A summary table of headwind direction has been supplied below (refer to Table 2-5).

Table 2-5 Table of percentage direction of headwind >25kts

	WSA	Sydney KSA
	>25kts	>25kts
North-easterly headwind	0.0%	4.3%
South-westerly headwind	100.0%	95.7%

The number of days per month in which the headwind exceeds 30kts at WSA and Sydney KSA has been graphed in Figure 2.7.

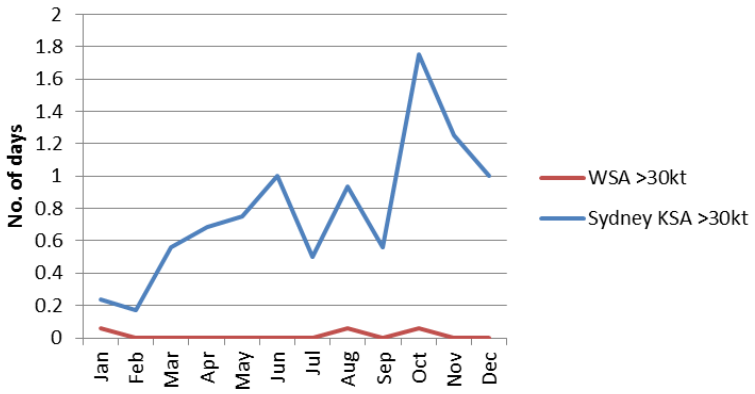

Figure 2.7 Average no. of days per month of headwind >30kts on WSA runway 05/23 and Sydney KSA runway 16/34

Although it is possible to see a headwind exceed 30kts at WSA it is extremely rare. However, headwinds in excess of 30kts occur at Sydney KSA on one day a month in June and on more than one day a month from October to December.

There is not historical data to date where a headwind exceeding 30kts would have impacted WSA on Runway 23; however a longer climatic record at Badgerys Creek would provide more detail. A summary table of headwind direction has been supplied below (refer to Table 2-6)

Table 2-6 Table of percentage direction of headwind >30kts

	WSA	Sydney KSA
	>30kts	>30kts
North-easterly headwind	0.0%	6.9%
South-westerly headwind	100.0%	93.1%

2.6 Discussion

Topographical wind effects are common at Badgerys Creek due to the proximity of the site to the Great Dividing Range. It is unclear if anabatic winds or valley flows affect the site from the preliminary data but neither wind would be expected to be significantly strong to impact on operations at WSA. However, it is clear from both the data and anecdotal evidence that a south-westerly katabatic wind commonly occurs overnight.

Winds from the south-west are common throughout the year but are most frequent during winter. The remaining winds have a more easterly or westerly component to the wind depending on the season. Easterly winds become more frequent during late winter and strengthen into spring. Winds from the eastern sector weaken during summer shifting to the west during autumn and remaining through much of winter.

The wind in all seasons is effectively blocked by topography from the west to north-westerly directions.

The WSA site would likely be less susceptible to both crosswind and headwind effects than Sydney KSA. The months of August to October are the most probable times to experience a crosswind exceeding 20kts at WSA, with the majority of crosswind events occurring from the southwest. In comparison, WSA would be expected to experience crosswind effects on average half as often as Sydney KSA.

There appears to be a threshold (approximately 20-25kts) in which the north-westerly synoptic winds are sufficiently strong to overcome the terrain and produce a crosswind at WSA.

Headwinds in excess of 25kts would be rare at WSA but could occur in almost any month of the year. Sydney KSA is approximately 4 times more likely to experience headwinds on the parallel runways (16/34) than WSA is on runway 05/23.

It is important to note that the clearance of vegetation and the erection of buildings can cause changes in wind speed and direction. Removal of vegetation is likely to cause a reduction in surface drag resulting in slightly stronger wind speeds than would have occurred otherwise. The effect may be more pronounced at the base of the lee side of the Great Dividing Range.

Recommendation 1: Clearance of vegetation to the west and south-west direction of the airport should be avoided as reducing drag may cause increases in wind speeds from downslope winds.

The erection of buildings such as a terminal has the ability to effect air movement around an airport. Obstacles such as buildings have the ability to redirect air flow around surfaces creating effects such as funnelling, lift and turbulence. Generally obstacles with a large surface area relative to the wind direction would have greater impact on air flow. Therefore orientating obstacles with large surface areas towards directions of greatest wind strength, such as the west, would not be recommended.

Recommendation 2: Orientation of buildings containing large surface areas should avoid the direction of strongest wind (westerly sector) as much as possible to avoid creating turbulent effects.

3 Temperature

Instruments measuring temperature are located at the Badgerys Creek AWS site. The equipment is housed within a Stevenson screen at a height of approximately 1.2m above the ground. Whilst average daily temperatures are important it is the extremes in heat or cold that can impact airport optimisation.

3.1 Mesoscale effects

Topography has the ability to affect temperature via both elevation and air movement. The AWS site at Badgerys Creek is only 81.2m above sea level producing negligible effects on temperature due to elevation. However, air movement around Badgerys Creek has the ability to affect temperatures at the site.

3.1.1 Coastal effects

Usually coastal locations see less temperature variability due to their proximity to the ocean. Ocean temperatures fluctuate slightly throughout the year but considerably less than the land surface. The ocean is a great moderator of air temperature in coastal locations. This results in milder nights and days.

Badgerys Creek experiences very limited temperature moderation from coastal influences; however the sea breeze has the potential to reach Badgerys Creek during the late afternoon producing cooler apparent temperatures during summer and early autumn. Otherwise, it is common to see larger daily fluctuations in temperature from sites in the western Sydney Basin.

3.1.2 Foehn effect

It is common to see precipitation triggered by orographic uplift on a mountain range such as the Great Dividing Range to the west of Badgerys Creek. Air reaching the top of the ridge cools to produce condensation by way of cloud or rainfall, and then continues as a dry air mass down the leeward side of the mountain. The air moving down the leeward side of the mountain warms at a rate faster than the surrounding environment causing an artificial increase in temperature.

Badgerys Creek lies at the bottom of the Great Dividing Range where it would be possible to see artificially high temperatures during the thunderstorm season, especially from November to March.

3.2 Temperature climatology

Table 3-1 below summarises the climatology of the temperature at Badgerys Creek since the site opened in October of 1995.

Table 3-1 Temperature climatology for Badgerys Creek

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temperature (ºC)	29.9	28.5	26.7	23.9	20.6	17.8	17.3	19.3	22.7	24.7	26.1	28.1
Highest temperature (ºC)	45.8	42.6	40.0	34.6	27.9	25.2	25.4	28.8	34.8	37.2	41.9	42.5
Mean daily minimum temperature (ºC)	16.9	17.1	15.1	11.3	7.6	5.4	4.2	4.6	7.7	10.2	13.4	15.2
Lowest temperature (ºC)	8.2	8.5	6.4	-0.1	-1.1	-3.0	-4.5	-1.9	-0.5	2.2	5.3	6.6

January at Badgerys Creek is the hottest month with an average temperature of 29.9ºC. The highest temperature ever recorded at the site was 45.8 ºC on 18th January 2013. Badgerys Creek has experienced temperatures exceeding 40ºC in the months of November to March.

3.3 Temperature extremes

The average number of days a month in which the temperature: exceeds 30ºC, exceeds 35ºC, or falls below 0ºC has been supplied in Table 3-2.

Table 3-2 Temperature climatology extremes for Badgerys Creek

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Number of Days over 30ºC	13.4	9.6	4.8	0.8	nil	nil	nil	nil	1.7	5.1	6.8	10.2
Mean Number of Days over 35 ºC	5.2	2.6	0.5	nil	nil	nil	nil	nil	nil	0.8	1.8	2.8
Mean Number of Days below 0 ºC	nil	nil	nil	0.1	0.3	2.0	3.3	2.1	0.2	nil	nil	nil

The month of January has the most days on average above 30ºC and 35ºC with 13.4 and 5.2 days respectively. July has the most number of days on average below 0 ºC with 3.3 days.

3.4 High temperatures

High temperatures have the ability to alter the optimum usability of an airport. Temperature has an indirect relationship with air density. As temperature climbs the air becomes less dense and affects aero-dynamical lift. Perhaps more significant is the effect of temperatures on fuel. High temperatures cause fuel to expand restricting the capacity to adequately refuel aircraft in some cases. Temperatures exceeding the flash point for jet fuel (Jet A/A1), approximately 38 ºC, are extremely important as liquid becomes a gas.

The average number of hours per month in which the temperature becomes exceedingly high, and the time of day at which these high temperatures are most likely has been supplied in section 3.4.1 to 3.4.3.

3.4.1 Temperatures exceeding 30ºC

The number of hours a month in which the temperature was greater than or equal to 30º at Badgerys Creek has been graphed in Figure 3.1.

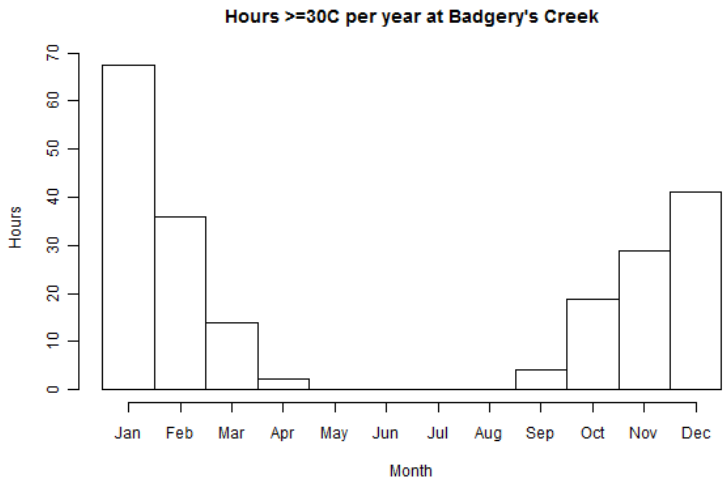

Figure 3.1 Average hours of temperature ≥ 30ºC at Badgerys Creek

The bar graph shows that the temperature is equal to or greater than 30ºC regularly throughout the end of spring, summer and the start of autumn at Badgerys Creek. A boxplot of the average hourly occurrence of temperatures exceeding 30ºC has been provided in Figure 3.2.

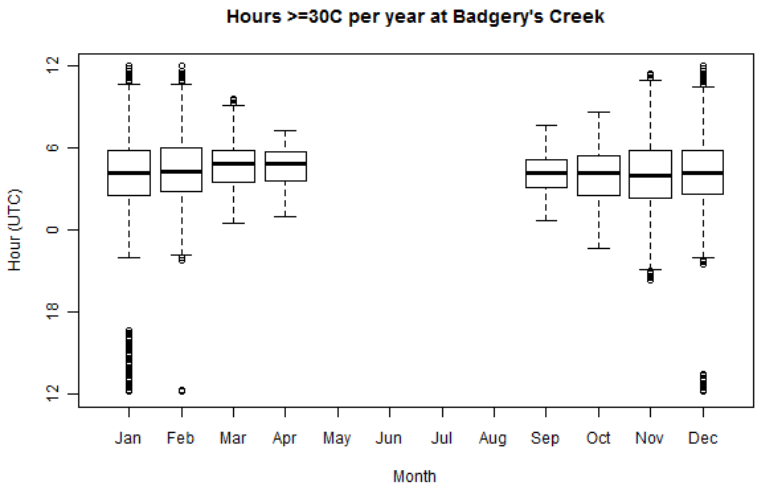

Figure 3.2 Boxplot[9] of average hourly occurrence of temperature exceeding 30ºC at Badgerys Creek

When the temperature exceeds 30º at Badgerys Creek, it is most commonly during middle to late afternoon.

[9] Boxplots display the median as a solid line. The box represents the first to third quartile (25-75%) of data. The lines extending from the box indicate the variability outside the first and third quartile. Additional points plotted are outliers in the data.

3.4.2 Temperatures exceeding 35ºC

The number of hours a month in which the temperature was greater than or equal to 35ºC has been graphed in Figure 3.3.

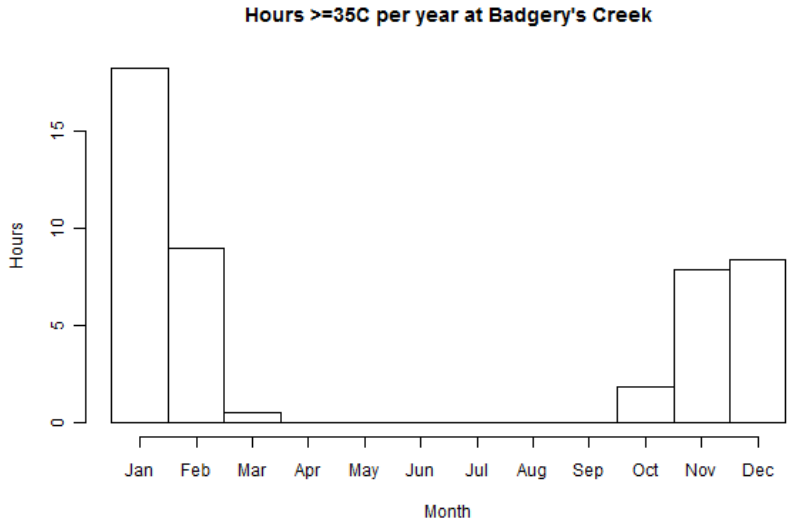

Figure 3.3 Average hours of temperature ≥ 35ºC at Badgerys Creek

The graph shows that it is not unusual to see temperatures exceed 35ºC in late spring and summer at Badgerys Creek. A boxplot of the average hourly occurrence of temperatures exceeding 35ºC has been provided in Figure 3.4.

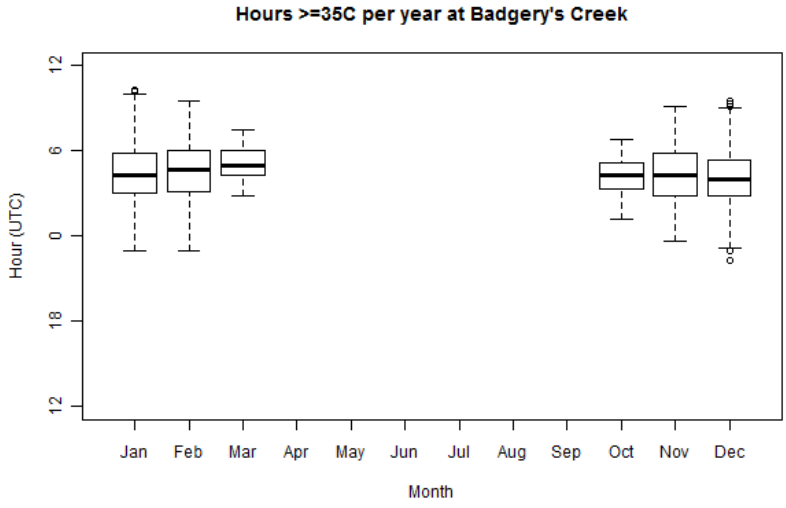

Figure 3.4 Boxplot of average hourly occurrence of temperature ≥ 35º at Badgerys Creek

On the days that the temperature does exceed 35ºC, it is middle to late afternoon when this is most likely to occur.

3.4.3 Temperatures exceeding 40ºC

The number of hours a month in which the temperature ≥ 40ºC has been graphed in Figure 3.5.

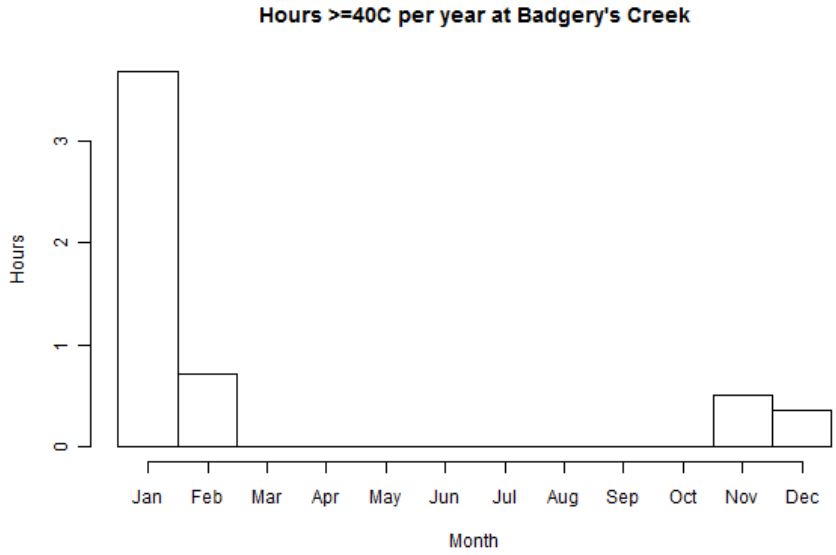

Figure 3.5 Average hours of temperature ≥40ºC at Badgerys Creek

It can be seen that whilst it is possible to see temperatures exceed 40ºC in late spring and summer it is not common. The month in which temperatures are most likely to exceed 40ºC is January, where there is an average of 3-4 hours a month. A boxplot of the average hourly occurrence of temperatures exceeding 40ºC has been provided in Figure 3.6.

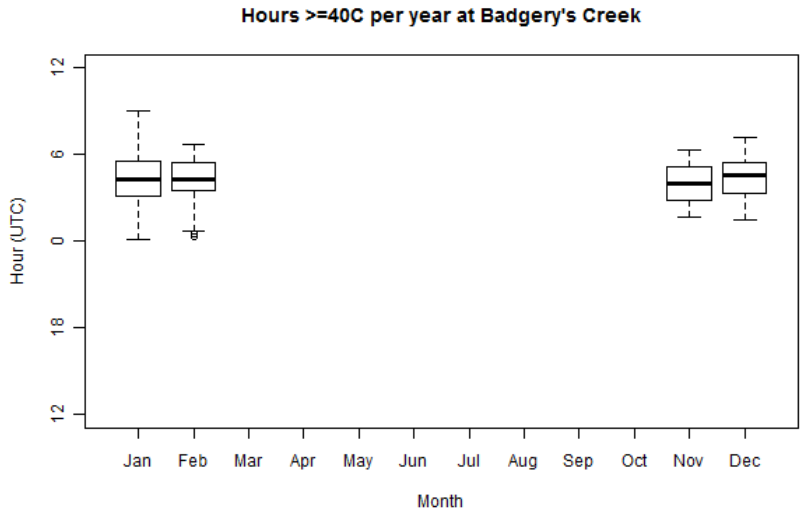

Figure 3.6 Boxplot of average hourly occurrence of temperature ≥ 40º at Badgerys Creek

On the days that the temperature is equal to or greater than 40ºC the time of day is generally middle to late afternoon.

3.5 Low temperatures

Temperatures below zero at surface level have the ability to produce adverse weather phenomena for aircraft including hail, snow, sleet, frost, icing and freezing fog.

3.5.1 Temperatures below 0ºC

The number of hours a month in which the temperature ≤ 0ºC has been graphed in Figure 3.7.

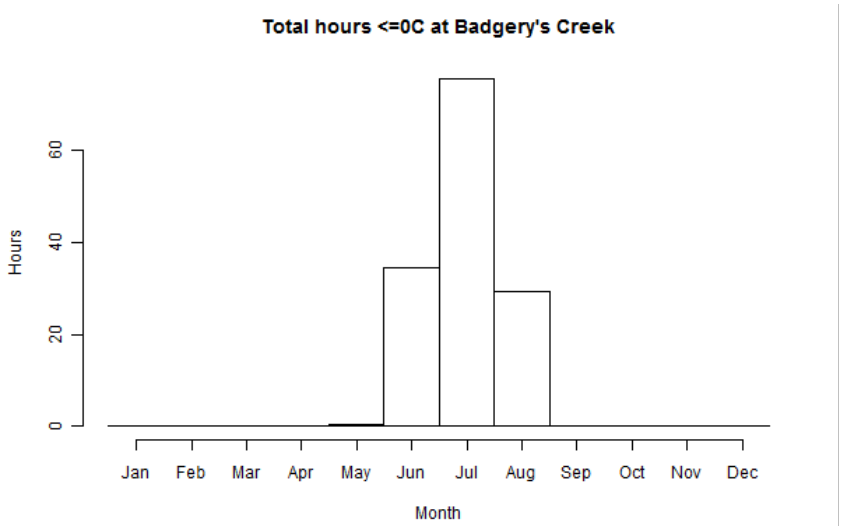

Figure 3.7 Average hours of temperature ≤ 0º at Badgerys Creek

It appears common for temperatures to drop below zero in the months from June to August at Badgerys Creek. Temperatures are most likely to drop below 0ºC in July, where there is in average of more than 75 hours a month. A boxplot of the average hourly occurrence of temperatures below 0ºC has been provided in Figure 3.8.

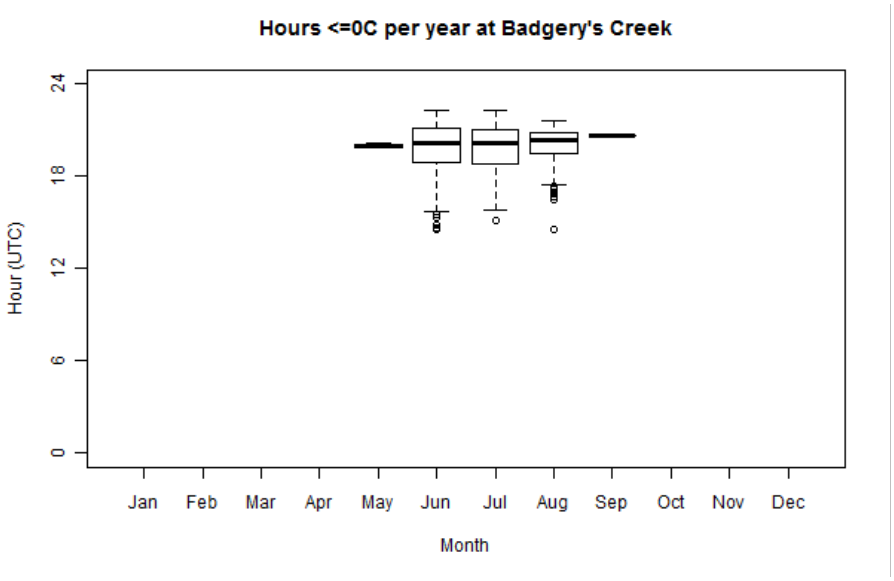

Figure 3.8 Hourly occurrence of temperatures ≤ 0º at Badgerys Creek

The early morning period prior to sunrise is the most common time for temperatures to be recorded below zero at Badgerys Creek.

3.5.2 Frost

Frost and ice accumulation on ground surfaces can occur at temperatures below zero. Data with a temperature of below zero[10] has been analysed to indicate the potential for frost at Badgerys Creek (refer to Figure 3.9). For comparison, data has also been extracted for Canberra Airport in Figure 3.10.

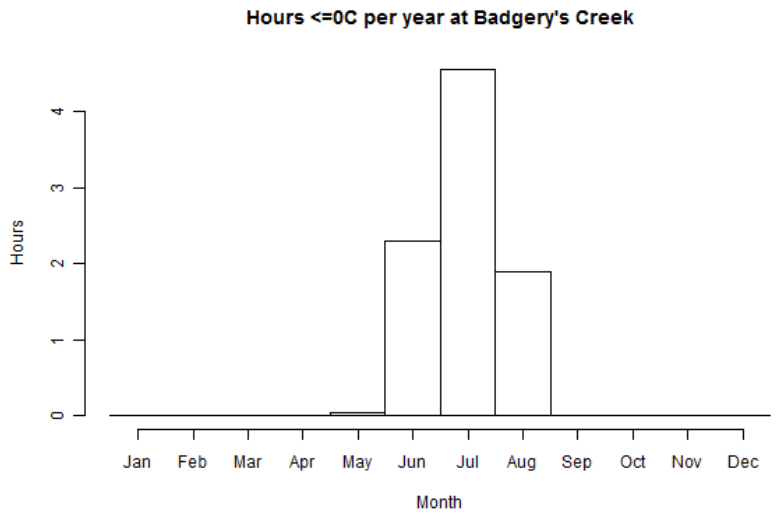

Figure 3.9 Average hourly inferred frost occurrence at Badgerys Creek

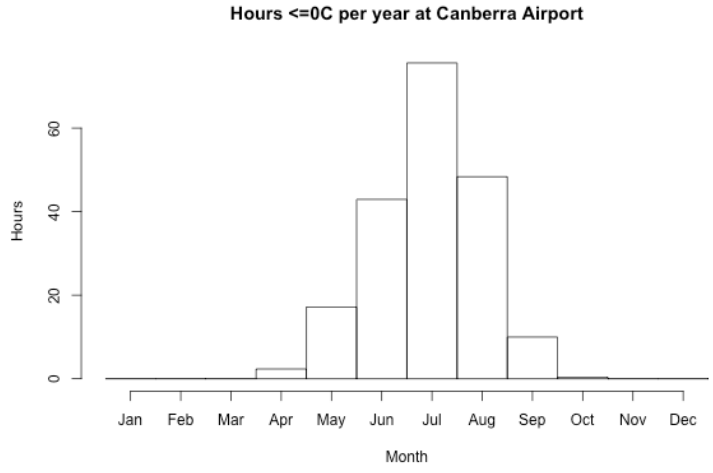

Figure 3.10 Average hourly inferred frost occurrence at Canberra Airport

Frost could potentially form between the months of May to August at Badgerys Creek. Frost is mostly likely to occur in July with over four hours on average expected at WSA. In comparison, From April to September Canberra Airport has approximately 20 times more hours of frost occurrence than Badgerys Creek.

[10] Temperatures below zero degrees at the site of the instrument approximately 1.2m height. Grass temperatures are not currently available at Badgerys Creek.

The hours of the day in which frost conditions are most likely at Badgerys Creek and Canberra Airport have been plotted in Figure 3.11 and Figure 3.12.

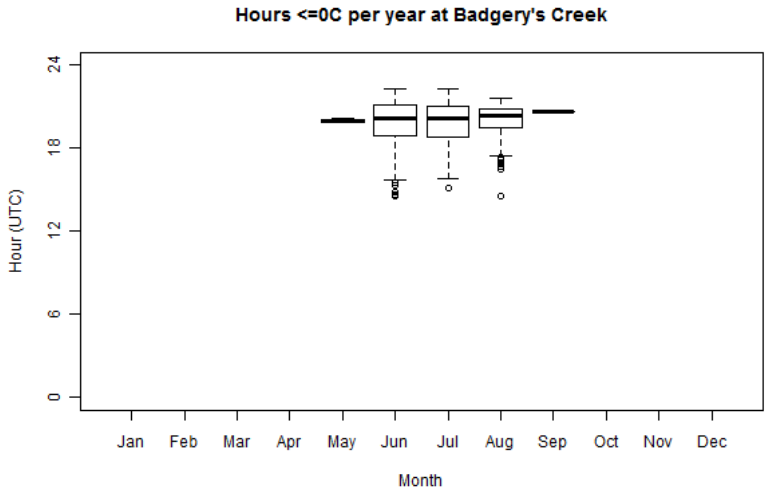

Figure 3.11 Hourly inferred frost occurrence at Badgerys Creek

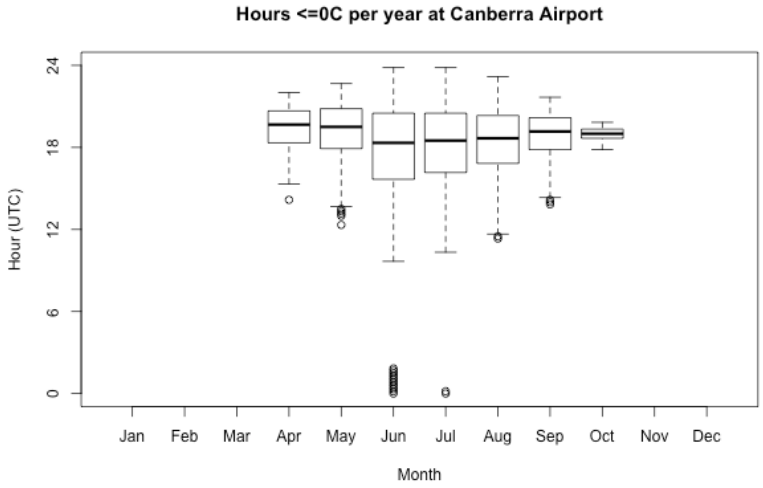

Figure 3.12 Hourly inferred frost occurrence at Canberra Airport

Frost is most likely to occur from May to September with the most frequent time of day being near sunrise at Badgerys Creek. The potential for frost at Canberra Airport extends from April to October where conditions exist from the early morning until mid-morning.

3.6 Freezing fog

Conditions are conducive to the formation of freezing fog when the temperature is below zero and the relative humidity is greater than or equal to 95%. In this circumstance the density of super-cooled liquid water suspended in the air would be significantly high enough to potentially cause rime icing on an aircraft's surface whose temperature is below zero. These atmospheric conditions also provide the ability for black ice to form on the tarmac, especially after rain.

The 10-minute data from Badgerys Creek AWS from 1999 to 2013 has been used to estimate the frequency of freezing fog (Figure 3.13). For comparison the annual average statistics for Canberra Airport have also been supplied in Figure 3.14.

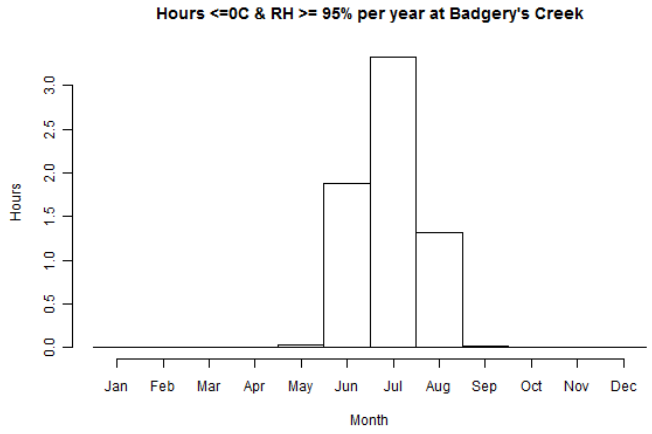

Figure 3.13 Average hours of inferred freezing fog occurrence at Badgerys Creek

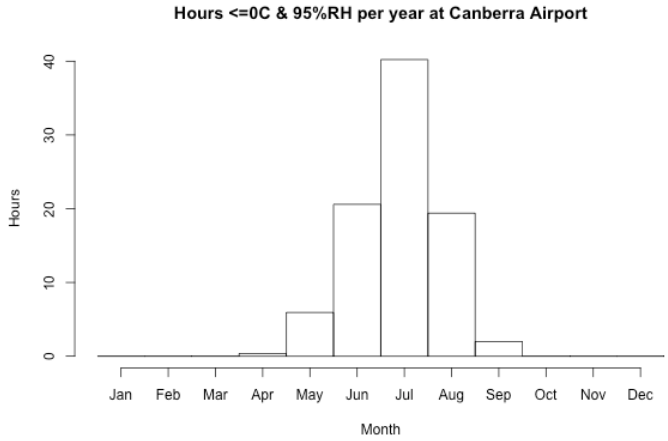

Figure 3.14 Average hours of inferred freezing fog occurrence at Canberra Airport

Conditions conducive to freezing fog could potentially occur annually in the months of May to September at WSA; however it is more common from June to August. On average there is 3.5hrs in July in which icing may impact surfaces at WSA. In comparison, Canberra Airport experiences on average 10 times more hours a month of freezing fog conditions during the winter months.

The hours of the day which may produce an icing problem have been plotted for Badgerys Creek and Canberra Airport in Figure 3.15 and Figure 3.16 respectively.

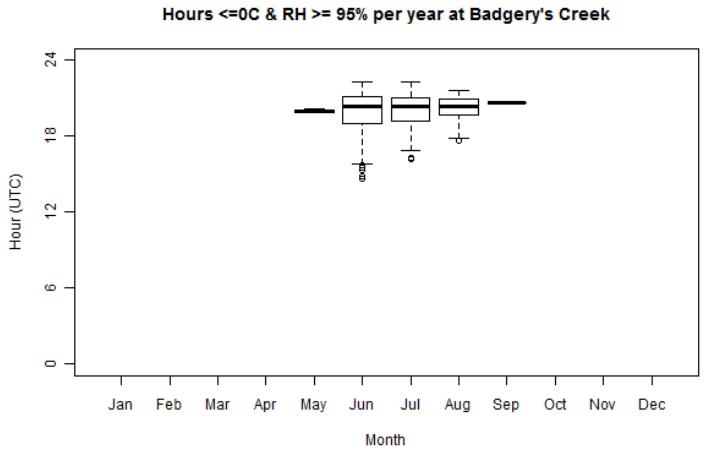

Figure 3.15 Hourly inferred freezing fog occurrence at Badgerys Creek

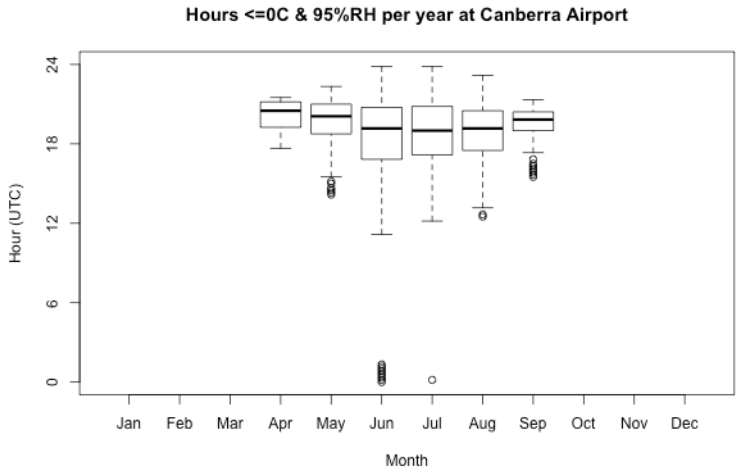

Figure 3.16 Hourly inferred freezing fog occurrence at Canberra Airport

Freezing fog would most commonly occur in the hours surrounding sunrise during the winter months at WSA. It would be possible, though rare, for events to initiate in the early morning hours. Freezing fog conditions at Canberra Airport are most probable in the early hours of the morning in winter and can extend until mid-morning in the worst of cases.

Conditions conducive to freezing fog could occur over short periods in the early morning hours at WSA. The availability of de-icing equipment at an airport can mitigate the impact of icing on an airframe.

3.7 Temperature inversions

A temperature inversion occurs when there is an increase in temperature with height above a location. The atmosphere beneath the inversion forms a stable layer of cold air trapped by the warm air aloft. The time taken for a ground-based temperature inversion to be broken down is directly correlated to surface temperature. Temperature inversions tend to be more significant during the cooler months where the air at the

surface is cooler than the air aloft, and the ability of the surface to heat during the early morning is diminished.

The presence of a temperature inversion has a significant influence on the ability of the atmosphere to disperse pollutants. An inversion layer effectively forms a barrier or 'lid' on the air in the lower atmosphere which restricts the mixing of air, and causes a build-up in pollutants. Pollutants from the previous day and those advected overnight into the area can be trapped by the inversion causing morning pollution problems. Generally, the concentration of pollutants in the air is strongest during the early morning hours when a low-level temperature inversion exists and wind speeds are light. Further study into inversion levels may be necessary for the calculation of pollution parameters.

3.8 Discussion

There appear to be two mesoscale effects affecting temperature at Badgerys Creek. The propagation of the sea breeze in the late afternoon into the western Sydney Basin has the ability to moderate temperatures. The sea breeze occurs frequently in the warmer months but may not always reach Badgerys Creek. On the other hand, the development of cloud and thunderstorms on the Great Dividing Range can contribute to anomalously high temperatures at WSA during the afternoon caused by a Foehn effect.

High temperatures (≥ 35ºC) primarily occur during the thunderstorm season from October to March. On the days that the temperature does exceed 35 ºC, it is middle to late afternoon when this is most likely to occur. Although temperatures above 35ºC do not occur frequently they have ability to constrain fuel loading.

Recommendation 3: The effect of high temperatures may need to be considered during the construction of jet fuel facilities at WSA.

Low temperatures (≤ 0ºC) occur frequently in the months June to August at Badgerys Creek. On the days that the temperature is recorded below 0 ºC, it is the early morning before sunrise when this is most likely to occur.

The frequency of freezing fog and frost is low and generally restricted to the hours near sunrise. The statistics surrounding freezing fog suggest that there would be instances where icing could occur during the winter period. De-icing equipment has the ability to mitigate against the build-up of icing on an airframe.

Recommendation 4: De-icing equipment may need to be considered in order to optimise operations at WSA during periods of low temperature.

Further directed studies into surface temperature inversions are required to provide a comprehensive analysis on temperature inversions.

The development of WSA and associated development is expected to create microscale meteorological changes; however it is unclear as to whether the changes would be expected to be significant. For example, the removal of the grass surface and its replacement by tarmac will likely lead to a measurable increase in temperature at Badgerys Creek. It would be expected that the leading cause of temperature changes would be the construction of surfaces, such as the runway, taxiways, car parks, aprons and roads which have a higher thermal conductivity than the existing vegetation.

4 Rainfall

The usability of an airport can be affected by rainfall in many ways. Rainfall can affect aircraft landing distance, runway nomination and the type of approach due to poor visibility or low cloud. Additionally, heavy rainfall leading to flash flooding can affect aircraft operations by flooding taxiways and runways, damaging the runway, severely reducing tyre traction and in the worst case hydroplaning.

4.1 Rainfall climatology

Rainfall data for Badgerys Creek has been extracted to produce a statistical summary supplied in Table 4-1. [11]

Table 4-1 Rainfall climatology for Badgerys Creek

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Rainfall (mm)	77.4	108.0	77.3	43.2	40.1	52.1	23.0	35.9	33.9	52.7	74.5	63.6
Highest Monthly Rainfall (mm)	192.2	342.4	198.0	129.4	155.6	220.0	71.6	231.0	82.2	182.2	173.2	131.2
Lowest Monthly Rainfall (mm)	13.6	13.4	21.4	1.8	1.8	2.0	2.8	1.0	6.4	0.4	8.4	14.2
Highest Daily Rainfall (mm)	138.0	106.8	67.8	82.4	54.0	63.8	28.4	70.0	50.8	63.0	63.0	65.0

The average annual rainfall at Badgerys Creek is 680.9mm with rain recorded on average on 117.8 days per year. The monthly rainfall statistics contained within Table 4-1 have been graphed in Figure 4.1.

[11] Unless otherwise stated the data range used for rainfall comparison is Badgerys Creek – Oct 1995 to 07 Jan 2015, Sydney KSA – Jan 1929 to 07 Jan 2015, Camden Airport – Jan 1943 to 07 Jan 2015.

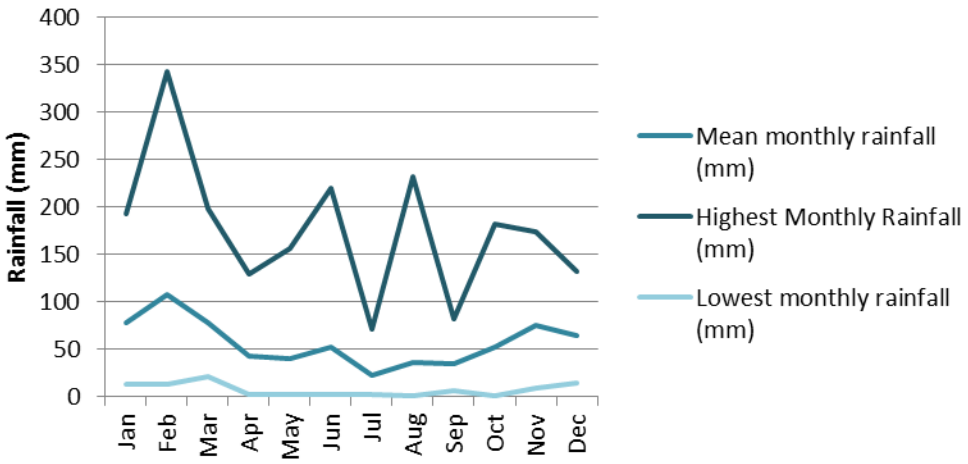

Figure 4.1 Monthly rainfall climatology at Badgerys Creek

The highest monthly rainfall at Badgerys Creek does not follow a smooth annual cycle due to the variable nature of rainfall and also to the short record of observations. However, the average rainfall and lowest rainfall follow a more predicable month-to-month cycle. Monthly rainfall in excess of 50mm on average occurs in the months from October to March at Badgerys Creek.

A statistical rainfall comparison between Badgerys Creek, Sydney KSA and Camden Airport has been supplied in the following sections (4.1.1 to 4.2.3).

4.1.1 Mean monthly rainfall comparison

A comparison of mean monthly rainfall between Badgerys Creek, Sydney KSA, and Camden Airport has been graphed in Figure 4.2.

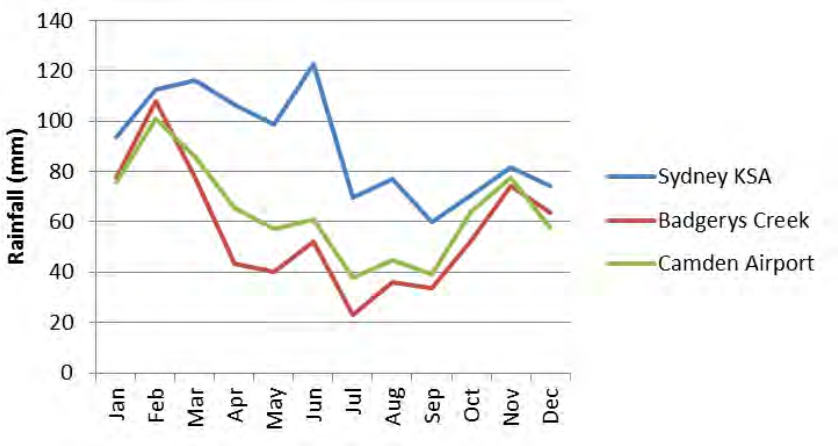

Figure 4.2 Comparison graph of mean monthly rainfall

Badgerys Creek receives slightly less rainfall per month than Camden Airport, and significantly less than Sydney KSA outside of thunderstorm season (October – March). It is possible that rainfall data at the Badgerys Creek site is not representative of climatology given the short period of recorded data.

4.1.2 Highest monthly rainfall comparison

A comparison of highest monthly rainfall between Badgerys Creek, Sydney KSA, and Camden Airport has been graphed in Figure 4.3.

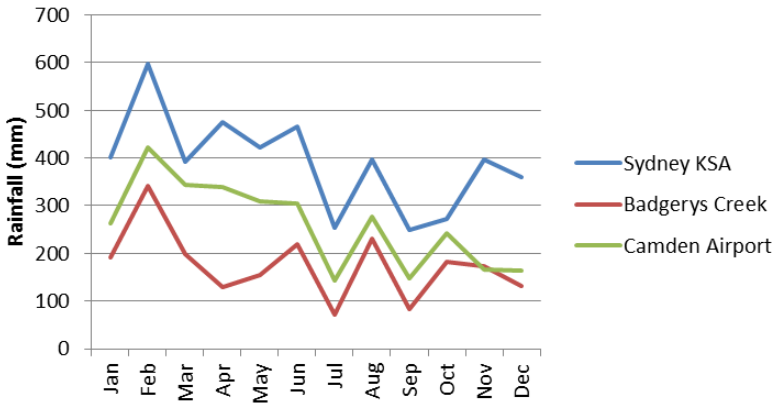

Figure 4.3 Comparison graph of highest monthly rainfall

For each month of the year the highest monthly rainfall on record at Badgerys Creek is approximately half of that ever experienced at Sydney KSA. Moreover, the highest monthly rainfall at Badgerys Creek is consistently lower than at Camden Airport with the exception of November. It is possible that rainfall data at the Badgerys Creek site is not representative of climatology given the short period of recorded data.

4.1.3 Lowest monthly rainfall comparison

A comparison of lowest monthly rainfall between Badgerys Creek, Sydney KSA, and Camden Airport has been graphed in Figure 4.4.

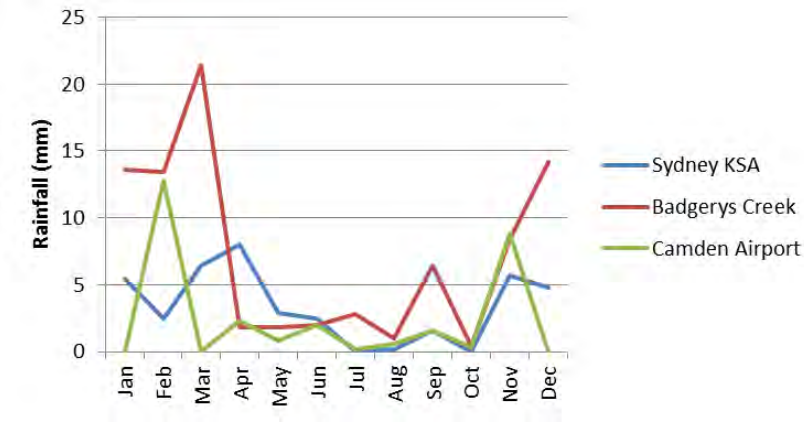

Figure 4.4 Comparison graph of lowest monthly rainfall

On average Badgerys Creek experiences rainfall in every month of the year. More specifically, rainfall records suggest that rainfall is more dependable at Badgerys Creek than at either Camden Airport or Sydney KSA. It is possible that rainfall data at the Badgerys Creek site is not representative of climatology given the short period of recorded data.

4.1.4 Highest daily rainfall comparison

A comparison of highest daily rainfall between Badgerys Creek, Sydney KSA, and Camden Airport has been graphed in Figure 4.5.

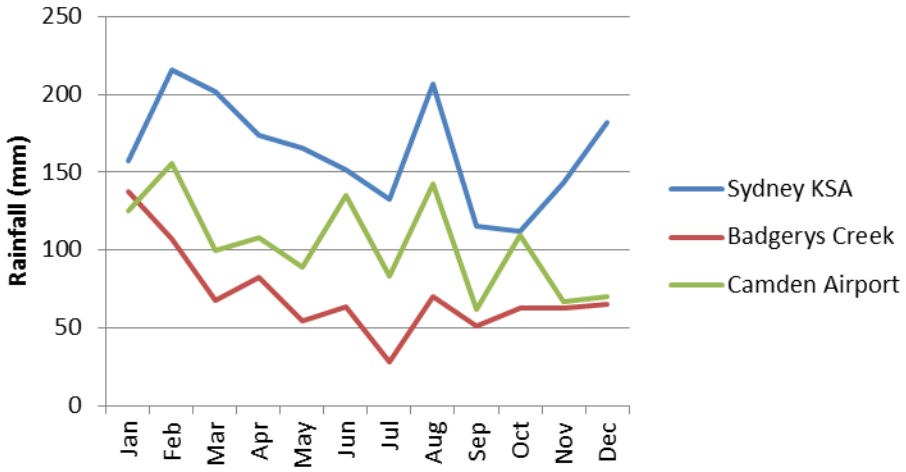

Figure 4.5 Comparison graph of highest daily rainfall

The highest daily rainfall records at Badgerys Creek are lower than those at Sydney KSA and Camden Airport in every month except January at Camden Airport. It is possible that rainfall data at the Badgerys Creek site is not representative of climatology given the short period of recorded data.

4.2 Monthly rain day climatology

Rain day data for Badgerys Creek has been extracted from 4 Dec 1998 to 7 Jan 2015 to produce the statistical summary supplied in Table 4-2.

Table 4-2 Rain day climatology for Badgerys Creek

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Number of Rain Days	11.4	11.3	11.7	10.4	8.2	10.4	7.8	6.7	8.1	8.8	11.4	11.4
Highest Number of Rain Days	18	16	18	18	14	17	15	14	13	17	15	17
Lowest Number of Rain Days	7	6	7	3	3	3	2	2	3	2	6	4

The monthly rain day statistics contained within the Table 4-2 have been graphed in Figure 4.6.

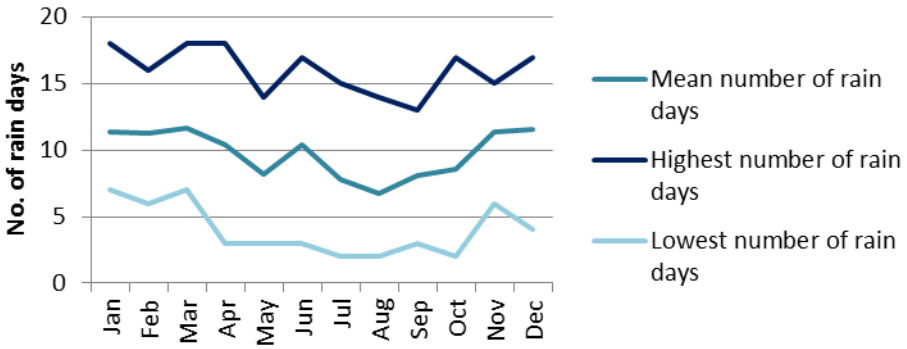

Figure 4.6 Mean monthly rain days at Badgerys Creek

On average, Badgerys Creek experiences rain more than 10 days per month from November to April, and June. There is little variation in the data throughout the year with rain days ranging from approximately 4-16 days per month.

A statistical rain day comparison between Badgerys Creek, Sydney KSA and Camden Airport has been produced.

4.2.1 Mean monthly rain day comparison

A comparison of mean monthly rain days between Badgerys Creek, Sydney KSA and Camden Airport has been graphed in Figure 4.7.

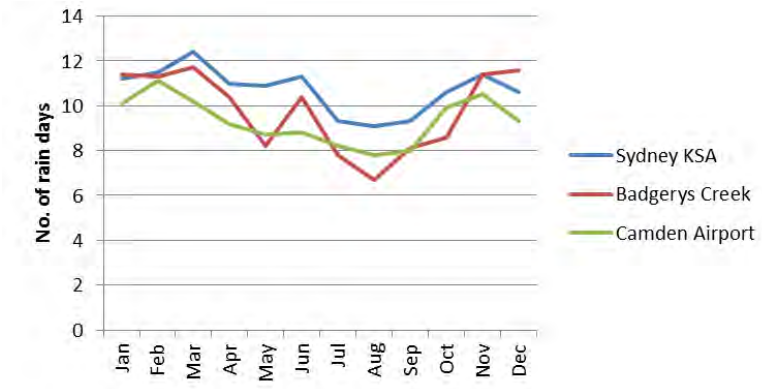

Figure 4.7 Comparison graph of mean monthly rain days

The graph above shows that there is little difference between the mean monthly rain days between the three sites. There is a variation in the data during the winter period with generally slightly lower rain days.

4.2.2 Highest monthly rain day comparison

A comparison of highest monthly rain days between Badgerys Creek, Sydney KSA, and Camden Airport has been graphed in Figure 4.8.

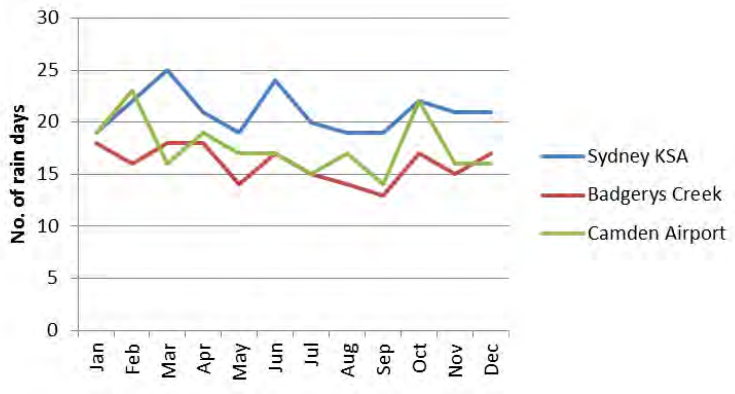

Figure 4.8 Comparison graph of highest monthly rain days

The graph shows that the recorded highest rain days per month are mostly lower at Badgerys Creek than at Sydney KSA or Camden Airport.

4.2.3 Lowest monthly rain day comparison

A comparison of lowest monthly rain days between Badgerys Creek, Sydney KSA, and Camden Airport has been graphed in Figure 4.9.

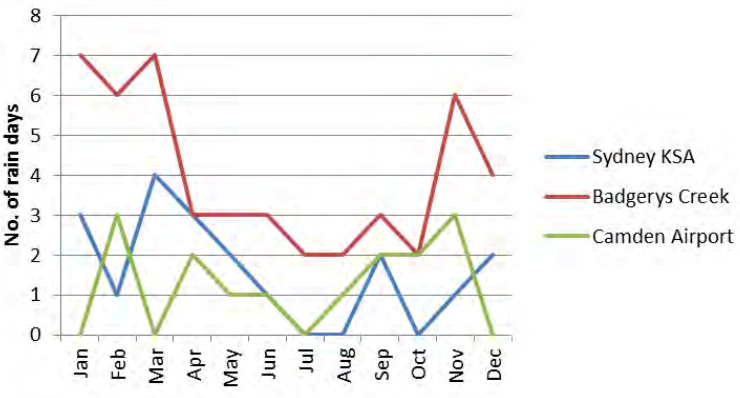

Figure 4.9 Comparison graph of lowest monthly rain days

Although the data appears highly variable, Badgerys Creek experiences higher records of lowest monthly rain days than either Sydney KSA or Camden Airport. The site at Badgerys Creek appears to receive at least 2 rain days per month with an average of 3-4 rain days per month across the year.

4.3 Discussion

Rainfall and the amount of rain days appear to be less variable at Badgerys Creek than at Camden Airport and Sydney KSA. Badgerys Creek experiences lower monthly highs and higher monthly lows in rainfall than the other two airports. This may be due to topographical effects or due to the shorter length of rainfall records.

If the data is representative of climatology then analysis shows that Badgerys Creek experiences less rainfall during recorded rain days than either Camden Airport or Sydney KSA. This theory would align with meteorological concepts and anecdotal evidence from experienced meteorological forecasters.

The construction of an airport is unlikely to have any significant effect on rainfall climatology at Badgerys Creek. Nevertheless the construction of an airport can impact the occurrence of flood effects due to increased runoff. Appropriate control measures and engineering can mitigate surface runoff.

Recommendation 5: Changes in land surface coverage will need to be accounted for in hydrological studies to ensure appropriate control measures and engineering can mitigate surface runoff.

5 Fog and low cloud

Fog is a suspension of water droplets in the air near the surface of the earth. Internationally fog is reported when the horizontal visibility has dropped below 1000 metres (ICAO 2007). However in order to exclude smoke and other circumstances which may cause a reduction in visibility an additional condition of relative humidity above 95% has been applied to data analysis.

For aviation purposes, a visibility of less than 1000 metres must be observed at a height of two metres above the ground or the fog is termed shallow fog. Instrumentation is currently unable to determine the difference between shallow fog and fog at an airport.

5.1 Fog types

There are various ways in which a fog can form in the Sydney Basin. However, fog rarely forms from a single mechanism, usually there are several processes operating collectively.

5.1.1 Radiation fog

Radiation fog, depicted in Figure 5.1, is caused by the rapid cooling of air at the earth's surface. This type of fog generally occurs overnight as heat escapes causing cooler conditions and condensation near the ground. Radiation fog forms in situ and is more prevalent on cloudless nights. This type of fog is common in the western Sydney Basin where surface cooling can occur quickly overnight. Similar atmospheric conditions can occur after rain or thunderstorm events and these events are called post-rain fog events. Additionally radiation fog may be advected by light winds at the surface in the correct atmospheric environment.

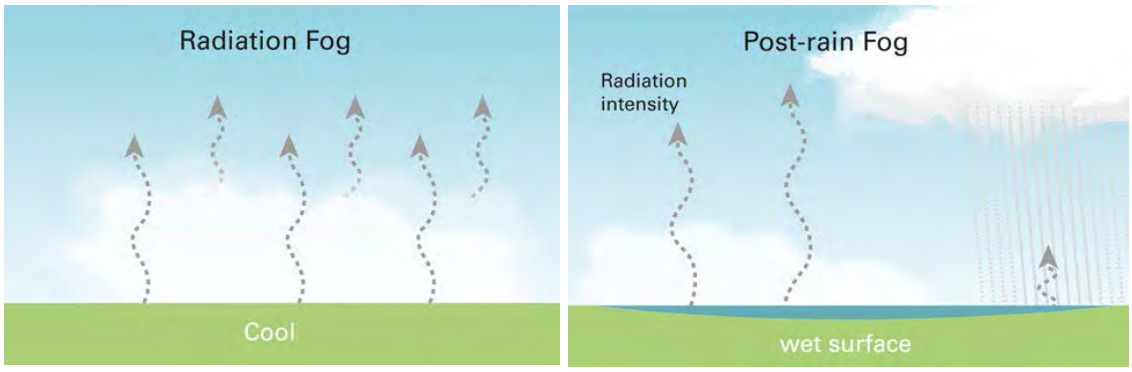

Figure 5.1 Illustration of Radiation Fog and Post Rain Fog Formation Processes (Bureau 2014)

5.1.2 Advection fog

Advection fog develops as warm moist air moves over a cooler surface (Figure 5.2). This type of fog development is not common in the Sydney Basin, however can occur when a warm moist sea breeze propagates inland late into the evening after the western basin has cooled substantially.

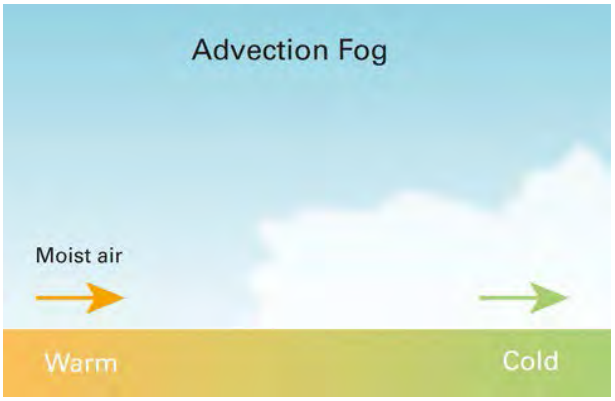

Figure 5.2 Illustration of Advection Fog Formation Processes (Bureau 2014)

5.1.3 Valley fog

Valley fog is a type of radiation fog which forms in mountain valleys. This fog can develop on the eastern slopes of the Great Dividing Range and travel into the Sydney Basin with the valley winds overnight.

5.1.4 Sea fog

Sea fog can occur at any time of the year along the Australian Coast. It has the ability to move over parts of the coast and inland, however these events are uncommon and rarely do they propagate extensive distances inland.

5.1.5 Advected fog

Advected fog forms remotely and moves into another space changing and/or displacing the original air mass (Figure 5.3). Advected fog is very common to the Sydney Basin with fog developing in western areas and advecting towards the coast during the evening.

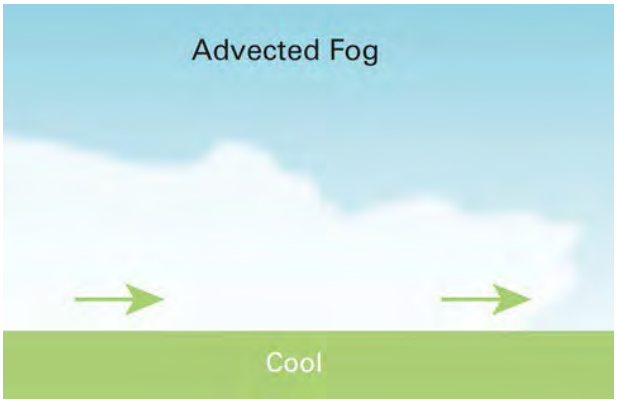

Figure 5.3 Illustration of Advection Fog Formation Processes (Bureau 2014)

5.1.6 Freezing fog

Freezing fog contains a suspension of supercooled liquid water droplets near the earth's surface at temperatures below freezing. Freezing fog is rare in Australia and particularly in the western Sydney Basin but it can occur. Freezing fog has been covered in section 3.6.

5.2 Fog climatology

The AWS at Badgerys Creek currently does not have the capability to determine visibility and cloud. Instead, these parameters have been based on the instrumentation at Camden Airport. Camden Airport is less than 20km to the south of Badgerys Creek and is a similar distance to the east of the Great Dividing Range. Camden Airport has been identified by meteorological forecasters as the most representative site available for fog statistics.

Senior meteorologists experienced in forecasting for the Sydney Basin suggest that fog at Badgerys Creek is likely to occur more often than fog at Camden Airport. However without adequate instrumentation it is impossible to confirm the frequency of fog at Badgerys Creek.

Camden Tower operated by Airservices personnel is active between 2200 – 0800UTC and does not regularly report weather phenomena. It is impossible to verify the occurrence of all operationally significant fog events at Camden Airport without 24hr manual input because the instrument observing visibility reports shallow fog identically to deeper fog events. For the purposes of this section, fog will be said to have occurred when the visibility meter records a horizontal visibility below 1000m as a 10 minute average.

5.2.1 Fog days with visibility below 1000m

Data was available at Camden Airport in 10-minute increments.[12] Approximately 4.5% of the data set did not contain an observation of visibility and cloud due to numerous factors including maintenance and quality control. With a total of 222,488 observations in the data set it was assumed that the missing data was not statistically significant.

The remaining observations were analysed to obtain the number of days in which the visibility dropped below 1000m for a 10-minute period or more for each month. An average was calculated using the four years of data (refer to Figure 5.4), and a fourth order polynomial trend line has been superimposed on to the monthly averages. Associated with the average is a minimum and maximum to indicate the spread of data from year-to-year.

[12] Unless otherwise stated the 10 minute data for Camden Airport was analysed from 26 Aug 2010 to 18 Oct 2014.

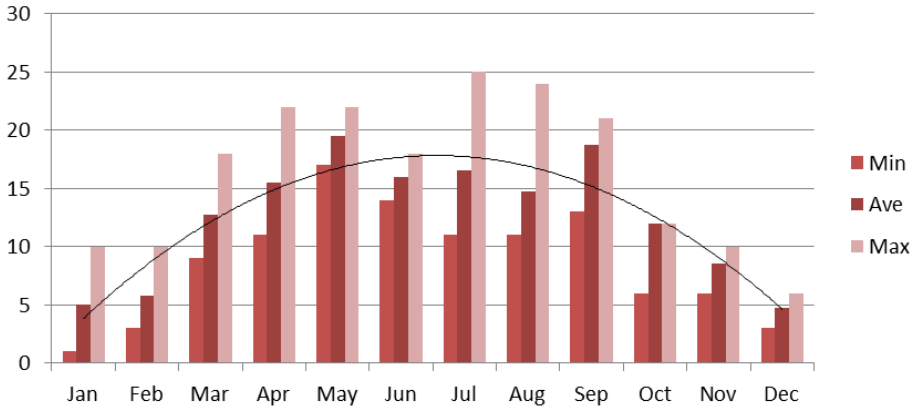

Figure 5.4 Monthly bar graph of number of days with visibility <1000m at Camden Airport

The graph shows that short periods (ten minutes) of low visibility are common during the winter months, and can occur in every month of the year. It was calculated that for the 50 months studied the visibility dropped below 1000m over a 10-minute period at least once on 39% of days. Although short periods of reduced visibility can be of concern, generally they pose no large impact on airport operations.

Further analysis was completed on the data to determine the frequency of fogs that lasted for periods equal to and greater than 1 and 4 hours. These longer periods with visibility continually below 1000m were termed fog 'events'. An average number of fog events per month over the four years of data was examined and has been supplied in Figure 5.5.

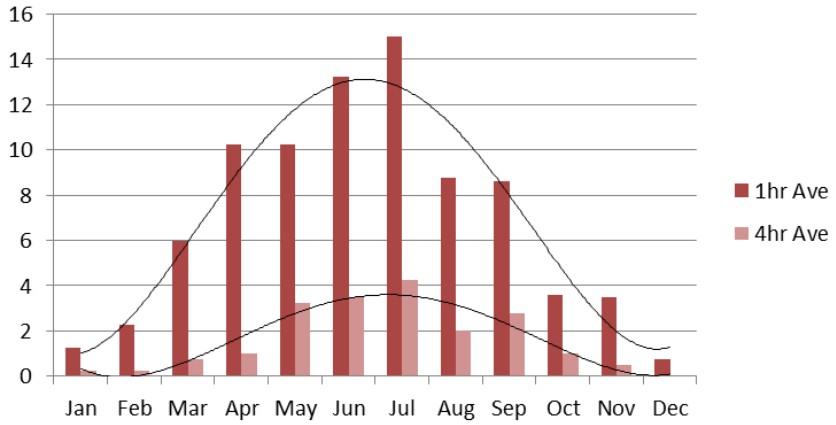

Figure 5.5 Monthly bar graph of number of days with fog events at Camden Airport

The number of events lasting an hour or more occurs on average more than 10 days a month during April to July. The average number of events that lasted more than 4 hours occurs two or more days a month during May to September.

It was calculated that fog events occurring for a period of an hour or more averaged 23% of days per year, whilst in winter the percentage increased to 40%. Furthermore, fog events of periods of four hours or more averaged 5% of days, increasing to 12% of days in winter. The calculated data has been summarised in Table 5-1.

Table 5-1 Summary table of calculated statistics for visibility <1000m

Time period	Daily average
10-minutes	39.4%
≥ 1hr all months	22.7%
≥ 1hr Jun-Aug	40.2%
≥ 4hr all months	5.4%
≥ 4hr Jun-Aug	12.0%

This data has been calculated using the available 50months of 10-minute data at Camden Airport which may not be representative of climatic trends.

5.2.2 Fog days with visibility below 500m

Most major Australian airports are equipped with Instrument Landing Systems (ILS) which allows a pilot to attempt to approach an airport in reduced visual conditions. However, in the event of a fog it is the Runway Visual Range (RVR) system which becomes critically important. The RVR system may allow aircraft to land in fog provided the RVR is above specified thresholds, the aircraft has the required instrumentation, and the pilot required valid certification.

With the implementation of specific navigational aids it is possible for aircraft to land safely (Autoland) when the RVR visibility is below 600m. Fog events below 500m have been analysed individually for Camden Airport to provide a more comprehensive picture.

The average number of days each month when the visibility dropped below 500m for a period of 10 minutes or more has been provided in Figure 5.6. A fourth order polynomial trend line has been superimposed on to the monthly averages. Associated with the monthly average are minimum and maximum to indicate the spread of data.

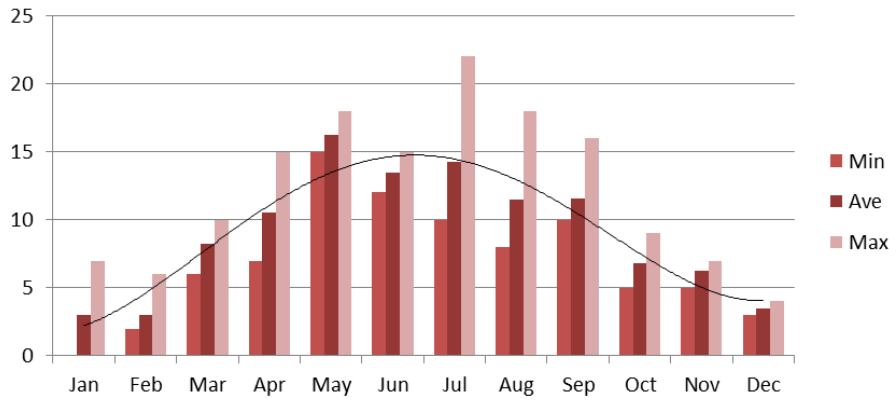

Figure 5.6 Monthly bar graph of number of days with visibility <500m at Camden Airport

The graph illustrates that short ten-minute periods of low visibility are common during the months from May to August. It was calculated that for the 50 months studied the visibility dropped below 500m over a 10-minute period on 30% of the days. Although short periods of reduced visibility can be of concern, generally they pose no large impact on airport operations.

Further analysis was completed on the data to determine the frequency of fogs that lasted for periods equal to and greater than 1 and 4 hours. These longer periods with visibility continually below 500m were termed fog 'events'. An average number of fog events per month over the four years of data was examined and has been supplied in Figure 5.7.

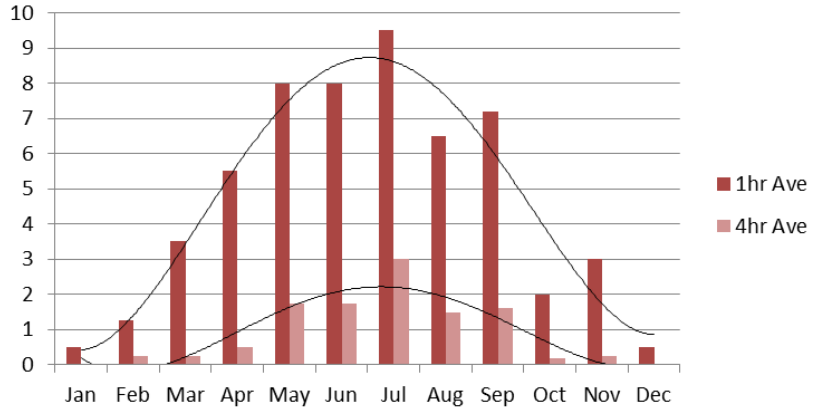

Figure 5.7 Monthly bar graph of number of days with fog events at Camden Airport

The average number of days in which the visibility drops below 500m for an hour or more occurs on more than 5 days a month during April to September. It can be seen that the average number of days in which a fog event has a visibility below 500m for 4 hours or more occurs on more than 1 day a month during May to September. It was calculated that fog events occurring for a period of an hour or more averaged 15% of the days, whilst in winter the percentage increased to 26%. Furthermore fog events with periods of four hours or more averaged 3% of days, increasing to 7% for days in winter. The calculated data has been summarised in Table 5-2.

Table 5-2 Summary table of calculated statistics for visibility <500m

Time period	Daily average
10-minutes	29.7%
≥ 1hr all months	15.2%
≥ 1hr Jun-Aug	26.1%
≥ 4hr all months	3.0%
≥ 4hr Jun-Aug	6.89%

This data has been calculated using the available 50months of 10-minute data at Camden Airport which may not be representative of climatic trends.

5.2.3 Hourly visibility statistics below 1500m

Whilst 10-minute data is preferred, the four year record at Camden is too short for climatic trends. Additional analysis has been completed on long range 30-minute data to determine the percentage occurrence of visibility conditions below 1500m at each hour of the day for each month of the year. Camden Airport data was extracted from 01 May 1995 to 05 December 2014 (see Table 5-3).

Table 5-3 Table of monthly percentage occurrence of visibility <1500m for each hour of the day at Camden Airport

Time(UTC)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0000	0.0	0.0	0.0	0.0	0.3	1.1	1.1	0.0	0.3	0.0	0.0	0.0
0100	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.5	0.0	0.0
0200	0.0	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0
0300	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0
0400	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0
0500	0.0	0.0	0.3	0.0	0.5	0.0	0.0	0.0	0.3	0.0	0.0	0.3
0600	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.3	0.5	0.0	0.0
0700	0.0	0.3	0.3	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
0800	0.3	0.0	0.0	0.3	0.3	0.8	0.3	0.0	0.0	0.0	0.0	0.0
0900	0.0	0.0	0.0	0.0	0.3	2.8	2.0	0.5	0.3	0.0	0.3	0.0
1000	0.0	0.3	0.0	0.9	1.1	4.0	2.2	0.5	0.0	0.3	0.3	0.3
1100	0.0	0.0	0.0	1.2	2.7	6.2	5.0	1.1	0.3	0.3	0.0	0.0
1200	0.0	0.3	0.0	1.4	3.0	9.4	7.8	3.0	0.3	1.1	0.3	0.0
1300	0.3	0.0	1.3	4.9	8.7	13.4	9.8	5.5	1.1	1.9	0.6	0.3
1400	0.3	1.9	2.2	7.5	12.3	15.3	15.7	7.1	3.9	3.2	1.4	0.9
1500	1.2	0.6	4.6	13.0	16.2	20.0	16.8	10.0	5.6	3.8	3.6	0.9
1600	2.1	2.8	9.4	18.6	20.8	20.3	18.8	12.5	11.9	7.0	5.0	2.9
1700	2.4	3.7	12.9	22.9	23.1	19.0	21.8	14.7	12.5	11.6	8.9	4.4
1800	6.3	5.6	16.7	19.4	20.7	19.9	19.7	14.4	14.5	14.6	11.2	5.5
1900	7.0	7.2	17.3	24.3	19.8	18.4	22.2	14.9	17.5	16.1	10.9	6.7
2000	2.7	5.0	19.9	20.6	18.7	17.2	21.6	15.2	17.3	8.1	4.4	1.4
2100	0.9	1.2	7.0	13.6	18.7	14.7	16.9	14.4	4.9	1.6	0.6	0.6
2200	0.0	0.0	0.5	2.3	4.7	7.2	7.3	3.0	1.1	0.5	0.0	0.0
2300	0.0	0.0	0.0	0.9	0.8	2.9	2.0	1.4	0.0	0.0	0.0	0.0

Periods of visibility <1500m are more frequent during the late evening to early morning in winter months, particularly in May from 2am to 4am LST (1600-1800 UTC) when low visibility conditions are reported on approximately one morning in five. A statistical comparison between Camden Airport, Sydney KSA, Canberra Airport, and RAAF Base Richmond for the months of June and July is shown in Table 5-4.

The analysis included all available data:

- Camden Airport – 01 May 1995 to 05 Dec 2014
- Sydney KSA – 10 Oct 1948 to 05 Dec 2014
- Canberra Airport – 01 Jan 1985 to 05 Dec 2014
- RAAF Base Richmond – 28 Apr 1995 to 27 Jan 2014

The data was tabulated as a percentage occurrence in Table 5-4.

Table 5-4 Comparison table of percentage occurrence of visibility <1500m for each hour of the day in June and July

	Camden Airport		Sydney KSA		Canberra Airport		RAAF Base Richmond	
Time(UTC)	Jun	Jul	Jun	Jul	Jun	Jul	Jun	Jul
0000	1.1	1.1	0.6	0.2	4.4	4.7	1.5	2.3
0100	0.0	0.3	0.3	0.0	2.0	0.7	0.2	0.0
0200	0.3	0.0	0.1	0.0	0.3	0.1	0.0	0.0
0300	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0400	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
0500	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
0600	0.0	0.0	0.2	0.2	0.0	0.1	0.0	0.0
0700	0.3	0.0	0.0	0.0	0.0	0.1	0.4	0.0
0800	0.8	0.3	0.0	0.0	0.0	0.0	0.8	0.2
0900	2.8	2.0	0.0	0.3	0.3	0.1	0.8	0.4
1000	4.0	2.2	0.1	0.0	0.8	0.4	2.3	2.3
1100	6.2	5.0	0.0	0.0	1.4	0.4	3.3	3.2
1200	9.4	7.8	0.1	0.0	2.0	0.4	5.3	4.6
1300	13.4	9.8	0.2	0.0	2.2	0.9	7.5	7.8
1400	15.3	15.7	0.4	0.0	3.7	2.0	12.4	10.1
1500	20.0	16.8	0.6	0.3	6.1	2.7	15.3	13.4
1600	20.3	18.8	0.8	0.4	7.9	5.3	18.5	19.0
1700	19.0	21.8	0.8	0.3	11.1	6.8	20.3	18.5
1800	19.9	19.7	1.6	0.4	13.5	9.8	22.0	23.4
1900	18.4	22.2	1.7	0.6	16.3	11.6	25.0	25.6
2000	17.2	21.6	1.7	0.6	17.3	14.9	25.5	25.6
2100	14.7	16.9	1.9	0.8	17.9	17.4	25.5	21.3
2200	7.2	7.3	2.3	0.9	15.3	15.0	14.5	13.3
2300	2.9	2.0	1.5	0.4	10.8	10.1	7.4	8.9
Mean	7.9	8.1	0.7	0.2	5.6	4.3	8.9	8.3

It can be calculated that conditions which reduce the visibility below 1500m in winter occurs approximately 20 times more often at Camden Airport than at Sydney KSA and approximately 2 times more often than at Canberra Airport. However, RAAF Base Richmond experiences fog of about the same frequency as Camden Airport, or slightly more. Data in Table 5-4 has been displayed graphically for the months of June and July separately in Figure 5.8 and Figure 5.9 respectively.

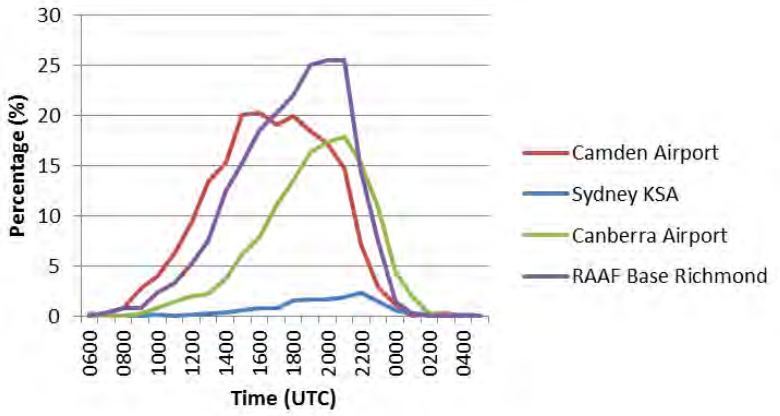

Figure 5.8 Line graph of percentage occurrence of visibility <1500m for each hour of the day in June

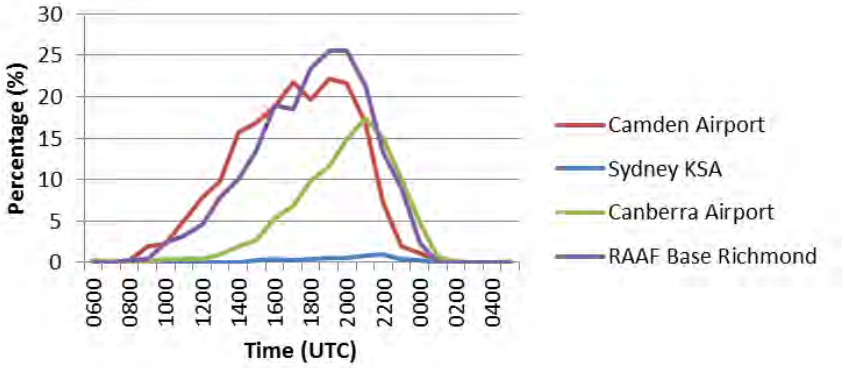

Figure 5.9 Line graph of percentage occurrence of visibility <1500m for each hour of the day in July

The institution of a threshold, such as 15%, assists in the comparison between airports. Camden Airport has at least a 15% chance of visibility below 1500m between the hours of 1400 to 2100UTC in June and July. Similarly RAAF Base Richmond breaches the threshold between 1500 to 2100UTC. Sydney KSA does not reach the 15% threshold at any stage. Canberra Airport has a greater than 15% chance of fog between the hours of 1900 to 2200UTC.

The graphs above show that low visibility conditions at Camden Airport tend to form earlier in the evening and finish earlier in the morning than those at Canberra Airport. Additionally, there is generally a higher probability of having the visibility fall below 1500m for more hours of the night at Camden Airport than at Canberra Airport.

5.2.4 Hourly visibility statistics below 800m

Analysis has been completed on long range 30-minute data to determine the percentage occurrence of visibility conditions below 800m at each hour of the day for each month of the year (see Table 5-5).

Table 5-5 Table of percentage monthly occurrence of visibility <800m for each hour of the day at Camden Airport

Time(UTC)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0000	0.0	0.0	0.0	0.0	0.0	0.3	0.8	0.0	0.0	0.0	0.0	0.0
0100	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0
0200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
0300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
0400	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0
0500	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.3
0600	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.3	0.0	0.0	0.0
0700	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
0800	0.0	0.0	0.0	0.0	0.3	0.6	0.3	0.0	0.0	0.0	0.0	0.0
0900	0.0	0.0	0.0	0.0	0.0	1.7	2.0	0.0	0.0	0.0	0.3	0.0
1000	0.0	0.0	0.0	0.6	0.8	2.8	2.2	0.0	0.0	0.0	0.0	0.0
1100	0.0	0.0	0.0	0.9	1.9	4.8	5.0	0.3	0.3	0.3	0.0	0.0
1200	0.0	0.0	0.0	0.9	3.0	6.0	7.8	2.2	0.3	0.5	0.0	0.0
1300	0.3	0.0	0.8	3.5	6.8	10.8	9.8	4.4	0.8	1.3	0.6	0.3
1400	0.0	0.9	0.3	4.9	9.6	11.4	15.7	4.9	2.2	2.7	1.4	0.3
1500	1.2	0.3	3.2	10.4	10.7	16.6	16.8	7.5	4.5	3.0	2.5	0.9
1600	1.5	2.5	5.9	14.5	17.0	16.0	18.8	9.4	9.0	5.7	3.0	1.7
1700	1.8	3.1	9.9	18.0	19.5	14.9	21.8	11.9	10.5	8.9	6.1	3.2
1800	3.3	4.3	13.2	16.5	16.3	15.6	19.7	12.2	11.1	11.6	8.4	5.0
1900	4.9	5.6	14.9	20.0	15.7	14.7	22.2	13.2	14.7	13.2	8.4	5.6
2000	2.1	4.1	15.3	15.9	14.6	12.6	21.6	11.8	14.4	6.7	3.3	1.2
2100	0.3	0.6	5.6	10.1	14.5	11.0	16.9	11.3	3.7	1.1	0.6	0.6
2200	0.0	0.0	0.5	1.4	3.0	6.0	7.3	3.0	0.9	0.5	0.0	0.0
2300	0.0	0.0	0.0	0.3	0.6	1.7	2.0	0.8	0.0	0	0.0	0.0

Fog occurs more frequently during the late evening to mid-morning in winter months, particularly in July from 3am to 6am LST (1700-2000 UTC) when fog is reported on approximately one in five mornings. Whilst fog is not as prevalent in summer, fog is not uncommon in the early hours of the morning at Camden Airport. A statistical comparison between Camden, Sydney and Canberra Airport for the months of June and July is illustrated in Table 5-6.

Table 5-6 Comparison table of percentage likelihood of visibility <800m for each hour of the day in June and July

	Camden Airport		Sydney Airport		Canberra Airport		RAAF Base Richmond	
Time(UTC)	Jun	Jul	Jun	Jul	Jun	Jul	Jun	Jul
0000	0.3	0.8	0.2	0.2	2.8	2.1	1.1	1.3
0100	0.0	0.3	0.1	0.0	0.5	0.1	0.0	0.0
0200	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0300	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0400	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0600	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0700	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0800	0.6	0.3	0.0	0.0	0.0	0.0	0.6	0.2
0900	1.7	2.0	0.0	0.0	0.1	0.1	0.6	0.2
1000	2.8	2.2	0.0	0.0	0.6	0.3	1.5	1.1
1100	4.8	5.0	0.0	0.0	1.3	0.1	2.7	1.7
1200	6.0	7.8	0.1	0.0	1.5	0.1	3.5	3.2
1300	10.8	9.8	0.1	0.0	1.8	0.7	6.9	6.1
1400	11.4	15.7	0.3	0.0	2.6	1.1	10.8	7.8
1500	16.6	16.8	0.4	0.3	3.5	1.6	13.4	10.2
1600	16.0	18.8	0.4	0.3	5.3	3.1	16.3	15.4
1700	14.9	21.8	0.7	0.1	6.9	4.3	18.9	16.4
1800	15.6	19.7	1.4	0.2	10.2	6.5	19.6	20.7
1900	14.7	22.2	1.3	0.5	10.8	7.7	20.4	21.2
2000	12.6	21.6	1.5	0.6	10.3	9.4	22.0	22.1
2100	11.0	16.9	1.7	0.5	11.6	10.4	21.2	17.2
2200	6.0	7.3	1.5	0.7	11.2	9.0	12.2	10.3
2300	1.7	2.0	1.0	0.4	7.0	6.0	5.1	7.5
Mean	6.2	6.5	0.4	0.1	3.6	2.6	7.4	6.8

By considering the 15% threshold it can be seen that Camden Airport has a probability of fog greater than 15% between the hours of 1500 to 1900UTC. RAAF Base Richmond has slightly longer hours of between 1600 to 2100 UTC. Canberra Airport breaches the threshold in June for two hours (2100 to 2200UTC), whilst Sydney KSA probability of fog does not exceed 2%.

From the table, it can be calculated that fog occurs approximately 30 times more often at Camden Airport than at Sydney KSA; and approximately 2 times more often at Camden Airport than at Canberra Airport. Alternatively, fog at RAAF Base Richmond is recorded on average an additional 10% of the time more than at Camden Airport. Data in Table 5-6 has been displayed graphically for the months of June and July separately in Figure 5.10 and Figure 5.11 respectively.

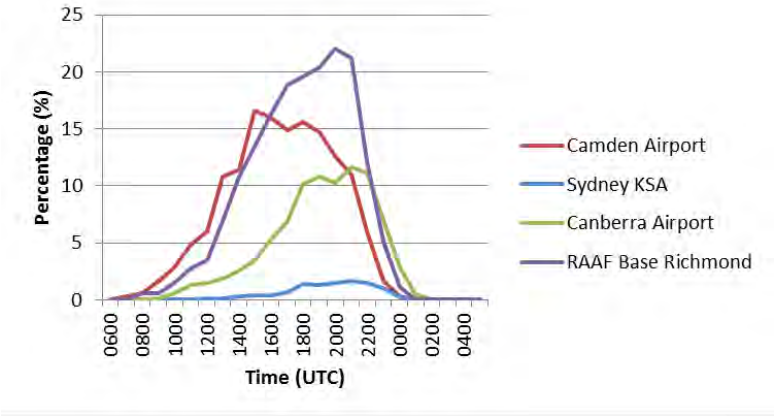

Figure 5.10 Line graph of percentage occurrence of visibility <800m for each hour of the day in June

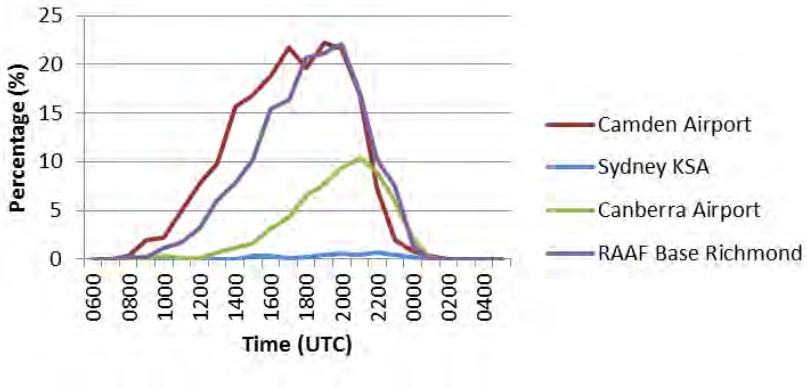

Figure 5.11 Line graph of percentage occurrence of visibility <800m for each hour of the day in July

The graphs above shows that fog at Camden Airport tends to form earlier in the evening and finish earlier in the morning than fog at Canberra Airport. Additionally, it is apparent that there is a higher probability of fog occurring in most hours of the overnight period at Camden Airport than at Canberra Airport.

5.3 Low cloud

The presence of a low cloud ceiling has the ability to affect airport operations and air traffic flow. To ensure that aircrew can adequately prepare for low cloud situations an 'alternate minima' is assigned dependant on aircraft type. The alternate minimum represents the broken cloud height below which additional fuel must be carried to enable the aircraft to safely land at an alternative aerodrome.

Airservices has provided the following preliminary advice regarding the proposed alternate minima for WSA.

Table 5-7 Aircraft category and corresponding alternate cloud minima

Category aircraft	Minima
CAT A/B Alternate	1198ft
CAT C Alternate	1358ft
CAT D Alternate	1488ft

(M. Shepherd 2014, pers. comm., 12 November)

5.3.1 Low cloud at Badgerys Creek

The formation of low cloud is dependent on factors such as temperature, low-level moisture content, low-level wind direction, atmospheric stability, and topography. From data it is possible to calculate the dewpoint depression which is the difference between temperature and dewpoint. Inferred cloud ceiling can be estimated by lifting the air parcel to a point of condensation; however the amount of sky covered with cloud cannot be predicted. For example, a dewpoint depression of 7ºC would be equivalent to a cloud base of 2800ft.

A graph of the hourly average dewpoint depression for each month of the year at Badgerys Creek can be seen in Figure 5.12.

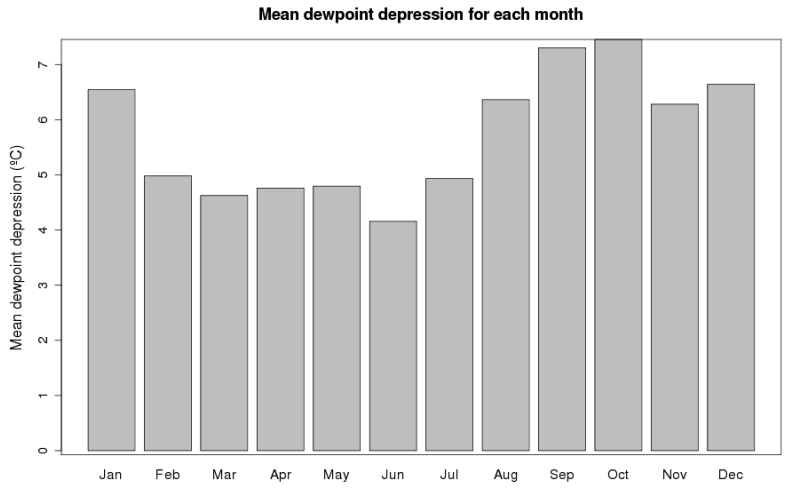

Figure 5.12 Histogram of monthly average dewpoint depression at Badgerys Creek

Given that a dewpoint depression of less than 7 ºC would correlate to a cloud base of less than 2800ft, it is possible to infer that a cloud base of 2800ft or below is the mean condition at Badgerys Creek for most of the year. Exceptions occur in September and October when westerly winds and drier conditions prevail over the Western Sydney Basin. An average dewpoint depression can be graphed for every hour of the day, Figure 5.13.

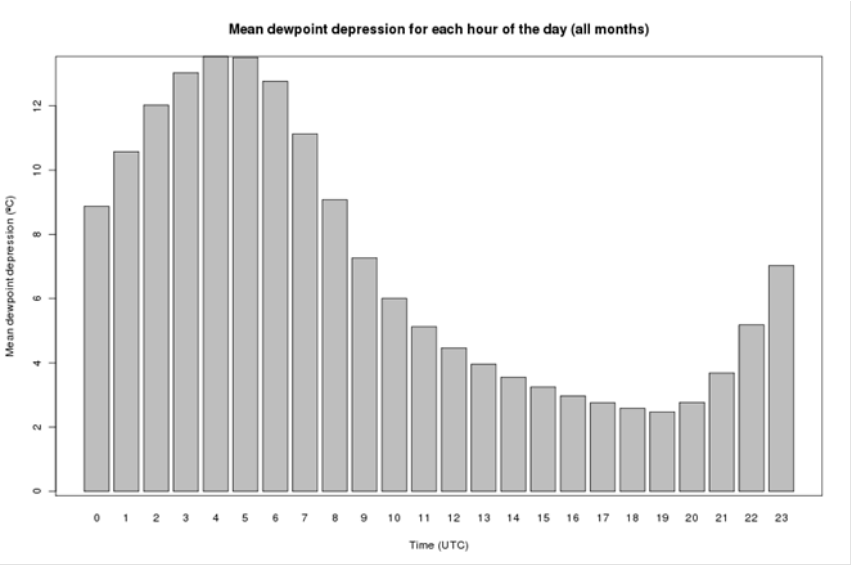

Figure 5.13 Histogram of hourly average dewpoint depression at Badgerys Creek

The histogram shows that higher dewpoint depressions, and therefore inferred cloud bases above 2800ft generally occur between 23-09UTC. On average however cloud bases appear to be below 2800ft for the remainder of the period.

5.3.2 Low cloud at Camden Airport

The AWS at Badgerys Creek currently does not have the capability to determine cloud height or the amount of sky covered. Instead, these parameters have been based on the instrumentation at Camden Airport. This instrumentation has the ability to estimate cloud amount and cloud height. Camden Airport is less than 20km to the south of Badgerys Creek and is a similar distance to the east of the Great Dividing Range. Camden Airport has been identified by meteorological forecasters as the most representative site available for cloud statistics.

30-minute data has been extracted to produce a statistical comparison between Camden Airport, Sydney KSA, Canberra Airport and RAAF Base Richmond for broken low cloud.

Data ranges included the following available data:

- Camden Airport – 01 May 1995 to 05 Dec 2014
- Sydney KSA – 10 Oct 1948 to 05 Dec 2014
- Canberra Airport – 01 Jan 1985 to 05 Dec 2014
- RAAF Base Richmond – 28 Apr 1995 – 27 Jan 2015

The occurrence of broken low cloud below 1500ft has the ability to limit the operations of all categories of aircraft. A graph of the percentage hourly occurrence of broken low cloud below 1500ft is provided in Figure 5.14.

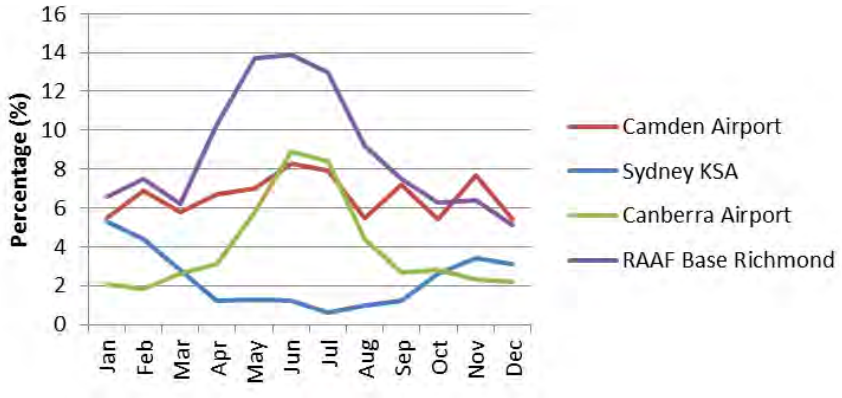

Figure 5.14 Percentage hourly occurrence of cloud base <1500ft

There is little seasonal variation in the development of cloud below 1500ft at Badgerys Creek. Camden Airport and Badgerys Creek are both in close proximity to water sources such as large creeks, rivers, lakes and reservoirs providing rich moisture source all year. It would appear that the availability of moisture combined with surface heating or orographic uplift is sufficient to produce cloud more frequently at Camden Airport than at either Canberra Airport or Sydney KSA.

Broken low cloud below 1500ft occurs approximately twice more at Camden Airport than Canberra Airport for all months except those in winter. However, broken low cloud below 1500ft occurs only half as often at Camden Airport than at RAAF Base Richmond during autumn and winter.

A graph of the percentage hourly occurrence of broken low cloud below 1000ft is provided in Figure 5.15.

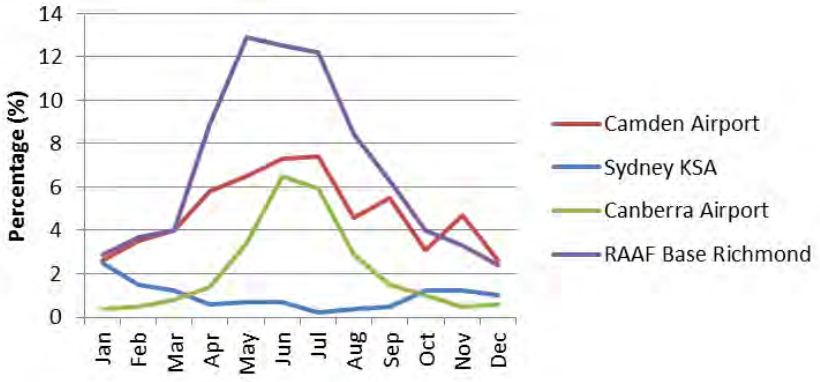

Figure 5.15 Percentage hourly occurrence of cloud base <1000ft

The occurrence of broken low cloud below 1000ft appears to have a more seasonal tendency at Camden Airport. A higher percentage of occurrences of low cloud in winter would not be uncommon and higher levels of radiative cooling overnight would allow for cooler moist conditions at the surface. Broken low cloud below 1000ft would impact air traffic operations at WSA and would cause restrictions on all aircraft categories. Broken low cloud below 1000ft is approximately 5 times more common at Camden Airport than Canberra Airport for all months except those in winter. Again, RAAF Base Richmond experiences broken low cloud below 1000ft approximately twice more often than Camden Airport during autumn and winter.

A graph of the percentage hourly occurrence of broken low cloud below 1000ft is provided in Figure 5.16.

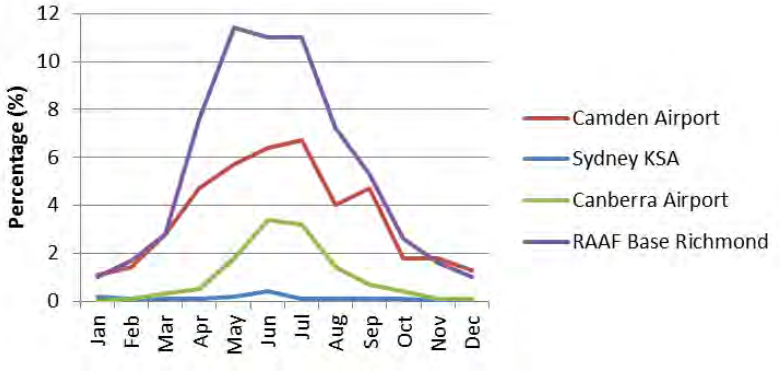

Figure 5.16 Percentage hourly occurrence of cloud base <500ft

The percentage likelihood of broken low cloud below 500ft is approximately three times more at Camden Airport than at Canberra Airport for all months of the year; whereas, RAAF Base Richmond experiences broken low cloud below 500ft almost twice as often during winter.

The percentage occurrence of broken low cloud below 500ft is the highest in winter. The reporting by a ceilometer of cloud below 500ft is often strongly linked to the occurrence of fog.

It is unclear as to the relationship between Camden Airport and Badgerys Creek due to the limited data available at Badgerys Creek. However, it is expected that the occurrence of low cloud at Badgerys Creek would be of a similar order to that experienced at Camden Airport.

5.4 Discussion

The data from Camden Airport suggests that both fog and low cloud could potentially produce low visibility conditions at WSA. More definitive fog and low cloud information would be possible with the implementation of further automatic meteorological equipment at Badgerys Creek.

Recommendation 6: Automatic instrumentation for cloud and visibility should be installed for the collection of climatological information and for the production of forecast products in future

Navigational instrumentation can be installed to mitigate against low visibility phenomena reducing the impact to 24/7 airport operations at WSA.

Recommendation 7: Appropriate low visibility landing equipment, such as runway visual range (RVR) needs to be considered in order to optimise operations at WSA.

The future development of the site into an airport is unlikely to affect low cloud frequency; however an increase in pollutants could potentially affect fog frequency, longevity and severity. The condensation of cloud, including fog, is partially dependent on the availability of Cloud Condensation Nuclei (CCN). CCN are aerosols within the atmosphere with hygroscopic properties which aid in the nucleation of water. Typically a CCN particle will be of the order of 0.1µm.The combustion of jet fuel releases additional CCN into the atmosphere. The development of a major airport at Badgerys Creek could impact on the fog climatology at the AWS site.

6 Turbulence

Turbulence is the effect caused by a disruption to laminar air flow. Turbulence in the lower atmosphere is generally created by the flow of air around an obstacle such as topography or buildings. However, meteorological conditions such as boundaries between different air masses can also provide turbulent effects.

6.1 Turbulence types

6.1.1 Mechanical turbulence

Mechanical turbulence, as depicted in Figure 6.1, is the mechanical disruption of the ambient wind flow caused by obstructions such as buildings, trees, and rough terrain. These obstacles break down smooth wind flow into complex snarls of eddies.

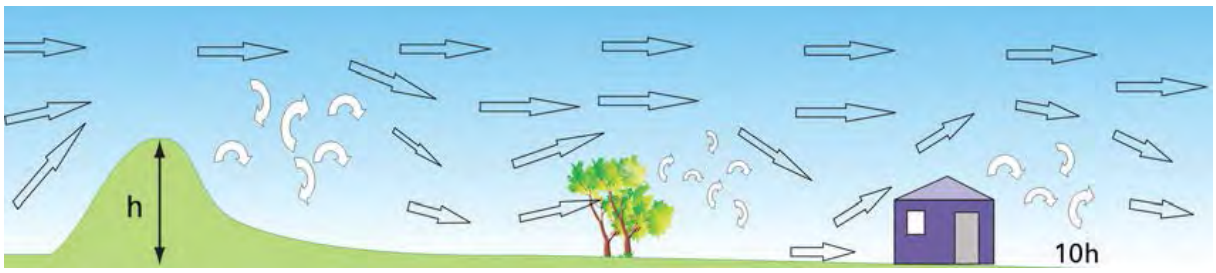

Figure 6.1 Example of effects of obstacle on fluid flow (Bureau, 2014)

An airport can be vulnerable to mechanical turbulence which invariably causes gusty surface winds. Aircraft in a low-level approach or climb can experience air-speed fluctuations and gusts.

The topographical map in Figure 1.2 shows that the AWS site at Badgerys Creek lies approximately 5km to the east at the base of the Great Dividing Range. Assuming the range has an average height of 1.5km it would be expected that mechanical turbulence would affect an area approximately 15km to the east including WSA. Mechanical turbulence in the form of stationary waves will reach Sydney KSA during periods of strong westerly winds and stable atmospheric conditions at ridge height.

Collaborative meteorological forecasting experience indicates that stationary waves typically reach to a height of approximately 5000ft above a mountain ridge. This would equate to approximately 8000ft above the surface at Badgerys Creek.

6.1.2 Rotors

Low level rotors form as friction drags air down the leeward side of a mountain creating a lee wave. The first wave crest has the potential to contribute to rotor formation in some circumstances (refer to Figure 6.2).

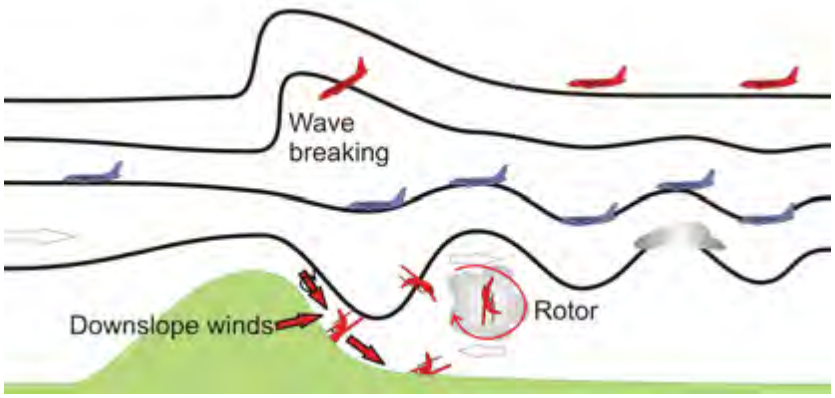

Figure 6.2 Turbulence in lee mountain environment (Bureau, 2014)

It is unclear as to whether the WSA site would be affected by rotor formation however it is a possibility due to the surrounding topography. Anecdotal reports from pilots at Camden Airport suggest that rotors are not likely during prevailing westerly winds at Badgerys Creek as the AWS site is too close to the base of the mountain range. However, pilots believe that sufficiently strong south-westerly winds could produce rotors at Badgerys Creek.

6.1.3 Thermals

Thermals are initiated by strong surface heating of the earth, typically temperature above 35°C. Thermals that produce significant turbulence are generally confined to periods of intense heating in the late afternoon. Thermal turbulence frequently occurs in clear air with no visual signs of the phenomenon. Conditions of light surface winds and strong surface heating are required to produce strong thermal updrafts.

6.1.4 Convective turbulence

Convective turbulence is generated by convective cloud masses such as thunderstorms. Turbulence can range in intensity from light through moderate, to severe or even extreme. The variation in turbulence intensity can be directly related to the strength of updrafts and downdrafts within the clouds, but is not confined to the cloud mass itself. Convective turbulence would frequently occur during the months of November to March when thunderstorm activity is present.

6.1.5 Frontal turbulence

Frontal zones, including southerly changes and sea breeze fronts, may be associated with wind shear and turbulence. Generally the magnitude of wind shear and turbulence associated with these boundaries diminishes as it moves inland. It would be possible to see turbulence associated with a southerly change or sea breeze front at WSA, however it would be highly unlikely.

6.1.6 Wake turbulence

Wake turbulence comprises jet wash and wingtip vortices. Wingtip vortices are produced by the aerofoils on all aircraft, including helicopters, when they are generating lift; they are shed from the wingtips and evolve into counter-rotating circulations that trail behind the aircraft. Jet wash is caused by the air movement through jet engines in the immediate wake of an aircraft departure.

Avoidance of wake turbulence is commonly managed though a system of minimum separation as defined by CASA.

6.1.7 Low-level vertical wind shear

Vertical wind shear is defined as change of horizontal wind direction and/or speed with height as depicted in Figure 6.3.

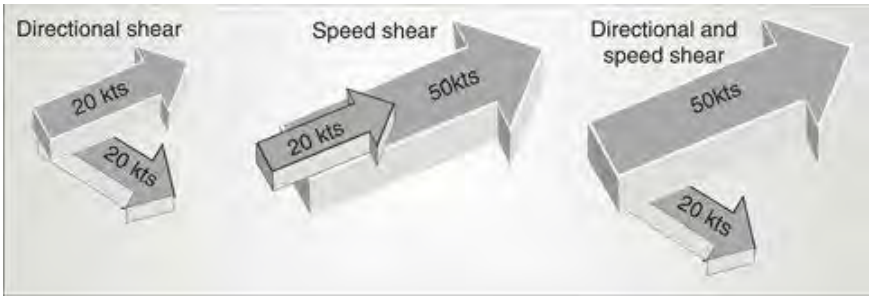

Figure 6.3 Vertical wind shear configurations (Bureau 2014)

Rapid changes in wind velocity encountered during the landing and take-off phases of flight can be extremely dangerous to aircraft (Bureau 2014).

Low-altitude wind shear can affect the aerodynamics of the aircraft in four main ways:

1. Undershooting or overshooting on landing associated with vertical wind shear;
2. Loss of lift on take-off associated with vertical wind shear;
3. Unexpected flight deviations due to horizontal and vertical wind shear generated by convective clouds; and
4. Unexpected rolling and yawing associated with horizontal wind shear.

An aircraft's response to wind shear depends on many factors, including:

- aircraft type, weight, load, speed and phase of flight;
- the scale on which the wind shear operates relative to the size of the aircraft;
- the intensity and duration of the wind shear encounter; and
- pilot intervention (Bureau 2014).

6.2 Numerical modelling of turbulence

The occurrence of turbulence is based on the Bureau's high resolution operational numerical weather prediction models. These models provide the highest resolution, routine depiction of conditions over the Sydney area. The forecast model is acknowledged as one of the leading forecasts systems in the world, and has a very comprehensive depiction of processes that influence the atmosphere. These models are based on the fundamental physical equations of motion for fluid flow (Bureau, 2013).

Linear interpolation of the archived grids from these numerical weather prediction models was used to derive the winds at various levels through the lower troposphere (Bureau, 2013). An algorithm was applied to the wind data to calculate the severity of turbulence and/or wind shear. Inaccuracies in the numerical modelling can be derived from inaccurate topography, incorrect interpolation between grid points, and the inaccurate derivation of the model wind.

Hourly data from the Bureau's numerical weather prediction (NWP) model (Bureau 2013) with a special resolution of 5km has been extracted for the four years including 2011-2014. Data points closest to Sydney KSA, WSA and RAAF Base Richmond (Richmond) have been analysed in the following sections.

6.3 Severe turbulence

Severe turbulence is categorised as producing a vertical wind shear of greater than 20kts in a layer of 1000ft thickness, or due to mechanical turbulence when the wind speed exceeds 25kt perpendicular to the Great Dividing Range. Either circumstance is likely to produce severe turbulence in the vicinity of WSA. Other turbulence types contributing to severe turbulence have not been included at this stage.

The levels included in the study were:

- 10m – 1000ft
- 1000ft – 2000ft
- 2000ft – 3000ft
- 3000ft – 4000ft
- 4000ft – 5000ft
- 5000ft – 6000ft

It is important to note that data pertaining to vertical shear in the bottom 2000ft of the atmosphere has been included in section 6.3 on low-level vertical wind shear. The occurrence of extreme turbulence (vertical shear >40kts/1000ft) will be included in the categorisation of severe turbulence.

Model output has been displayed as both monthly (Figure 6.4), and hourly (Figure 6.5) climatological occurrence rates.

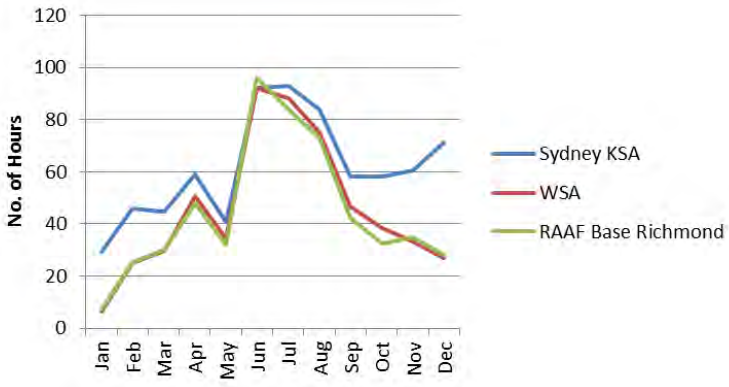

Figure 6.4 Monthly occurrence of severe turbulence

Severe turbulence would be most common in the months of June to August with on average three hours per day expected during these months at Sydney KSA, WSA or Richmond. WSA and Richmond appears to experience slightly less severe turbulence events than Sydney KSA, especially during the months from September to May.

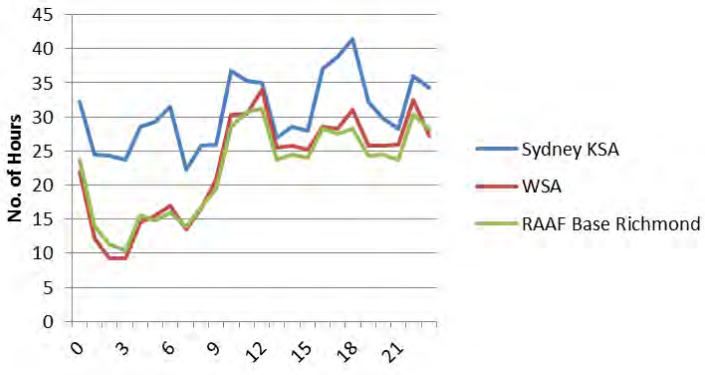

Figure 6.5 Hourly occurrence of severe turbulence

On an hourly basis there are large variations in the expected occurrence times of severe turbulence. Generally severe turbulence would be most likely in the overnight and early morning period at both WSA and Richmond.

6.4 Moderate turbulence

Moderate turbulence is categorised as producing a vertical wind shear of greater than 15kts in a layer of 1000ft thickness, or when the wind speed exceeds 20kt perpendicular to the Great Dividing Range. Model output has been displayed as both monthly (Figure 6.6), and hourly (Figure 6.7) climatological occurrence rates.

It is important to note that cases of severe and extreme turbulence will be included in the categorisation of moderate turbulence.

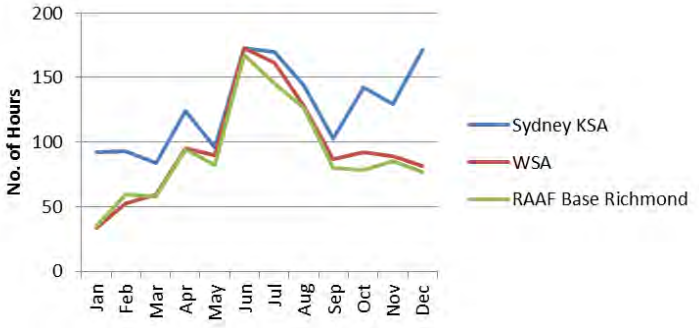

Figure 6.6 Monthly occurrence of moderate turbulence

The graph above follows an almost identical pattern to the monthly occurrence of severe turbulence. Turbulence of moderate or above severity is most commonly experienced during the months of June to August at Sydney KSA, WSA, and Richmond. During these months there is an average of five hours per day in which conditions of moderate or above severity turbulence is likely to occur. In the months from October to March WSA and Richmond would both be expected to experience slightly less events of turbulence than Sydney KSA.

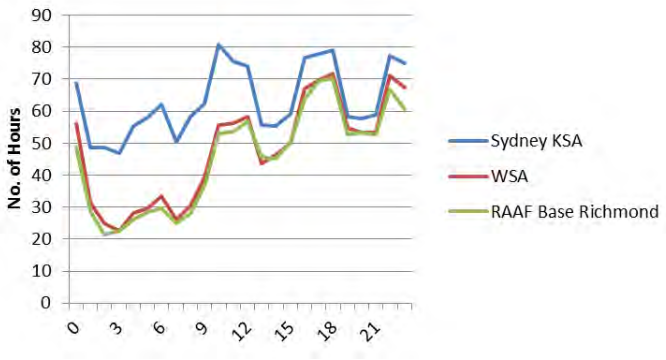

Figure 6.7 Hourly occurrence of moderate turbulence

Figure 6.7 shows similar trend to Figure 6.5. Events of moderate or above severity turbulence are possible during any hour of the day at all three airports. However, there is a slight trend towards less turbulent conditions during the afternoon period at both WSA and Richmond.

6.5 Low-level vertical wind shear

Severe low-level vertical wind shear is categorised as shear of greater than 20kts in a layer of 1000ft thickness in the lowest 2000ft of the atmosphere. The model data was analysed in two layers of wind between 10m to 1000ft, and 1000ft to 2000ft. The data has been displayed as both monthly (Figure 6.8), and hourly (Figure 6.9) climatological occurrence rates.

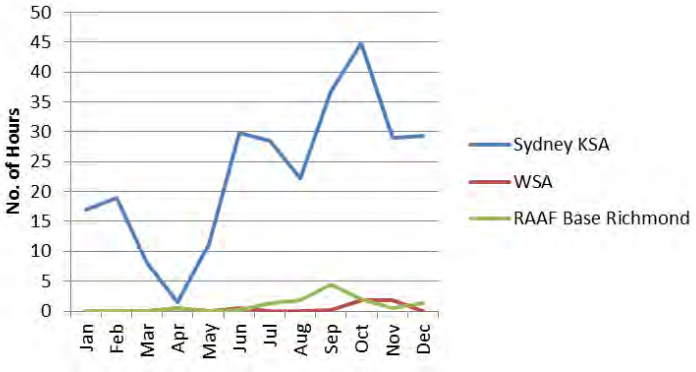

Figure 6.8 Comparison graph of monthly occurrence rates of severe wind shear

There is little to no severe wind shear experienced at either WSA or Richmond in most months of the year. Conversely, severe wind shear is significantly more frequent at Sydney KSA. Severe low-level wind shear most commonly occurs in the months from August to December at Sydney KSA with on average one hour per day.

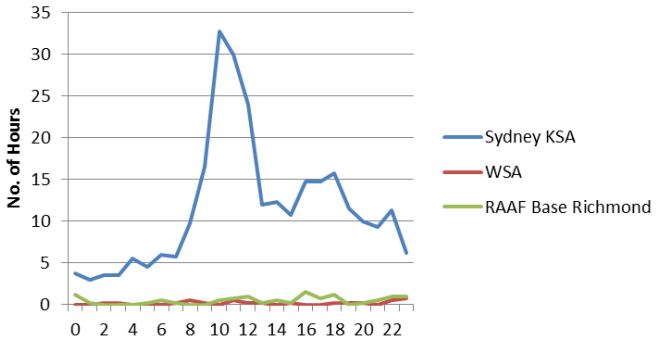

Figure 6.9 Comparison graph of hourly occurrence rates of severe wind shear

The hourly data graphed in Figure 6.9 shows that rare events of severe wind shear at WSA or Richmond could occur at almost any time of the day. In contrast, Sydney KSA would typically experience more severe low-level wind shear events, occurring predominantly during the late evening and overnight period. However, four years of data is not sufficient to establish climatology for wind shear conditions at either WSA or Sydney KSA.

6.6 Discussion

Numerical modelling of both severe and moderate turbulence at WSA shows that there is little additive effect from wind shear to turbulence at any elevation measured. Therefore, the majority of any turbulence experienced at WSA is expected to be mechanical turbulence caused by westerly winds moving over the Great Dividing Range.

It is not possible to determine whether rotors affect WSA but anecdotal observations from pilots operating out of Camden Airport suggests that strong south-westerly winds have the ability to create rotors in close proximity to Badgerys Creek.

At some international airports remote sensing technology called Doppler LIDAR performs an integral part of a low level wind shear alert system. Doppler LIDAR both transmits and received infrared wavelengths to determine the direction and speed of wind in the atmosphere.

Recommendation 8: A Doppler LIDAR system at Badgerys Creek can provide the necessary information for observing wind movement in the lower atmosphere including detection of wind shear and rotors. The Doppler LIDAR system is costly and a cost-benefit analysis would be recommended.

Numerical modelling of winds shows that the expected occurrence of severe and moderate turbulence at WSA is less than that expected at Sydney KSA. It is important to note that model verification consistently shows that forecast winds in the lower atmosphere are weaker than actual winds observed (P. Steinle 2015, per. comm., 7 January). Therefore, the occurrence of turbulence modelled for WSA may be less than actually experienced at WSA.

Additionally, the construction of structures in close proximity to a runway may add to the occurrence of mechanical turbulence events (refer to Recommendation 2).

7 Thunderstorms

Regardless of size or intensity, any thunderstorm is hazardous to aviation. The impacts include disruption to the management of air traffic both enroute and in the terminal area, and disruptions to airport ground operations. Aviation hazards encountered in and near thunderstorms include; severe wind shear and turbulence, severe icing, downbursts, hail, lightning, heavy rain, tornadoes, low cloud, poor visibility, and rapid air pressure fluctuations.

Whilst most 'ordinary' thunderstorms individually have lifetimes of thirty minutes to an hour, under the right atmospheric conditions organised systems of thunderstorms or even individual storms may last for several hours.

7.1 Thunderstorm properties

Within the vicinity of a thunderstorm many additional phenomena other than lightning may occur. Other phenomena can include:

- Tornadoes
- Hail
- Wind Gusts
- Severe Wind Shear
- Severe Turbulence
- Severe Icing
- Heavy Rain
- Low Cloud
- Poor Visibility
- Downbursts and Updrafts
- Rapid Air Pressure Fluctuations

It is important to note that most thunderstorms develop over the Great Dividing Range moving eastwards into the Sydney Basin. The close proximity (approx. 20km) of Badgerys Creek from the mountain ridge would mean that this would only allow for a short lead time for thunderstorm aerodrome warnings at WSA. For example, thunderstorms moving at 20kts towards Badgerys Creek would reach WSA approximately 30mins after initiation.

7.2 Lightning data

Data from February 2008 to October 2014 has been extracted from the Global Positioning and Tracking System (GPATS) for which the Bureau holds a licence agreement. The GPATS system uses a network of sensors that detect the radio frequency signal that is emitted from a lightning strike. GPATS has the ability to record cloud to ground lightning strikes, ground to cloud lightning strikes, as well as cloud to cloud lightning strikes.

7.3 Lightning within 5nm

Thunderstorm cells within 5nm of an airport affect the ability of aircraft to land and taking-off; and the provision of services to aircraft once on the ground. Service disruptions include the ability of aircraft to move into and out of bays, and the absence of ground staff on the tarmac since work health and safety regulations require the removal of ground staff from the tarmac when a thunderstorm is within 5nm.

7.3.1 Monthly climatology

Since February 2008 there have been 500 less lightning strikes in the 5nm surrounding WSA than there have been in the 5nm surrounding Sydney KSA. And, Brisbane Airport has had an approximately 650 more lightning strikes than Sydney KSA within 5nm.

The total number of lightning strikes within 5nm for each month at WSA, Sydney KSA and Brisbane Airport has been graphed in Figure 7.1.

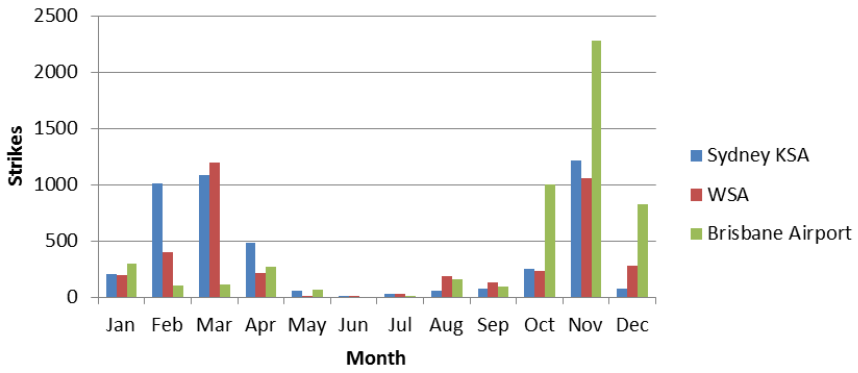

Figure 7.1 Monthly graph of lightning strikes within 5NM of Sydney KSA, WSA and Brisbane Airport

Climatology shows that majority of the lightning within 5nm occur at WSA in the months of November and March. Alternatively, Sydney KSA experiences a high incidence of thunderstorms in February, March and November. Data shows that April can also be very active with respect to lightning at Sydney KSA. Lightning within 5nm of Brisbane Airport occurs most frequently during the months of October to December, and at a higher frequency than at either Sydney KSA or WSA.

Additionally, Figure 7.1 shows that lightning is generally experienced earlier in the thunderstorm season at WSA and becomes less frequent later in the season. This trend confirms anecdotal evidence provided by meteorological forecasters stating that thunderstorm events affecting WSA are most commonly caused by the development of thunderstorms along the Great Dividing Range during summer being steered over the WSA site.

7.3.2 Hourly climatology

The total number of lightning strikes recorded within 5nm of Sydney KSA, WSA and Brisbane Airport for each hour of the day (UTC) has been graphed in Figure 7.2.

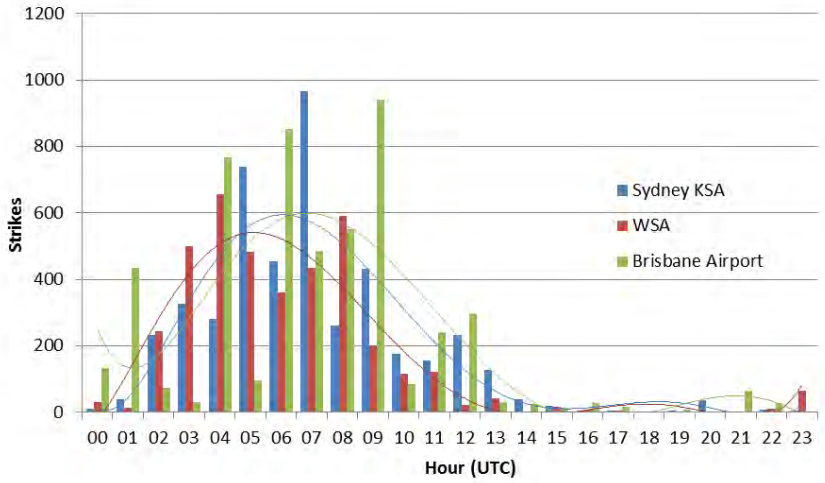

Figure 7.2 Hourly graph of lightning strikes within 5nm of Sydney KSA, WSA and Brisbane Airport

The histogram shows that generally thunderstorms within 5nm are recorded earlier in the day at WSA than at Sydney KSA. Thunderstorms appear to also finish earlier at WSA compared to Sydney KSA. This timing correlates with the typical movement of thunderstorm off the Great Dividing Range over Badgerys Creek and towards coastal areas, including Sydney KSA.

There appears to be fluctuations in the timing of lightning at Brisbane Airport. However, lightning strikes are most frequent during the period from 06 to 09 UTC at Brisbane Airport.

7.3.3 Lightning days within 5nm

The cumulative number of days in which lightning has occurred since February 2008 is provided in Figure 7.3. Calculations for each month have been completed to find an average number of days in which lightning occurred, as well as the maximum number of lightning days for that month.

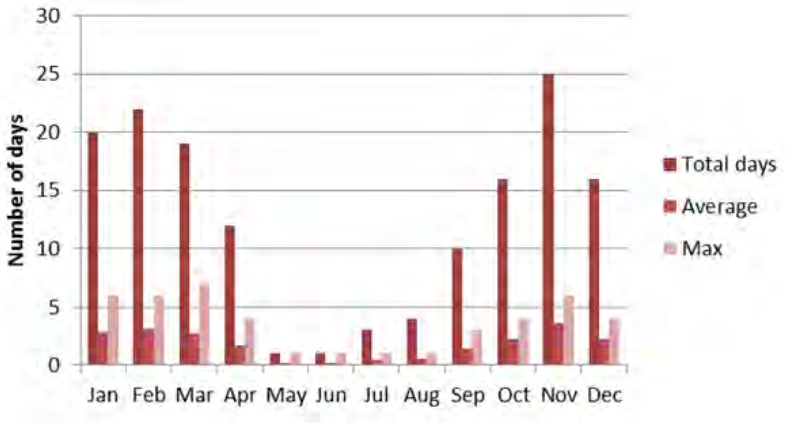

Figure 7.3 Monthly graph of lightning days within 5NM of WSA since Feb 2008

It is expected that lightning within 5nm of WSA will be most active from November to March. The average lightning days per month is less than 4 for each month, however there appears to be some variation between the average and maximum lightning days in the months covering January to March.

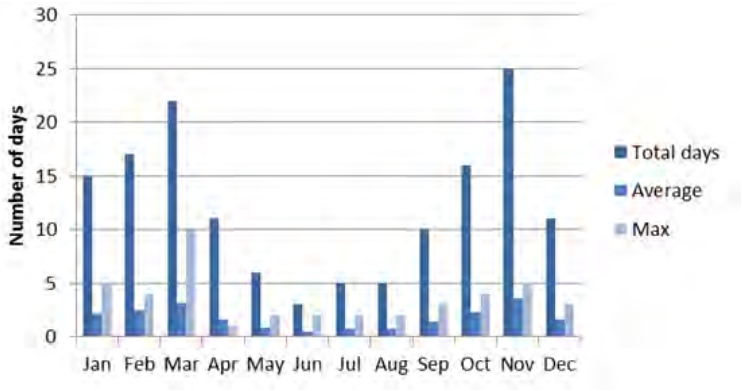

Figure 7.4 Monthly graph of lightning days within 5NM of Sydney KSA since Feb 2008

The months from October to March have been the most active months on average for lightning days at Sydney KSA within 5nm. Like WSA, each month at Sydney KSA records less than 4 lightning days per month, with the most variation in activity occuring in March.

7.4 Lightning within 10nm

It is common for an aircraft to join an Instrument Landing System (ILS) approach is at 10nm. Thunderstorms within 10nm can cause problems for aircraft if they occur on or near the path to final on a runway. Additionally, thunderstorms occurring within 10nm of a major airport place the ground staff in an ‘alert’ phase for a ramp closure and the potential removal of ground staff from the tarmac.

7.4.1 Monthly climatology

Since February 2008 there have been 1000 less lightning strikes in the 10nm surrounding WSA than there have been in the 10nm surrounding Sydney KSA. Brisbane Airport has experienced another 900 lightning strikes over and above Sydney KSA within 10nm.

The total number of lightning strikes within 10nm for each month at WSA, Sydney KSA and Brisbane Airport has been graphed in Figure 7.5.

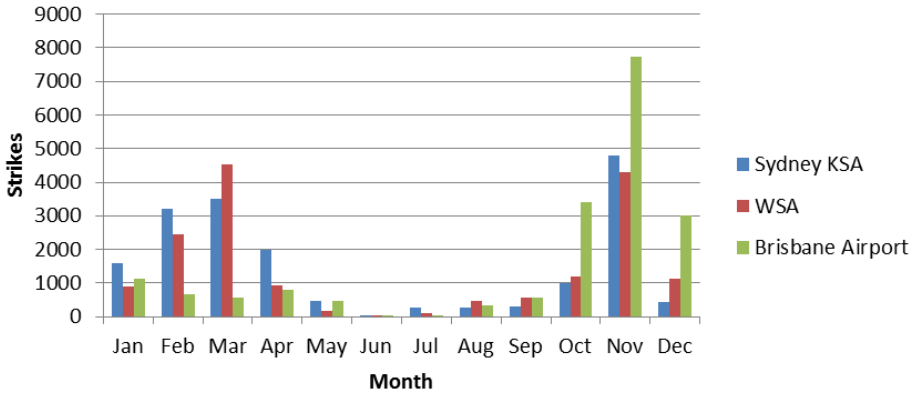

Figure 7.5 Monthly graph of lightning strikes within 10NM of Sydney KSA, WSA and Brisbane Airport

The same seasonal trends can be seen in the 10nm data as was seen at 5nm. The majority of the lightning within 10nm occurred at WSA in the months of November and March, and to a lesser extent February. Alternatively, Sydney KSA experienced a high incidence of thunderstorms in February along with November and March. Brisbane Airport has the most lightning strikes in the months of October to December.

Furthermore, it can be seen that lightning at WSA is more prevalent early in the thunderstorm season but also less frequent later in the season.

7.4.2 Hourly climatology

The total number of lightning strikes recorded within 10nm of Sydney KSA, WSA and Brisbane Airport for each hour of the day (UTC) has been graphed in Figure 7.6.

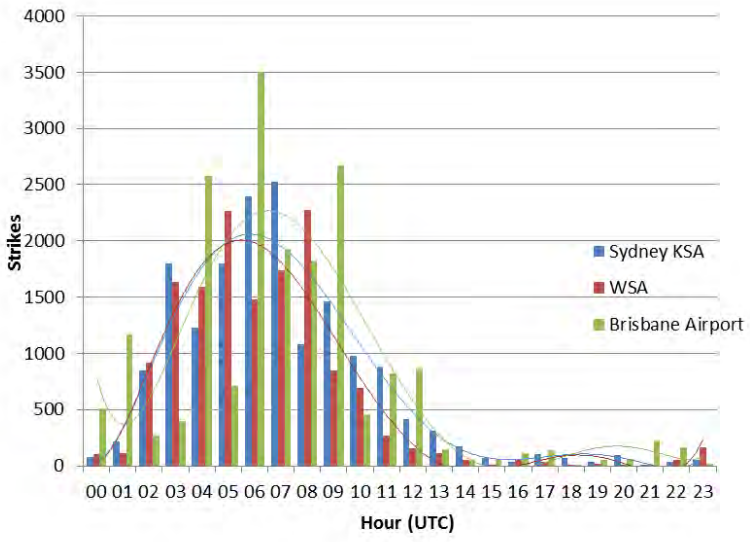

Figure 7.6 Hourly graph of lightning strikes within 10NM of Sydney KSA, WSA and Brisbane Airport

Typically thunderstorms begin to occur at approximately the same time of day at Sydney KSA as they do at WSA within the 10nm radii. Brisbane Airport, however appears to see lightning begin to occur within a 10nm radii a little later in the day than either Sydney KSA or WSA. Thunderstorms appear to typically finish earlier in the day at WSA compared to Sydney KSA; whereas lightning at Brisbane Airport would usually cease later in the day than either of the southern ports.

7.4.3 Lightning days within 10nm

The lightning days have been graphed for both WSA and Sydney KSA to show the total number of days of lightning recorded within 10nm since February 2008, as an average and maximum number of days per month (refer to Figure 7.7 and Figure 7.8).

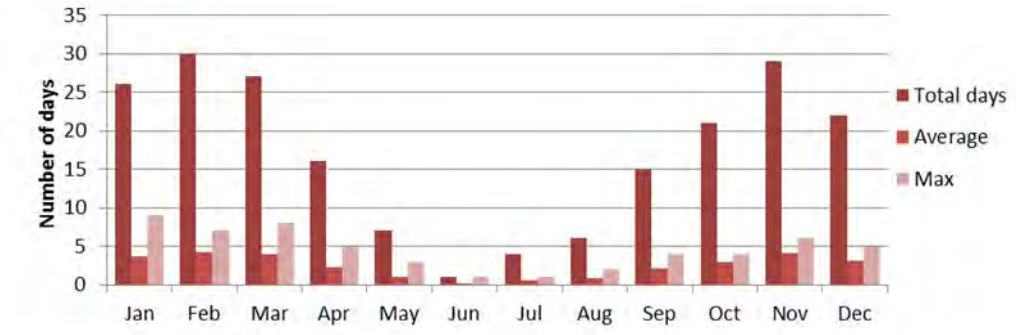

Figure 7.7 Monthly graph of lightning days within 10NM of WSA since Feb 2008

On average the most lightning days within 10nm of WSA would occur in the months from October to March. The average number of days for thunderstorms each month is less than 5, and the variation between the average and maximum lightning days is more pronounced in the first four months of the year.

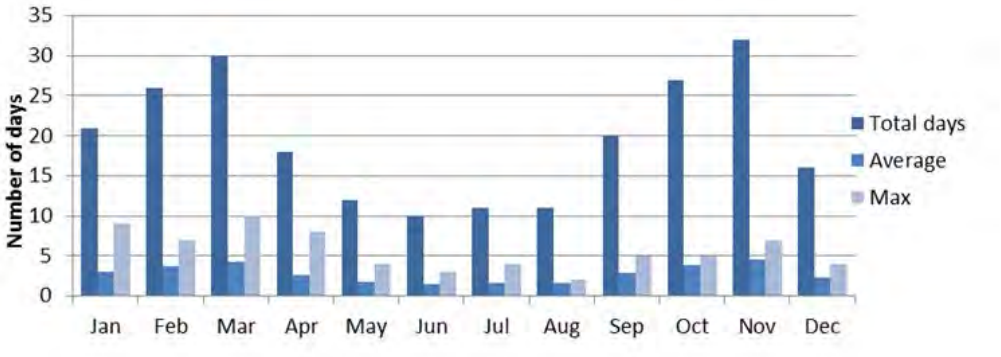

Figure 7.8 Monthly graph of lightning days within 10NM of Sydney KSA since Feb 2008

The data for Sydney KSA is again similar to WSA. The graph shows that the most active months for lightning within 10nm are September to March at Sydney KSA. The average number of days with lightning within 10nm is less than 5, and the variation between the average and maximum lightning days is more pronounced in the first four months of the year.

7.5 Lightning within 45nm

The Terminal Area (TMA) is a 45nm radial area surrounding Sydney KSA. This term is used to describe the designated area of controlled airspace surrounding a major airport where there is a high volume of traffic. The TMA is divided into segments called corridors for arriving and departing aircraft. For Sydney KSA the main airport arrival corridors are to the N and SW.
Thunderstorms within the Terminal Area (45nm) also affect operations. Specifically thunderstorms in the entry corridors to the north and southwest of Sydney KSA can have major impacts on traffic flow.

7.5.1 Monthly climatology

Since February 2008 there have been 2000 less lightning strikes in the 45nm surrounding WSA than there have been in the 45nm surrounding Sydney KSA. Moreover, Brisbane Airport had over 30,000 less lightning strikes within 45nm than either Sydney KSA or WSA.

The total number of lightning strikes within 45nm for each month at Sydney KSA, WSA and Brisbane Airport has been graphed in Figure 7.9.

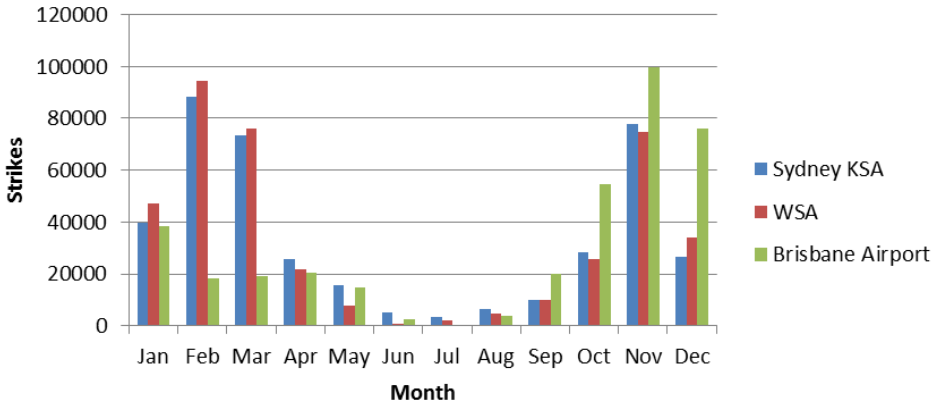

Figure 7.9 Monthly graph of lightning strikes within 45NM of Sydney KSA, WSA and Brisbane Airport

Lightning within 45nm is expected to occur most frequently at both WSA and Sydney KSA from November to March. On the other hand, Brisbane Airport has thunderstorms most frequently in the months from October to January.

7.5.2 Hourly climatology

The total number of lightning strikes recorded within 45nm of Sydney KSA, WSA and Brisbane Airport for each hour of the day (UTC) has been graphed in Figure 7.10.

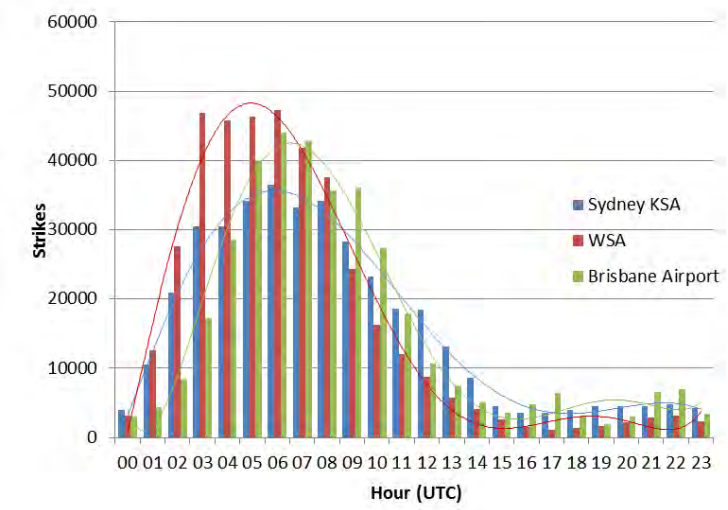

Figure 7.10 Hourly graph of lightning strikes within 45NM of Sydney KSA, WSA and Brisbane Airport

The hourly climatology of lightning strikes within 45nm of WSA shows that whilst the lightning events appear to start and finish later at Sydney KSA, the frequency of the lightning strikes between the hours of 02-08UTC are significantly more at Badgerys Creek than those at Sydney KSA. Brisbane Airport also has a significant peak above the Sydney KSA data between 05-10Z for lightning strikes within 45nm.

7.5.3 Lightning days within 45nm

The number of days in which lightning has occurred since February 2008 has been graphed below in Figure 7.11 and Figure 7.12, as an average and maximum number of days per month.

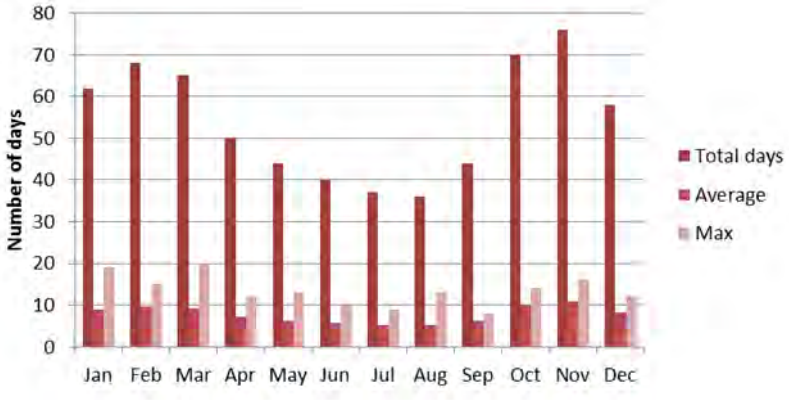

Figure 7.11 Monthly graph of lightning days within 45NM of WSA since Feb 2008

On average the most lightning days within 45nm of WSA are expected to occur in the months from October to March. The average number of days for thunderstorms each month is less than 11, and the variation between the average and maximum number of lightning days is more pronounced in the months of January and March.

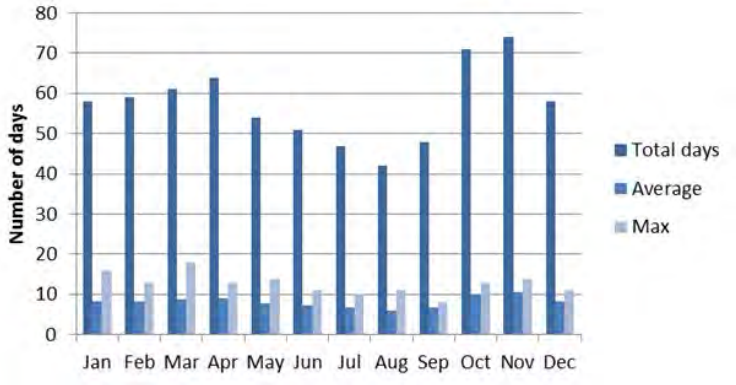

Figure 7.12 Monthly graph of lightning days within 45NM of Sydney KSA since Feb 2008

Thunderstorms within 45nm of Sydney KSA are possible in any month of the year. The average number of days per month in which lightning is recorded within the 45nm radius is less than 11. Variations between the maximum and average number of lightning days appear to be less pronounced with January and March containing the highest data range.

Overall, the expectation of lightning at WSA does not appear to be largely different from that at Sydney KSA; except that there are less total lightning days recorded over the winter months within 45nm of WSA than Sydney KSA.

7.6 Discussion

It is common for thunderstorms to develop on the Great Dividing Range and track over the Sydney Basin during the afternoon. Generally lightning will occur close to WSA earlier in the day and weaken as thunderstorms dissipate after sunset. The airspace within 45nm of WSA would be expected to experience more lightning during the afternoon than Sydney KSA over the same period. It is not possible to determine from the data whether the increase in lightning frequency was due to the occurrence of organised thunderstorms resulting in more lightning strikes, or if there were more thunderstorms in total. However, WSA has experienced fewer lightning strikes in total within 5nm, 10nm, and 45nm than Sydney KSA since February 2008.

The thunderstorm season appears to both start and finish earlier in the year by approximately a month at WSA than Sydney KSA. Outside of the thunderstorm season there are more thunderstorm days at Sydney KSA during the winter months. During data extraction it was observed that the increase in thunderstorm activity over winter chiefly occurred over the ocean to the east of Sydney KSA.

Importantly, it needs to be noted that the close proximity of Badgerys Creek to the Great Dividing Range would only allow for a short lead time for aerodrome warnings at WSA with regards to thunderstorms. Aerodrome warning lead times of less than 1 hour may occur at WSA in future.

For every international airport in Australia the Bureau has a system capable of visually displaying the location of potential thunderstorms with respect to an airport, including size and forecast movement. The Automated Thunderstorm Alert Service (ATSAS) is used in partnership with a procedural alert system for ground based activities at the airport. This system is integral to the safety of both aircraft and ground staff.

Recommendation 9: The Bureau implements an Automated Thunderstorm Alert Service (ATSAS) at WSA to improve the accuracy of thunderstorm forecasting for the airport whilst increasing the operational safety of ground staff and aircraft.

8 Conclusion

The siting of the Western Sydney Airport at Badgerys Creek has many meteorological advantages compared to Sydney KSA, namely the minor exposure to significant crosswind and headwind, the lack of low-level vertical wind shear and lower frequency of thunderstorms.

The runway availability and usability of WSA is primarily determined by crosswind. Mitigation processes and equipment exists for most weather phenomena except for wind at WSA where an intersecting runway to the parallel runway is not planned. The usability of WSA based solely on a prevailing crosswind of less than 20kts is approximately 99.5%.

There are factors which need consideration during the operational planning of the airport that are more likely at WSA than Sydney KSA. These include weather phenomena such as high temperatures, freezing fog and frost. Through adequate planning and infrastructure it is possible to mitigate the influences of most weather phenomena.

The report has revealed that perhaps the most significant aspect of the Badgerys Creek site is likely to be the occurrence of fog. The development of fog overnight in the western Sydney Basin is possible during all months of the year; and often for extended periods of time during winter. It is important to acknowledge that an increase in pollutants in the adjacent atmosphere to the airport could likely affect fog formation in the future. Additional equipment for monitoring visibility and cloud is required in order to develop a true fog climatology at Badgerys Creek, and for meteorologists to improve forecast skill into the future.

Further detailed studies in the following areas may be considered important:

- Correlating low visibility statistics with instrument landing system categories will likely aid airport planners in determining the navigational aids required for optimal usability at WSA.
- Estimated correlation between the occurrence of fog events simultaneously at Sydney KSA and WSA may inform decisions regarding network management.
- Anecdotal evidence of wind rotors at Badgerys Creek indicates that rotors may impact the airport in certain wind regimes. It is unclear as to whether further effort in this area would yield any significant gain in airport usability. A scoping study into different methods of measuring rotors and associated costs could provide key elements for a cost-benefit analysis in this area.
- A comparison study into the numerical modelling of turbulence at major airports such as Brisbane and Melbourne will be considered and conducted as required.
- Research into the potential impact of freezing fog at WSA and associated mitigation measures available for implementation.
- Further calculations for crosswind and headwind will be conducted as required.

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VOLUME 4

Appendix E1
Aircraft overflight noise



ACOUSTICS AND AIR

WESTERN SYDNEY AIRPORT EIS

AIRCRAFT OVERFLIGHT & OPERATIONAL NOISE

REPORT NO. 14168
VERSION D

SEPTEMBER 2015

PREPARED FOR

DEPARTMENT OF INFRASTRUCTURE AND REGIONAL DEVELOPMENT
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WILKINSON MURRAY

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TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY **1**

1 INTRODUCTION **11**

1.1 Background **11**

1.2 Terms of Reference **12**

1.3 Scope of this Report **12**

2 NOISE ASSESSMENT METHODOLOGY **15**

2.1 Descriptors of Aircraft Noise Impact **15**
2.1.1 ANEF 15
2.1.2 ANEC 15
2.1.3 N70 16
2.1.4 90th Percentile N70 17
2.1.5 N60 17
2.1.6 Respite Period 17
2.1.7 Single-Event Noise Contours & Flight Path Density Charts 18
2.1.8 Health Related Noise Descriptors 18

2.2 EIS Assessment Scenarios **19**

2.3 Aircraft Noise Calculation Procedures **20**

2.4 Aircraft Types used in Calculations **21**

2.5 Aircraft Movements **22**

2.6 Flight Tracks **25**
2.6.1 Arrivals 26
2.6.2 Departures 27
2.6.3 Track Dispersion 27

2.7 Airport Operating Modes **28**
2.7.1 Initial Development (2030) and Additional Capacity Scenario (2050) 28
2.7.2 Longer Term Development 30

2.8 Meteorological Data **30**

2.9 Calculation of Aircraft Noise Levels **31**

2.10 Sensitive Receivers and Noise Exposure Calculation **32**

2.11 Sources of Key Information **32**

3 ASSESSMENT OF INITIAL AIRPORT DEVELOPMENT **35**

3.1 Development Overview **35**

3.2 Single-Event Noise Contours **35**

3.3 Summer and Winter Operations **47**

3.4 Noise Levels Over 24 Hours 47
3.4.1 N70 Results 47
3.4.2 90th Percentile N70 Results 50
3.4.3 Population Exposure Estimates 52

3.5 Night Time Noise 52
3.5.1 N60 Results 52
3.5.2 90th Percentile N60 Results 56
3.5.3 Population Exposure Estimates 59

3.6 Land Use Planning Impacts 60
3.6.1 ANEC Contours 60

3.7 Aircraft Noise Levels in Recreational Areas 63

4 ASSESSMENT OF ADDITIONAL CAPACITY SCENARIO 65

4.1 Development Overview 65

4.2 Single-Event Noise Contours 65

4.3 Noise Levels Over 24 Hours 68
4.3.1 N70 Results 68
4.3.2 90th Percentile N70 Results 71
4.3.3 Population Exposure Estimates 73

4.4 Night Time Noise 73
4.4.1 N60 Results 73
4.4.2 90th Percentile N60 Results 76
4.4.3 Population Exposure Estimates 79

4.5 Land Use Planning Impacts 79
4.5.1 ANEC Contours 79

4.6 Aircraft Noise Levels in Recreational Areas 82

5 ASSESSMENT OF LONGER TERM AIRPORT DEVELOPMENT 85

5.1 Development Overview 85

5.2 Noise Levels Over 24 Hours 96
5.2.1 N70 Results 96
5.2.2 90th Percentile N70 Results 98
5.2.3 Population Exposure Estimates 100

5.3 Night Time Noise 100
5.3.1 N60 Results 100
5.3.2 90th Percentile N60 Results 102
5.3.3 Population Exposure Estimates 104

5.4 Land Use Planning Impacts 104
5.4.1 ANEC Contours 104

6 NOISE-INDUCED VIBRATION 107

7 GREATER BLUE MOUNTAINS WORLD HERITAGE AREA 109

7.1 Track Density Methodology 109

7.2 Track Density Diagrams – Original Merge Point 109
7.3 Track Density Diagrams – Alternative Merge Points 116

8 MITIGATION & MANAGEMENT MEASURES 125
8.1 Mitigation of Aircraft Noise Impacts 125
8.2 Monitoring of Aircraft Noise 126
8.3 Existing and Future Operational Framework 126

9 CONCLUSIONS 129
9.1 Initial Development Stage (2030) 129
9.2 Additional Capacity Scenario (2050) 130
9.3 Longer Term Airport Development (2063) 132
9.4 Options for Noise Mitigation 132

APPENDIX A – Preliminary Indicative Flight Tracks – Initial Development

APPENDIX B – Preliminary Indicative Flight Tracks – Longer Term Development

APPENDIX C – Comparison of Summer, Winter & Annual Contours

APPENDIX D – GBMWHA Flight Density Plots for Aircraft below 5000 Ft

APPENDIX E – Glossary of Acoustic Terms

EXECUTIVE SUMMARY

This report presents an assessment of aircraft overflight and operational noise from the proposed Western Sydney Airport which is described in detail in the Western Sydney Airport Environmental Impact Statement (EIS).

EIS investigations are centred upon two principal stages of proposed airport development; an initial development and a possible longer term development. For the purposes of the EIS, the initial (or Stage 1) development of the airport includes a single runway and corresponding facilities to handle up to approximately 10 million annual passenger movements. It is considered this level of demand could nominally occur in 2030.

Subject to any further approvals required, a longer term development of the Western Sydney Airport could include parallel runways and additional associated infrastructure sufficient to facilitate approximately 82 million annual passenger movements. It is predicted that this level of travel demand could be reached around 2063.

This aircraft noise assessment considers the likely impacts of aircraft overflights in the vicinity of the proposed Western Sydney Airport occurring at these two key stages. It also considers an additional scenario when the first runway is considered to be near its nominal capacity, which could be reached around 2050. This reflects the change in noise impact as airport usage grows, and also illustrates the change in impact that would be brought about by the commencement of second runway operations. This change would result in a major reconfiguration of airport operations, and therefore also changes in the pattern of noise impact. While this scenario is based on the runway to be constructed as part of the Stage 1 development, a number of other stages of development would need to occur in the lead up to the 2050 scenario, including a requirement for additional taxiways, aprons and terminal space that would be subject to separate approvals under the Airports Act.

Calculation and Assessment Procedures

Noise assessment is based on information and projections from a number of sources, including projected air traffic volumes, aircraft flight tracks, airport operating modes, assumed fleet mix and scheduling, expected noise emissions from future aircraft types, and future population densities in areas around the proposed airport. The basis of the information used in this report is described in the body of the report.

Noise impact from aircraft in flight and operating on the runway is assessed in this study in terms of a number of measures, including the following descriptors:

- N70: The average number of aircraft noise events per day (i.e. over 24 hours) with maximum noise levels exceeding 70 dBA, this descriptor is used to indicate potential daily noise impacts from aircraft operations;
- N60: The average number of aircraft noise events per day with maximum noise levels exceeding 60 dBA during the night time period 10pm-7am, this descriptor is used to indicated potential night time noise impacts from aircraft operations;
- 90th percentile N70 and N60: Values of N70 and N60 calculated for the 90th percentile day. Noise impacts would be expected to exceed these values on only 10% of days, and hence they can be considered as the “N70 or N60 on a typical worst-case day”; and

- ANEC: A standard measure of aircraft noise exposure used in Australia used to define land use planning around airports based on hypothetical operating scenarios. In the Australian Noise Exposure Forecasting (ANEF) system areas outside the 20 ANEF contour are "acceptable" for new residential development. Between ANEF 20 and 25, new residential development is considered "conditionally acceptable". Above ANEF 25, new residential development is considered "unacceptable".

Calculations were performed using the industry-standard INM calculation program and involved calculation of noise levels from all relevant aircraft types on all indicative flight tracks. The number of operations on each track depends in part on assumptions regarding the airport's operating strategy and a number of strategies are compared in terms of their outcomes for noise impact.

Airservices Australia has assessed the airspace implications and air traffic management approaches for Sydney basin airspace arising from the potential introduction of operations at the proposed Western Sydney Airport.[1] The principal objective was to establish whether safe and efficient operations could be introduced at the airport by developing indicative proof-of-concept air traffic management designs. Importantly, this work does not present a comprehensive airspace and air route design, nor does it consider all of the essential components that would be necessary to implement an air traffic management plan for the Sydney basin.

While the formal flight path design for the proposed airport would be undertaken much closer to the commencement of operations – within several years of the first flights occurring – indicative flight paths for Stage 1 (single runway) and long-term (parallel runway) operations have been prepared based on Airservices Australia's preliminary analysis. This report is based on the indicative flight path design.

The indicative design incorporates a "point merge" system for arrivals, under which all arriving aircraft pass over a single point before commencing their final approach to the airport. The "point merge" system promotes "continuous descent approaches", which result in savings in fuel, as well as reduced noise emissions. Assessment in this report assumes that all arrivals at the proposed airport would use a continuous descent approach track passing through a single "merge point".

Noise impact around the airport would depend on the airport operating strategy that was adopted by Air Traffic Control. This report considers two basic operating strategies – "Prefer 05" in which aircraft approach and depart the airport in a south-west to north-east direction (unless this is not possible due to wind or other conditions), and "Prefer 23" in which the opposite direction is preferred. A "Head-to-Head" mode of operation, in which aircraft both approach and depart from / to the south-west, is also considered for night time operations.

Impacts on land use planning are assessed in terms of ANEF system, in accordance with Australian Standard 2021:2015. In particular, this Standard indicates that areas outside the 20 ANEF contour are "acceptable" for new residential development. Alternative land use planning assessment methodologies have been proposed, but are not implemented in any relevant planning documents.

The following sections summarise the findings of aircraft noise modelling for the proposed initial airport development and subsequent future indicative stages of development, which would be the subject of future assessments and approvals.

[1] Airservices Australia – Western Sydney Airport – Preliminary airspace management analysis – Final report, April 2015.

Initial Airport Development (2030)

For this first stage of airport development, the analysis focusses on the nominal year 2030 when operations allowing 10 million annual passenger movements would occur on one (northern) runway. The conclusions from the assessment can be summarised as follows.

Maximum noise levels:

Maximum noise levels are described by combined single event noise contours for the loudest and most common aircraft, being B747 and A320 aircraft, respectively.

In the case of departure noise levels, the contours follow the main departure flight paths. The associated maximum noise contours for departure to the north extend over the residential areas of St Marys and Erskine Park. In the case of departures to the south, contours extend towards The Oaks, Lake Burragorang and Bringelly. Noise contours also extend to the village of Luddenham.

The predicted departure noise contours of the B747 are significantly larger than those of the A320 aircraft; for example, the 70 dBA contour extends approximately 15 km from the runway end to St Marys for a B747, whilst the same contour extends only 5 kms for an A320 aircraft.

In the case of arrivals, the noise contours follow arrival tracks from a merge point over the lower Blue Mountains. The arrival noise contours of the B747 are also significantly larger than the same contours for the A320 aircraft; for example the 70 dBA contour extends approximately 15-17 km from the runways ends for a B747, whilst the same contour extends only 8-10 kms for an A320.

It is determined that;

- For the loudest aircraft operations (medium-range departures by Boeing 747 aircraft or equivalent), maximum noise levels over 85 dBA would be experienced at a small number of residential locations close to the airport site, in the area of Badgerys Creek. Maximum noise levels of 70 – 75 dBA could be expected within built-up areas in St Marys and Erskine Park due to these worst-case operations, which are predicted on average to occur once per day in 2030.
- Maximum noise levels due to more common aircraft types, such as the Airbus A320 or equivalent, are predicted to be 60 – 70 dBA in built-up areas around St Marys and Erskine Park and over 70 dBA in some adjacent areas to the south-west of the airport, notably the area of Greendale on a “Prefer 05” operating strategy.

Noise impact over 24 hours:

N70 contours for the initial stage of the airport extend well beyond the runway ends. Typically, the N70=5 contour extends approximately10 kms to the north and 14 kms to the south west of the runway. Depending on the strategy priority, either “Prefer 05” or “Prefer 23”, the contours include “lobe” towards St Marys and Greendale respectively. To the side of the runway the contours would extend approximately 1.5 kms into parts of Luddenham.

However, these “lobes” do not extend into major population centres.

It is determined that;

- In 2030, the choice of airport operating strategy is predicted to have a minor effect on the total number of residents affected at various noise levels over 24 hours, although the location of the affected residents differs. The “Prefer 23” strategy results in fewer people being affected at lower noise levels (generally to the north of the airport), but this is offset by more people being affected at higher noise levels – generally in rural residential areas to the south and west of the airport.
- Under any of the considered scenarios, approximately 1,500 people are predicted to be exposed to at least 5 aircraft operations per day with maximum levels exceeding 70 dBA. None of these are in built-up residential areas.

Night time noise impact:

N60 night time contours for the initial stage of the airport extend out from the runway ends. Typically, the N60=5 contour extends approximately 15 km to the north to St Marys and 20 km to the south-west of the runway when the “Prefer 05” strategy is implemented. The contour to the north of the runway is predicted to extend into the population centres around St Marys.

The adoption of a “Prefer 23” priority strategy results in the contours extending to the north-east for a distance of approximately 17 km and to the south-west for 24 km. The contours would include a “lobe” towards Greendale.

To the side of the runway, the contours extend into Luddenham.

The adoption of Head-to-Head operations results in a significant reduction in the size of the contours to the north of the airport , particularly for the “Prefer 05” strategy.

It is determined that;

- The extent of night time noise impact depends strongly on the airport operating strategy and, in particular, the adoption of a “Head-to-Head” operating mode when practicable. Use of a ‘Head-to-Head” strategy results in an estimated 4,300 residents being exposed to more than 5 aircraft noise events per night above 60 dBA in 2030. An outside noise level of 60 dBA corresponds to an internal level of approximately 50 dBA if windows are open to a normal extent, which is the design criterion for aircraft noise in sleeping areas under Australian Standard 2021. Under the above strategy, the affected residents would be largely in rural residential areas to the south-west of the airport, including Greendale and parts of Silverdale. However, some residents to the north-east of the airport around Horsley Park would also be affected.
- Airport operating strategies that do not include a “Head-to-Head” mode are predicted to result in substantially greater numbers of residents impacted by night time noise and, in particular, a “Prefer 05” strategy would result in large parts of St Marys experiencing more than 5 aircraft noise events per night above 60 dBA in 2030.

Land use planning:

The ANEC contours extend beyond the runway ends for a distance of approximately 7 km. To the sides of the runway the contours extend approximately 1 km from the runway centreline.

- In ANEC contours produced for the 2030 scenario, the area covered by the 20 ANEC contour is located closely around the airport, with only an estimated 200 – 240 residents living within the contour. However, because land use planning guidelines are intended to address long-term planning issues, ANEC contours for longer term scenarios, as described below, are considered more relevant. An ANEF chart based on further formal flight path design would be produced for endorsement by Airservices Australia prior to the commencement of airport operations to inform land use planning.

Based on airport usage patterns projected for this report, 20 ANEC contours cover areas that are currently largely rural residential in nature, with some industrial use. No areas of built-up residential development are included in the 20 ANEC contour under any scenario. The "Prefer 23 with Head-to-Head" operating scenario results in the smallest area being covered. One point of interest is that an area to the west of the airport site, including the townships of Warragamba and Silverdale, although relatively close to the airport, is not included in the 20 ANEC contour under any scenario. This is due to the fact that, although a departure track is located over this area, the track is designated as being for use by non-jet aircraft only. The ANEC contours presented in this report should not be used for land use planning purposes until the validity of all underlying assumptions has been confirmed.

Greater Blue Mountains Area:

- Based on the indicative airspace design for the proposed airport, large areas of the Greater Blue Mountain World Heritage property would not experience significant aircraft noise. However, some parts of the property would be subjected to a substantial increase in aircraft overflights. The aircraft would be at heights generally greater than 5,000 feet above ground level. Maximum noise levels may occasionally reach 60 dBA at some points, but levels directly under a flight track would typically be below 55 dBA, and often much lower. The periodic intrusion of aircraft noise may result in occasional disturbance to recreational and other visitors to the property.

- At locations directly under the indicative flight tracks, the number of audible aircraft overflights (typically at levels of 55 dBA or below) could be over 70 per day in 2030. Worst-case locations would be under one of two approach paths that emanate from a "merge point" in the area of the lower Blue Mountains.

- The nominal location of this merge point based on the indicative flight tracks would be almost directly over the township of Blaxland, meaning that in 2030, residents could expect to experience aircraft overflights at significant altitude (typically over 5000 ft above ground level) almost 100 times per day, with maximum noise levels ranging up to 55 dBA.

- Alternative locations for this merge point were considered within about 3 nautical miles from the nominated location. Use of these alternative merge points would substantially reduce the number of overflights passing over populated areas, but would result in other locations within the World Heritage Area experiencing a similar number of overflights to those currently predicted for Blaxland.

Additional Capacity (2050)

Demand for air travel would continue to grow following the proposed initial stage of airport development. This noise assessment therefore includes a subsequent assessment scenario, notionally at the capacity of the first runway, when total passenger demand is estimated to be approximately 37 million passengers per annum. This scenario provides an indication of potential change in noise impacts associated with the growth of aircraft movements on the proposed first runway over time.

Conclusions from the assessment of this scenario can be summarised as follows.

Maximum noise levels:

Maximum noise levels are the same as those described for the initial stage development (2030), with the exception of B747 aircraft that depart on long haul international routes. In this case, the noise contours extend up to 50 kms from the runway ends. Noise contours also extend to the village of Luddenham.

- Predicted aircraft operations for the 2050 scenario include longer-range departures by B747 or equivalent aircraft. B747 aircraft are currently being phased out of operations and replaced with quieter aircraft. This scenario has modelled a worst-case scenario and for these operations, maximum noise levels over 85 dBA would be experienced at a small number of residential locations close to the airport site, in the area of Badgerys Creek. Maximum noise levels of 75 – 80 dBA could be expected within built-up areas in St Marys and Erskine Park due to these worst-case operations, which are predicted on average to occur once every two days in 2050. These operations may occur during day or night periods.

- Maximum noise levels due to more common aircraft types, such as Airbus A320 or equivalent, would be the same as those described above for 2030.

Noise impact over 24 hours:

N70 contours would extend from the runway ends. The N70=5 contour would extend approximately 15 km to the north and 19 km to the south-west of the runway. Depending on the strategy, either “Prefer 05” or “Prefer 23”, the contours would “lobe” towards St Marys and Greendale / Bringelly respectively.

In the case of the “Prefer 05” priority strategy, the noise contours would cover the densely populated areas around St Marys. However, the Greendale / Bringelly “lobes” would not extend into population centres.

It is determined that;

- In 2050, there would be a very substantial difference between the “Prefer 05” and “Prefer 23” operating strategies in terms of noise impact.

- Most residents predicted to be affected under the “Prefer 05” strategy are in suburbs to the north around St Marys and Erskine Park. In terms of total population affected, the “Prefer 05” strategy is predicted to have a greater impact with an estimated 30,000 residents experiencing more than 5 events per day over 70 dBA in 2050, compared with 5,000 residents for the “Prefer 23” strategy. These numbers are reduced slightly if a “Head-to-Head” mode is also adopted.

Under the "Prefer 23" strategy, the residents predicted to experience the greatest number of overflights over 70 dBA are in rural residential areas to the south-west, including Greendale and parts of Silverdale. These residents would be affected to a greater extent than those to the north – an estimated 700 residents in this area would experience more than 100 events per day above 70 dBA, compared with 300 residents under the "Prefer 05" scenario.

Night time noise impact:

For the additional capacity stage of the airport, the N60=5 contour extends approximately 20-22 km to the north to St Marys and 25 km to the south-west of the runway when a "Prefer 05" strategy is implemented. The contour to the north of the runway would extend into the population centres around St Marys.

The adoption of a "Prefer 23" priority strategy would result in the contours extending to the north-east for a distance of approximately 20 km into the Blacktown area and to the south-west for more than 40 km into a southern part of the Blue Mountains National Park. The contours would lobe towards Greendale.

The adoption of Head-to-Head operations would result in a significant reduction in the size of the contours to the north of the airport, particularly under the "Prefer 05 Head-to-Head" strategy.

To the side of the runway, the contours extend into Luddenham.

It is determined that;

- The extent of night time noise impact would also depend strongly on the airport operating strategy. The most favourable strategy from the point of view of noise impact would be "Prefer 23 with Head-to-Head", which would result in an estimated 40,000 residents being exposed to more than 5 aircraft noise events per night above 60 dBA. The affected residents would be largely to the north-east of the airport around Horsley Park, Blacktown and St Marys. However, the bulk of these receivers would be in the 5 – 10 noise event range.

- Airport operating strategies that do not include a "Head-to-Head" mode are predicted to result in substantially greater numbers of residents impacted by night time noise, and in particular, a "Prefer 05" operating strategy would result in large parts of St Marys experiencing more than 20 aircraft noise events per night above 60 dBA in 2050.

Land use planning:

Under the 2050 assessment scenario the ANEC contours would extend along the runway alignment for a distance of approximately 12-15 km . In the case of the "Prefer 05" strategy, the contours would extend towards the north, but would not reach the major population areas.

To the sides of the runway, the contours extend approximately 1.5 km from the centreline of the runway.

It is determined that;

- Based on airport usage patterns projected for this report, 20 ANEC contours for the 2050 scenario would cover areas that are currently largely rural residential in nature, with some industrial use. No areas of built-up residential development would be included in the 20 ANEC contour under any scenario. The "Prefer 23 with Head-to-Head" operating strategy results in the smallest area being covered

- One point of interest is that an area to the west of the airport site, including the townships of Warragamba and Silverdale, although relatively close to the airport, would not be included in the 20 ANEC contour under any operating strategy. This is due to the fact that although a departure track would be located over this area, the track is designated as being for use by non-jet aircraft only.

- The ANEC contours presented in this report should not be used for land use planning purposes until the validity of all underlying assumptions has been confirmed. As noted above, an ANEF chart, based on further formal flight path design would be produced for endorsement by Airservices Australia prior to the commencement of airport operations to inform land use planning.

Greater Blue Mountains Area:

- Parts of the Greater Blue Mountains World Heritage Area would be subjected to larger numbers of aircraft overflights compared to the 2030 scenario. As in 2030, the aircraft would be at heights generally greater than 5,000 feet. Maximum noise levels may occasionally reach 60 dBA at some points, but levels directly under a flight track would typically be below 55 dBA, and often much lower. The intrusion of aircraft noise may result in some disturbance to recreational and tourist visitors to the property in areas under a flight track.

- At locations directly under indicative flight tracks, the number of audible aircraft overflights could be over 200 per day in 2050. Worst-case locations would be under one of two approach paths that emanate from a "merge point" in the area of the lower Blue Mountains.

- As for the 2030 scenario, the nominal location of this merge point based on the indicative flight tracks would be almost directly over the township of Blaxland, and in 2050 residents could expect to experience aircraft overflights at significant altitude (typically over 5000 ft) some 230 times per day with maximum noise levels ranging up to 55 dBA.

- As for the 2030 scenario, the use of alternative merge points would substantially reduce the number of overflights passing over populated areas, but would result in other locations within the World Heritage Area experiencing a similar number of overflights to those currently predicted for Blaxland.

Longer Term Airport Development (2063)

- In considering future projected impacts from an airport comprising two runways, nominally in 2063, the proposed airport's operating strategy would again have a significant bearing on the noise outcomes. A number of alternative airport operating modes may be available under conditions of low traffic volume, and these may result in reduced noise impacts, particularly at night. However, at the time of production of this report, it was not possible to identify which modes could be available and under what conditions. Hence in this report, only the two basic operating strategies – "Prefer 05" and "Prefer 23" are considered.

- Predicted noise impacts for the longer term development are similar to those described above for the modelled single runway scenarios and occur in similar areas. However, the total number of residents affected is generally higher, largely as a result of expected population growth and ongoing housing development. For example, under a "Prefer 23" operating strategy, the number of residents experiencing more than 5 events per day above 70 dBA is estimated at 17,000 (compared with 5,000 nominally in 2050).

- ANEC contours for this case would be similar to those for the 2050 scenario, although somewhat larger. Once again, the 20 ANEF contour would not enclose any existing built-up residential areas and does not include the townships of Warragamba and Silverdale.

Options for Noise Mitigation

There are three fundamental options for mitigation of aircraft noise:

- reduce noise emissions from the aircraft themselves;
- plan flight paths and airport operating modes to achieve lower impacts over noise-sensitive areas; and
- develop land use planning or other controls to ensure that future noise-sensitive uses are not located in noise-affected areas.

With respect to the first point, the use of continuous descent approaches has already been adopted in noise assessments for this report and, at this time, there appear to be no other feasible options by which noise emissions from aircraft in flight could be reduced through alternative operating procedures.

It is difficult to foresee the magnitude of future reductions in aircraft noise emission levels as this is primarily the role of aircraft designers and manufacturers, and while reduced noise levels are highly desirable, they are one of many outcomes that aircraft designers strive to achieve in newer aircraft.

In fact, aircraft noise emissions have reduced very substantially over the past 30 years. Although it is very likely that noise emission from future aircraft will also be lower than from current aircraft due to the absence of specific information, this report has adopted a conservative approach by modelling future aircraft types on the basis of existing noise emission levels. This is reflected in the inclusion of B747 or equivalent aircraft in the assumed fleet mix in all scenarios. The B747 is being phased out of operations and by 2030 the number of operations by this aircraft type at the proposed airport is expected to be very low (see Joint Study on aviation capacity in the Sydney region, 2012, p.123).

The mitigation measures most relevant to the EIS process, and for which detailed preliminary noise impact information has been provided in this report, are related to airspace design and airport operating modes. While both these issues are subject to their own specific objectives and legislation, consideration of environmental impact is one important consideration in the future design process. This report canvasses a number of options and considers the range of possible outcomes for each.

The indicative airspace design, and particularly the location of the “merge point” for arriving aircraft, provides some flexibility for reducing the noise exposure of residents in the lower Blue Mountains.

However, in considering both airspace design and the selection of operating modes, it should be noted that competing interests will include the safety of all aircraft, consideration of other airspace users, and aircraft fuel consumption. Some of these may compete with the aim of lowering environmental noise impact.

With respect to planning issues, since approximately the 1980s the NSW Government and local governments have been actively planning for an airport at Badgerys Creek and have undertaken a number of steps aimed at limiting future noise exposure of the residential population. These have included zoning land near the airport as appropriate for less sensitive uses, as well as ensuring that local government has planning procedures in place to limit sensitive uses in areas potentially affected by aircraft overflight noise. This has limited the potential noise impact from an urban greenfield airport to a level that is lower than would otherwise be expected for a development of this type and scale.

One important form of mitigation for aircraft noise impacts is the provision of information to both existing and potential residents in areas likely to be affected by noise. This allows potential residents who are particularly sensitive to noise impacts to choose not to move into the area. Information presented in this report provides a starting point for this process, but other tools, including the website information tool, can help to facilitate a greater understanding of the likely impacts at specific locations.

Should the Government decide to proceed with development of the proposed airport, more detailed planning of the airspace design and operating procedures, including consideration of noise and mitigation measures, would be undertaken in consultation with industry and stakeholders.

The current design for both the proposed airport and airspace is indicative, and the noise modelling presented in this report would be subject to further detailed design and assessment closer to the commencement of operations. When operations did commence, some aspects of airport operations could be introduced to mitigate noise impacts on the community such as flight path planning, preferred runway directions and continuous descent approaches.

It is important to note that the proposed airport has a lengthy construction period and current planning is for the airport to commence operations in about 2025. In this timeframe, technological improvements, including the upgrading of airline fleets, are expected to continue to reduce the industry's noise impacts on communities. These and other potential improvements would be considered in formal airspace design and assessment processes in the future.

The Government would pursue the development of a noise management plan in consultation with appropriate stakeholders. This plan would be developed in parallel with the detailed airport design and future airspace review to provide the local community and other important stakeholders with the chance to be consulted and fully informed of the final expected impacts before the airport commences operations.

1 INTRODUCTION

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies – including two previous environmental impact statements for a site at Badgerys Creek – having been completed over the last 30 years.

More recently, the Joint Study on Aviation Capacity in the Sydney Region (Department of Infrastructure and Transport, 2012) and A Study of Wilton and RAAF Base Richmond for civil aviation operations (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24-hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, a delegate of the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the Airports Act 1996 (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan.

The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Terms of Reference

Guidelines for the EIS have been issued in accordance with the *Environment Protection and Biodiversity Conservation Act 1999*. Requirements relevant to aircraft noise are as follows:

> *Impacts to the environment (as defined in section 528) should include but not be limited to the following:*
>
> *Aircraft noise and vibration impacts on everyday activities and on sensitive environmental receptors (all sensitive receptors within the community and natural environment). Discussion and quantification/modelling of aircraft noise impacts should include consideration of all potential flight paths, height of flights, noise exposure patterns, noise contours, the range of frequencies of the noise, cumulative exposure, peak noise, frequency of overflights and temporal variability of this (including long term trends), varying aircraft types, varying aircraft operating procedures, and variations in noise patterns due to seasonal and meteorological factors*

This assessment has been prepared in accordance with the EIS guidelines.

1.3 Scope of this Report

This report seeks to document the likely impact of aircraft overflight noise resulting from the proposal using information that is currently available.

This report considers only noise associated with aircraft overflights from the proposed Western Sydney Airport. It does not consider any potential change in noise exposure at other airports, including Sydney and Bankstown Airports, which may arise as a result of operations at the proposed airport. Changes to operations at other airports are not anticipated as a result of the initial development at Badgerys Creek.

The introduction of operations at the proposed airport would result in significant changes to the pattern of aircraft noise in Western Sydney, due to required new aircraft flight paths and airport operating modes. The changes would result in noise impacts which may be significant in some areas. In addition, projected future growth in air traffic beyond the proposed initial airport development would result in increased numbers of aircraft operations, and noise impacts would also generally increase in the future, although the level of impact would likely be mitigated to some extent by the introduction of new, quieter aircraft into the fleet.

The pattern of noise exposure that would result from operation of the proposed airport is complex, and depends on time of day, season and other factors. In some cases, alternative airport operating modes would be available, each with differing impacts on different areas.

This report considers aircraft overflight noise, defined as being from the start-of-roll on departures and until an aircraft exits the runway (i.e. enters a taxiway) on arrivals. This includes noise produced whilst the aircraft is on the ground, such as elevated thrust during take-off procedures and reverse thrust during landing procedures. The separation of these noise sources from other on-ground sources such as engine ground runs, aircraft taxiing and aircraft at the terminal is consistent with the noise classification in the Airports (Environment Protection) Regulations 1997.

Noise associated with construction of the proposed airport, and noise from aircraft on the ground including noise while taxiing and standing at a terminal are addressed in a separate report. That report also addresses the potential noise impact from additional airport-induced road traffic.

The remainder of this report is structured as follows:

Chapter 2 – Methodology

Chapter 3 – Assessment of Initial Airport Development

Chapter 4 – Assessment of Additional Capacity Scenario

Chapter 5 – Assessment of Longer Term Airport Development

Chapter 6 – Noise-induced Vibration

Chapter 7 – Greater Blue Mountains World Heritage Area

Chapter 8 – Mitigation and Management Measures

Chapter 9 – Summary and Conclusions

The appendices to this report also contain other relevant information including the indicative flight tracks for the proposed single runway and longer term parallel runway airport developments, comparison of summer, winter and annual noise contours and flight density figures for the assessment of impact on the Greater Blue Mountains World Heritage Area.

2 NOISE ASSESSMENT METHODOLOGY

2.1 Descriptors of Aircraft Noise Impact

A number of acoustic units are available to describe the level of aircraft noise in an area, each being useful for a different purpose. The most important are described in the sections below.

2.1.1 ANEF

For land use planning in Australia, the accepted measure of aircraft noise exposure is the Australian Noise Exposure Forecast (ANEF). Australian Standard 2021 provides guidance on the acceptability of areas around an airport for certain types of development, in terms of the ANEF level in the area. For example, in Table 2.1 of the Standard, residential development is considered "acceptable" in areas with ANEF lower then 20, "conditionally acceptable" in areas with ANEF between 20 and 25, and "unacceptable" in areas with ANEF greater than 25. (In "conditionally acceptable" areas the Standard recommends that new buildings should incorporate acoustic treatment to achieve specified internal noise levels.)

The ANEF unit was developed on the basis of social survey data, and is relatively well correlated with the proportion of people who would describe themselves as "seriously affected" by the noise. However, its definition is complex, and as a single-number index, it does not provide the level of information generally sought by interested members of the public. In addition, it is not used outside Australia, and is therefore not generally used in describing the findings of overseas research. Most importantly, the studies underpinning the use of this and similar units are of reaction to noise that has been relatively constant over at least a number of years. Reaction to newly-introduced aircraft noise is known to be greater than the reaction of a community that has been exposed to the noise for some time. The relationship between ANEF values and the proportion of people "seriously" or "moderately affected" by aircraft noise is shown in Figure 2-1.

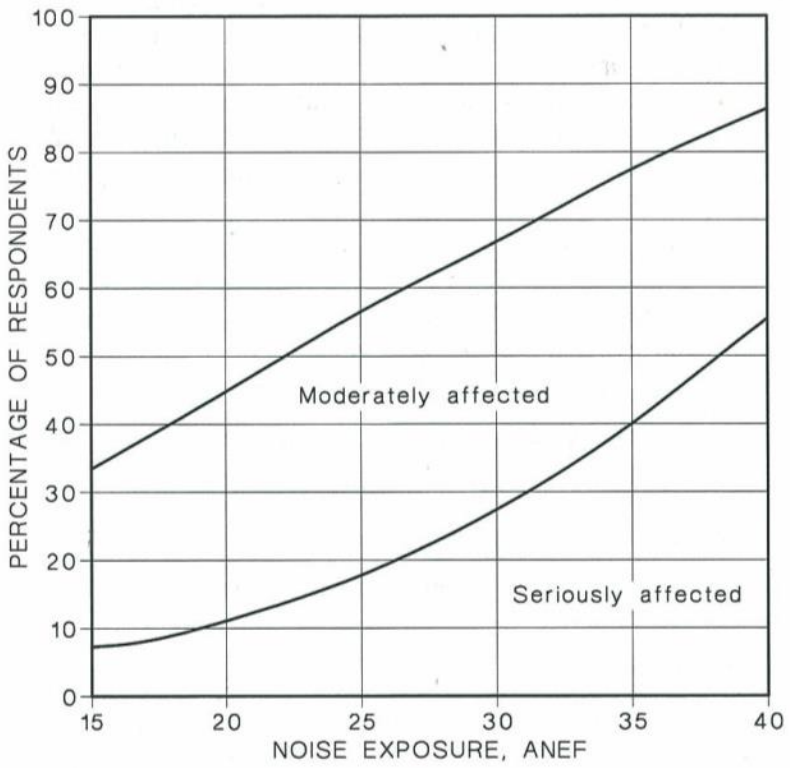
An "ANEF chart" is a set of land use planning contours for a specific airport which has been formally endorsed for technical accuracy by Airservices Australia, after a period of public consultation. The production of an ANEF chart for all major airports is a requirement of the *Airports Act 1996*.

2.1.2 ANEC

The Australian Noise Exposure Concept (ANEC) uses indicative data on aircraft types, aircraft operations and flight paths to provide a measure of aircraft noise exposure. The results are calculated using the same methods as the ANEF, but the ANEC is indicative and is therefore typically used in an environmental impact assessment. It represents a preliminary noise forecast produced for a hypothetical future usage pattern, and is useful for considering the land use planning consequences of alternative strategies.

ANEC contours for various airport operating scenarios are presented in this report. Final ANEF contours will not be produced until subsequent regulatory processes have been undertaken. Indicatively, if construction of the proposed airport proceeds, ANEF contours for the airport may not be known for several years.

Figure 2-1 Relationship between ANEF & Proportion of People "Seriously Affected" by Aircraft Noise (from Australian Standard 2021)



NOTE: This graph was derived from the National Acoustic Laboratories Report No. 88.

2.1.3 N70

Over the last 15 years, a system of describing aircraft noise has been developed by the Australian Government through industry and community consultation, which is oriented toward providing information in a form that can be understood more readily by interested members of the public, and provides a comprehensive description of the nature of aircraft noise exposure at any point. The information is presented in terms of a number of descriptors, and is intended to provide sufficient detail to allow members of the public to understand the likely impact of the noise.

This system is described in the discussion paper "Expanding Ways to Describe and Assess Aircraft Noise" published in 2000 by the then Commonwealth Department of Transport and Regional Services. The most commonly-used noise descriptor in this system is N70 – the number of aircraft noise events per day with maximum levels exceeding 70 dBA.

A noise level of 70 dBA outside a building would generally result in an internal noise level of approximately 60 dBA, if windows are open to a normal extent. This noise level is sufficient to disturb conversation, in that a speaker would generally be forced to raise their voice to be understood, or some words may be missed in speech from a television or radio. If external windows are closed, such effects would be experienced at an external noise level of approximately 80 dBA. N70 values indicate the average number of times per day when such events would occur. N70 contours can be calculated for different periods, indicating the average number of events experienced per day in that period.

In this project, N70 contours are calculated for six separate periods, representing combinations of:

- Whole Day (24hr) or Night (10pm-7am); and
- "Summer", "Winter" or Annual, representing differing ambient meteorological conditions. Inspection of meteorological data for the site indicated that from the point of view of noise impacts the "Summer" period was best defined as being from September to March, and "Winter" from April to August.

2.1.4 90th Percentile N70

Standard calculations of N70 represent an average over all days (or all days in a specified season), and may potentially be misleading if the number of events above 70 dBA varies significantly between days. To address this, this report also provides contours of 90th percentile N70, representing the N70 value exceeded on only 10% of days. This gives an indication of the value of N70 on days when there is a particularly high number of movements.

2.1.5 N60

For assessment of night time noise impacts, it is customary to consider N60 values, representing the number of events with maximum noise levels exceeding 60 dBA. An external noise level of 60 dBA represents approximately an internal level of 50 dBA if windows are open to a normal extent. An internal noise level of 50 dBA is commonly used as a design criterion for noise in a bedroom, to protect against sleep disturbance (for example in Australian Standard 2021), and hence N60 values represent the average number of times per night when this criterion would be exceeded (with open windows). N60 contours are presented in this report for the night time period 10pm-7am.

Similarly to N70, contours showing 90th Percentile N60 values are also presented representing the N60 value exceeded on only 10% of nights.

2.1.6 Respite Period

An associated measure of noise impact is "respite" – the proportion of days when there are no aircraft movements within a flight zone. This has been found to be a useful indicator in areas where noise exposure is highly variable, generally due to meteorological variability, and airport operations can be flexibly managed. This is less relevant at the proposed Western Sydney Airport, where the absence of a cross runway means that at most points around the airport there will be relatively few days with no overflights. For the proposed airport, the difference between 90th Percentile and average values of N70 is suggested to be a more useful indicator of variability.

It is noted that respite at night time will be a relevant measure depending on runway mode of operations.

2.1.7 Single-Event Noise Contours & Flight Path Density Charts

Single-event noise contours show the maximum noise level resulting from a single movement by a specified aircraft type, using a single flight track. Thus, they provide information on the highest noise level experienced, but not how often it is experienced. Single-event contours for movements on several tracks are often combined to show the maximum noise level experienced due to a movement by the selected aircraft type on any of the selected tracks. These are known as L_{Amax} contours.

Conversely, flight path density charts show the number of movements, by any aircraft type, for which the aircraft's flight path passes close to any point on the ground (measured horizontally). Thus they provide information on the number of aircraft movements experienced, but not on their noise level.

These two forms of presentation are often used to describe aircraft noise in areas that are more remote from the airport, for which N70 and related contours may be less meaningful and subject to greater uncertainties. For residences, flight path density charts in these areas indicate the number of aircraft per day that may be visible and that would be audible under conditions of low background noise.

In this report, a form of flight path density chart is used to describe aircraft noise exposure over the Greater Blue Mountains World Heritage Area (GBMWHA). This area is relatively remote from the airport, but is considered sensitive to potential noise impacts. Flight path density charts visually describe both the existing and the projected future number of movements within the GBMWHA. Movements can be segregated at different heights as an approximate way of differentiating between potential noise levels.

2.1.8 Health Related Noise Descriptors

Assessment of specific health impacts related to aircraft noise is addressed in a separate report. The impacts considered in that report include:

- effects on educational facilities and other noise sensitive facilities or population groups (including potential impacts on student learning etc.);
- sleep disturbance (number of awakenings, sleep latency etc.);
- effects on amenity (e.g. speech interference, annoyance, enjoyment of natural areas);
- cumulative noise impacts (e.g. associated with new noise sources or changed noise environment – new roads, ground based noise etc.); and
- community response and adaptation to a new noise source.

However, to allow assessment of these impacts it was necessary to provide measures of predicted noise exposure in units that are consistent with those used in health studies. The relevant units are:

- $L_{night,outside}$: This is simply the equivalent-continuous noise level between 11pm and 7am, or $L_{Aeq,11pm-7am}$. It is used to describe night time noise exposure in a number of documents produced by the World Health Organisation;
- $L_{Aeq,9am-3pm}$: This unit is used in a number of studies of the impact of noise on school students and teachers; and

- for assessment of night time noise impacts, the number of occurrences of L_{Amax} noise levels at various levels is required. This can be described by a set of 'number-above' metrics as described in Sections 2.1.3 to 2.1.5.

These units were calculated at specific nominated locations, using the same assumptions and procedures described below for the descriptors considered in this report.

2.2 EIS Assessment Scenarios

Consistent with other environmental impact assessments documented in the EIS, it was necessary to define a number of scenarios on which to base the impact assessment. For noise impact assessment, three stages of passenger demand were modelled:

- 10 million annual passengers – This represents the initial stage in the airport's development and is nominally forecast to occur in 2030. At this stage, the proposed airport has been operating for approximately 5 years and comprises a single (northern) runway that is accommodating about 63,000 aircraft movements.

- 37 million annual passengers – This represents a later stage of development at which the single runway is likely to be approaching its maximum capacity and further demand growth would require construction of an additional runway. The EIS considers the capacity of the first, single runway could be reached about 2050.

- 82 million annual passengers – This represents a longer-term stage of development when the airport comprises two operating parallel runways and the second runway is operating close to capacity. This equates to approximately 370,000 aircraft movements per year. This is nominally forecast to occur in 2063.

Note that the dates outlined in the above assessment scenarios are based on forecasts by the business advisory team engaged by DIRD. The assessment scenarios should be thought of as representing noise exposure at certain hypothetical stages in the airport's development – the exact time when those stages are reached will depend on factors that are difficult to predict. The nominal years give some indication of time frames that are currently considered likely, however, the noise impact predictions are based more fundamentally on passenger movement forecasts than specific forecast dates.

In this report, aircraft overflight noise is considered for each of the above assessment scenarios. Within each scenario, a number of options are considered, representing summer/winter and various alternative operating procedures. In addition, for each of these options, impact is considered separately for the day and night periods.

Information for all noise exposure metrics and scenarios is included in this report and its appendices. In addition, an on-line noise information tool is available on the Department's website. This provides interested readers with the ability to explore potential impacts in a more detailed and flexible manner, specific to their circumstances. Given the nature of the proposed development, this would not be possible in a report format.

2.3 Aircraft Noise Calculation Procedures

Detailed calculation of future aircraft overflight noise levels at any airport requires estimates of the number of future aircraft operations, broken down by:

- aircraft type (as defined in the INM noise calculation program);
- flight track (including several flight tracks for arrivals and departures on each runway);
- stage length for departures (representing distance to destination); and
- time of day at which the operation occurs.

The number and mix of operations on each flight track will be different for each scenario considered. Given the above information, values of all the above noise descriptors can be calculated, either at specific points or in terms of contours, using noise levels calculated using the industry-standard INM calculation program (version 7d).

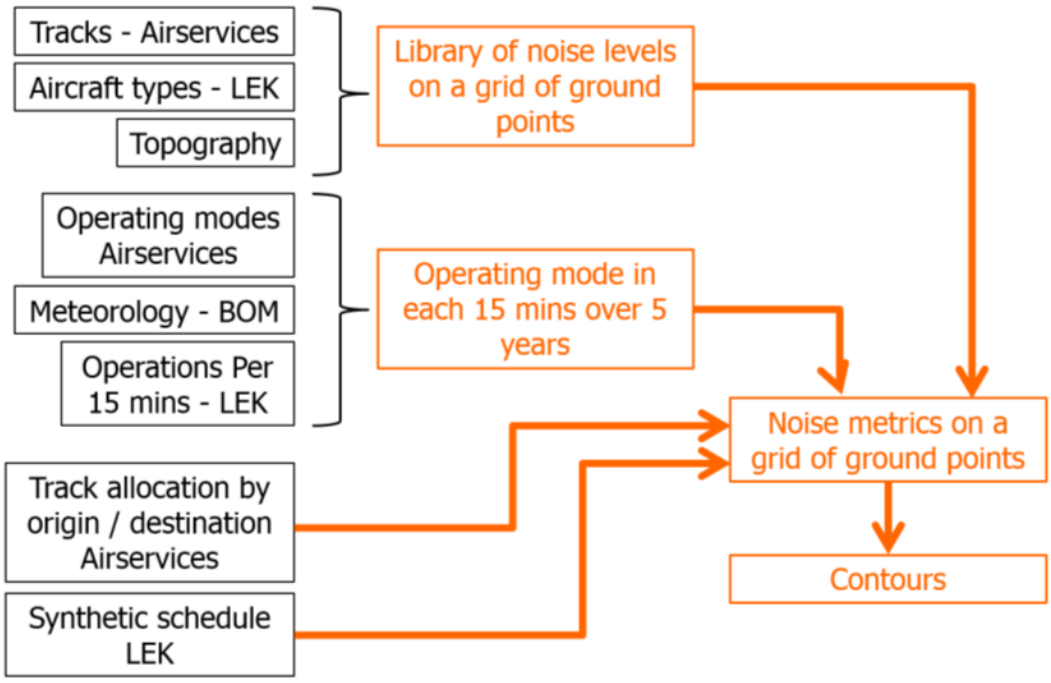
The INM is a computer model that evaluates aircraft noise impacts in the vicinity of airports. It was developed based on the algorithm and framework from the SAE AIR 1845 standard, which used noise-power-distance (NPD) data to estimate noise accounting for specific operation mode, thrust setting, and source-receiver geometry, acoustic directivity, and other environmental factors. The INM can output either noise contours for an area or noise level at pre-selected locations. The noise output can be exposure-based, maximum-level-based, or time-based.

The INM focusses mainly on aircraft overflight noise, but also includes departure noise and landing and reverse thrust noise when the aircraft is on the runway.

It is noted that the US Federal Aviation Administration, which developed the INM, has recently superseded the INM with the Aviation Environmental Design Tool (AEDT). At the time of writing of this report, AEDT had not been evaluated for Australian conditions. On this basis the INM was selected for the aircraft noise predictions in the current assessment. It is noted that the calculation and prediction algorithms relating to aircraft noise are understood to be equivalent in both calculation programs.

Figure 2-2 shows the general process which was used to derive this input data, using movement forecasts, aircraft flight tracks, airport operating modes and other data. Each step in this process is described in detail in the following sections. Sources of data are provided in Section 2.11.

Figure 2-2 Noise Calculation Methodology



2.4 Aircraft Types used in Calculations

Projections of aircraft movements for future years were provided in terms of "families" of aircraft types. Each family was represented by one or a number of aircraft types that are included in the standard INM aircraft noise modelling program (see Section 2.9), with the representation of types within a family potentially changing between years. For passenger movements, Table 2-1 shows the aircraft families, and the INM types used to represent them, for each modelling year.

For freight movements, individual aircraft types were nominated and the range of types is shown in Table 2-2.

The aircraft types shown in Table 2-1 and Table 2-2 were used for noise level calculations in all scenarios. They were selected to be representative of the aircraft types expected to use the proposed Western Sydney Airport, including potential future aircraft types. Understandably, the noise emission characteristics of aircraft types decades into the future are not currently known, but it can reasonably be assumed that they will not be higher than those of current equivalent types, and in general they are expected to be lower. Approximately 70% of freight is carried on passenger aircraft and dedicated freight are often the same type of aircraft as those used for passenger services. However, for modelling purposes and to provide a worse-case scenario, dedicated freight aircraft are assumed to be older and noisier aircraft types, and to be phased out more slowly. In particular, the model includes 747-400 freight aircraft (or aircraft with equivalent noise emissions) even in 2063. Hence the adopted procedure of representing future aircraft types by reference to only current aircraft types and emissions is considered conservative.

Table 2-1 Aircraft Types Modelled – Passenger Movements

		Proportion of Family Represented by INM Type		
Aircraft Family	**INM Aircraft Type**	**2030**	**2050**	**2063**
Airbus A320	A320-211	60%	0%	0%
	A320-232	40%	100%	100%
Airbus A330	A330-301	45%	5%	0%
	A330-343	55%	95%	100%
Airbus A380	A380-861	-	100%	100%
Boeing 737	737-800	80%	0%	0%
	737-700	20%	100%	100%
Boeing wide-body general	777-200	-	40%	40%
	787-8R	-	15%	15%
	A330-343	-	40%	40%
	747-8	-	5%	5%
Boeing 777	777-200	48%	85%	85%
	777-300	37%	0%	0%
	787-8R	15%	15%	15%
De Haviland DHC8	DHC830	25%	75%	100%
	DHC8	75%	25%	0%
Saab 340	SF340	100%	100%	100%

Note: - indicates there are no movements of this family in the schedule for this year.

Table 2-2 Aircraft Types Modelled – Freight Movements

Aircraft Family	INM Aircraft Types Represented
Airbus A330	A330-301
Boeing 737	737400
Boeing 747	747400
Boeing 767-400	767400
Boeing 767-300	767300
Boeing 777-300	777300
Boeing 777-200	777200
Small Freight	SF340

Note: Modelling conservatively assumes freight aircraft types are maintained across all forecast periods.

2.5 Aircraft Movements

Predicted future numbers of aircraft movements have been based on modelling supplied by the DIRD business advisory team. This was in the form of “synthetic schedules” which detail a list of aircraft operations for a typical busy day in each EIS assessment year, including aircraft family, operation type (arrival or departure), time of operation and port of origin or destination for each operation. These schedules form the basis of all modelling described below.

Table 2-3 shows predicted total aircraft movements per day for each EIS assessment year, while Table 2-4 shows a breakdown by aircraft family. Figure 2-3 shows the predicted number of movements for each hour of the day.

Note that because the synthetic schedules represent a typical busy day, the number of movements is slightly greater than an annual average for the relevant scenario. For example, in 2030 the estimated 63,000 movements per year represents an annual average of approximately 173 per day, compared with 198 in the schedule. This provides some conservatism in estimates of noise exposure.

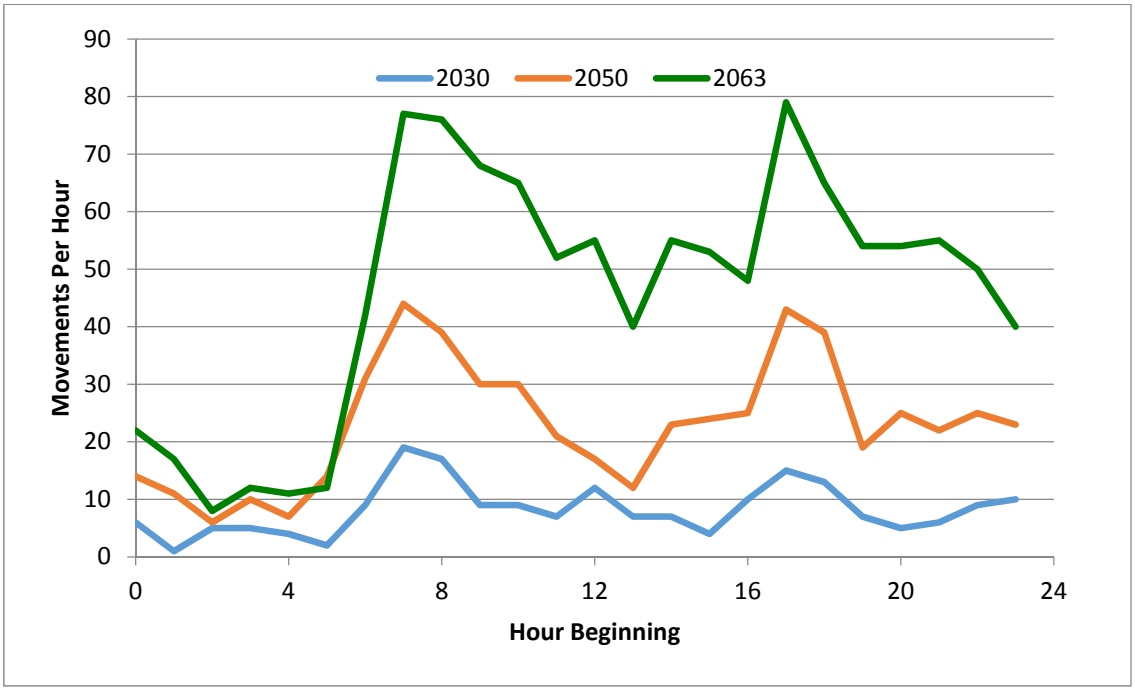
Table 2-3 Total Predicted Daily Aircraft Movements by Type by Year

Assessment Year	Movements Per Day		
	Freight	Passenger	Total
2030	28	170	198
2050	74	480	554
2063	104	1006	1110

Table 2-4 Predicted Daily Aircraft Movements by Aircraft Family by Year

Aircraft Family	Movements Per Day		
	2030	2050	2063
Passenger Movements			
Airbus A320	100	176	378
Airbus A330	18	128	286
Airbus A380	-	4	8
Boeing 737	28	104	196
Boeing wide-body general	-	20	40
Boeing 777	4	26	78
DeHaviland DHC8	8	12	10
Saab 340	12	10	10
Freight Movements			
Airbus A330	2	2	2
Boeing 737	2	6	6
Boeing 747	10	28	38
Boeing 767-400	4	8	10
Boeing 767-300	-	4	6
Boeing 777-300	-	2	4
Boeing 777-200	-	4	6
Small Freight	10	20	32

Figure 2-3 Predicted Aircraft Movements per Hour for Each Assessment Year



Each operation in each synthetic schedule is assigned a port of origin or destination. This allows:

- assignment of the movement to a flight track, based on the direction of the port. (Note that this applies only to departures, because as described below arrival tracks are assumed to be determined using a "point merge" system); and
- for departures, assignment of a "stage length" based on the distance to the port. (This affects the assumed fuel load and hence noise emission from the aircraft.)

Table 2-5 shows the way in which nominated ports were assigned to directions for determination of flight tracks.

Table 2-5 Assignment of "Direction" to Airports in Synthetic Schedules

Direction	Airport Name
Domestic North	Darwin, Brisbane, Cairns, Coffs Harbour, Gold Coast
International North	Singapore, Hong Kong
Domestic West	Adelaide, Karratha, Perth
International West	Dubai
Domestic South	Melbourne, Canberra, Hobart, Avalon, Albury
International South	Johannesburg
International East	Auckland, Fiji (Nandi), Los Angeles, Santiago

2.6 Flight Tracks

Airservices Australia has assessed the airspace implications and air traffic management approaches for Sydney basin airspace arising from the potential introduction of operations at the proposed Western Sydney Airport. The principal objective was to establish whether safe and efficient operations could be introduced at the airport through developing indicative proof-of-concept air traffic management designs.

Importantly, this work does not represent a comprehensive airspace and air route design, nor does it consider all of the essential components that would be necessary to implement an air traffic management plan for the Sydney basin. These indicative flight tracks have been developed to demonstrate the feasibility of flight paths for the airport.

While the formal flight path design for the proposed airport would be undertaken much closer to the commencement of operations – within several years of the first flights occurring – indicative flight paths for Stage 1 (single runway) and long-term (parallel runway) operations have been prepared based on Airservices Australia's preliminary analysis.

These tracks have been confirmed as being appropriate for the purposes of the EIS. The report in which the tracks are presented contains the following disclaimer:

"The design and analysis presented in this report is intended to meet a narrow scope focussed on demonstrating a proof of concept. It does not present a comprehensive airspace and air route design and does not consider all essential components that would be necessary to implement an air traffic management plan for the Sydney basin. Certain assumptions have been made and significant additional steps would be required to develop air traffic management plans suitable for implementation*".*

The indicative flight tracks are shown in Appendices A and B and are described in more detail in the following sections.

The following matters described below would be taken into account in determining final flight tracks.

- In designing airspace management arrangements for the airport, flight paths and procedures would be optimised for noise management purposes as part of the work that Airservices Australia would undertake before the airport became operational.
- Under the *Air Services Act 1995*, Airservices Australia is required to exercise its functions, as far as practicable, so as to protect the environment. It has published a document called 'Airservices commitment to noise management' which outlines the considerations which are taken into account in designing flight paths and procedures. http://www.airservicesaustralia.com/wp-content/uploads/Aircraft_Noise_Management_WEB.pdf
- The Civil Aviation Safety Authority (CASA) would also need to approve proposed flight paths and procedures. Under the Civil Aviation Act 1988, CASA is also required to exercise its functions so as to, as far as practicable, protect the environment.
- It is expected that a referral to the Minister for the Environment under the *Environment Protection and Biodiversity Conservation Act 1999* would be required before flight paths for the airport are put into place.

2.6.1 Arrivals

For the 2030 and 2050 assessment years, arrival tracks are assumed to follow a "point merge" configuration in which all aircraft approaching the airport pass over a single point, located to the north-west of the airport, and then move to a final approach in either of the two runway directions. Airservices Australia (Airservices Australia 2015) nominates one location for the merge point. However, subsequent advice from Airservices indicated that the merge point could be moved by up to 3 nautical miles without significant impacts to the preliminary airspace design.

The location of this point makes little difference to analysis of noise impacts relatively close to the airport. However, when considering impacts within the GBMWHA and nearby residential areas, the location is significant. Analysis of impacts in these areas includes consideration of two alternative merge points (see Section 1.1).

For the 2063 assessment year, arrivals are assumed to use four separate merge points, all located generally to the north of the airport – one point for each runway and each runway direction.

In the 2030 assessment year, arriving aircraft were allocated to each of the arrival tracks that approach the "merge point" on an 80/20/10/10 percentage basis. That is, when aircraft movements are relatively low, most presenting aircraft would use the shortest approach track. In the years 2050 and 2063, when movement numbers are greater than even allocation of aircraft to all tracks approaching the merge point was adopted.

Airservices Australia nominates a single arrival track from the merge point to the proposed airport, which represents the "ILS" track and would be used when instrument landing conditions prevail. However, under visual meteorological conditions, a series of tracks may be used, allowing aircraft to be sequenced more efficiently. In noise modelling, five or six additional "visual" arrival tracks were defined from the initial development merge points, with the following rules:

- under instrument meteorological conditions, all aircraft follow the ILS track; and
- under visual meteorological conditions, aircraft are assigned in equal proportions to the ILS track and each of the visual tracks.

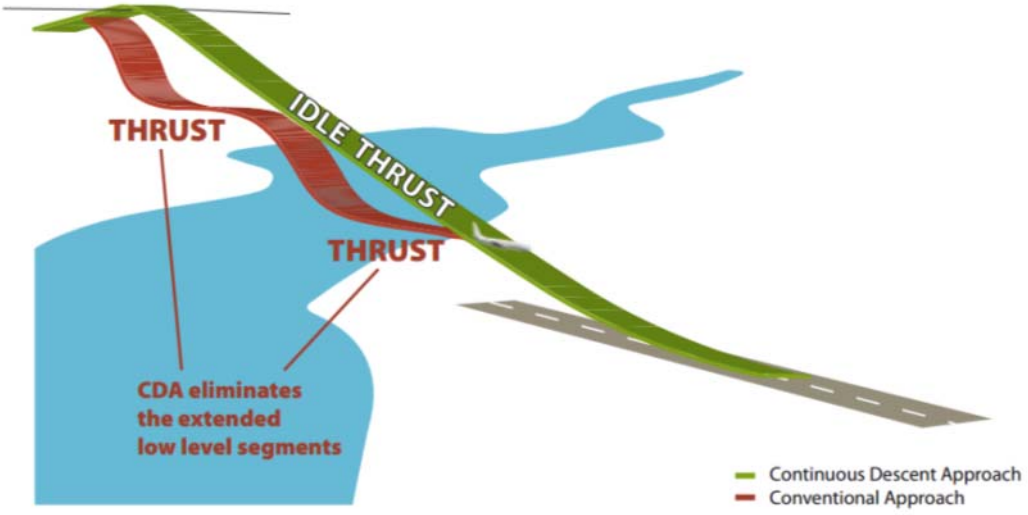
Visual meteorological conditions are defined by:

- visibility > 10 km; and
- cloud height > 4000 ft,

Meteorological data was obtained from Camden Airport as the nearest representative location to the proposed Western Sydney Airport with visibility observations available. See the discussion in Section 2.8.

When using the point merge system, aircraft would adopt a "continuous descent" approach (CDA), in which the aircraft begins its approach from well beyond the merge point and continues at a constant rate of descent until landing. CDA is defined as "an aircraft operating technique aided by appropriate airspace and procedure design and appropriate ATC clearances enabling the execution of a flight profile optimized to the operating capability of the aircraft, with low engine thrust settings and, where possible, a low drag configuration, thereby reducing fuel burn and emissions during descent." Figure 2-4 illustrates the concept of "CDA".

Figure 2-4 Concept Diagram of "CDA"



The adoption of CDA results in reduced noise emission compared with a profile in which the aircraft is required to maintain a constant height for a section of the approach. Noise emission reduction is possible because the aircraft can be configured to reduce the need for power settings above flight idle. Modelling in this report assumes that all arrival profiles will be "continuous descent".

2.6.2 Departures

For 2030 and 2050 assessment years, the flight tracks depict two major departure tracks in each direction, which each branch into other tracks at distances that are sufficiently far from the airport that they are not relevant for noise assessment.

For departures to the south-west (the 23 direction) there is a third track passing roughly over the township of Warragamba that is nominated to be used by non-jet aircraft only. The current nomination of this track for non-jet aircraft results in a significant reduction in predicted noise exposure in areas beneath this track compared to the previous EIS study.

2.6.3 Track Dispersion

Dispersion refers to the assumed variability of actual flight tracks around a nominated flight track. In modelling for this project, dispersion for departure tracks is modelled using one main track and four sub-tracks, two on either side of the main or median track. The extent of dispersion, and proportional allocation of operations to the sub-tracks, uses INM defaults (being 38.6% on main track, 24.4% on each of the inner subtracks and 6.3% on each of the outer subtracks), with the exception that some adjustments are made close to the runway end points to be more representative of typical flight paths.

No dispersion is added for arrival tracks, including the section of track prior to the merge point, on the basis that these would be strictly controlled. However, the use of a number of tracks for visual approaches, as described above, provides a form of dispersion over the relevant areas.

2.7 Airport Operating Modes

2.7.1 Initial Development (2030) and Additional Capacity Scenario (2050)

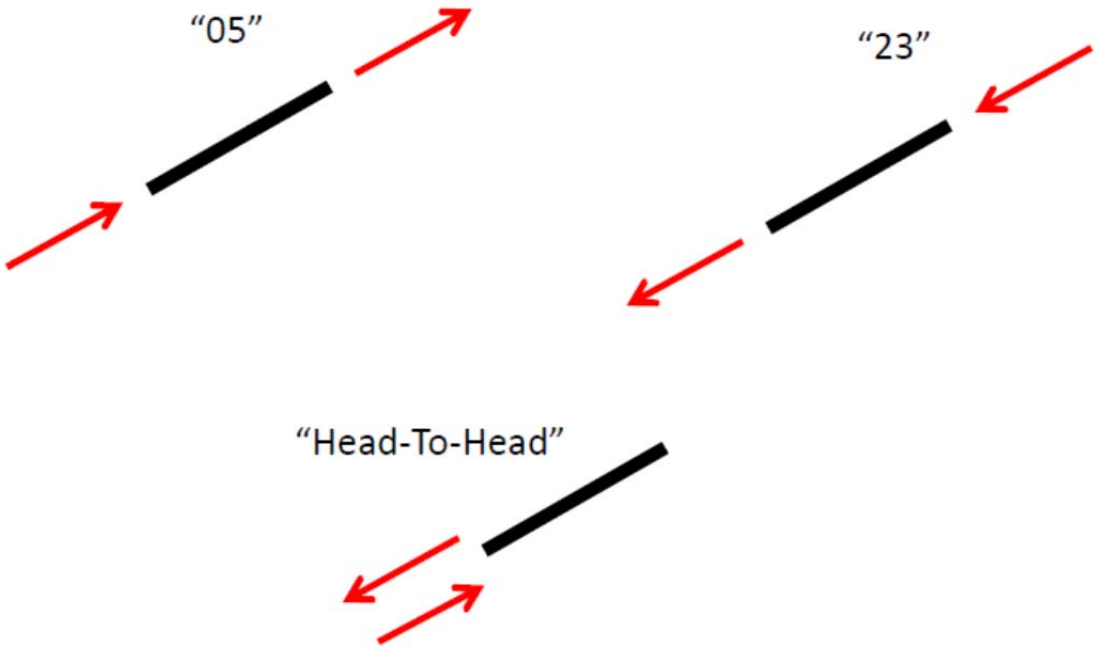
Three operating modes have been considered for the proposed initial single-runway airport development, namely “05”, “23” and “Head-to-Head” modes as follows:

- Mode 05: Aircraft arrive from the South-West and depart to the North-East.
- Mode 23: Aircraft arrive from the North-East and depart to the South-West.
- Head-to-Head Mode: Aircraft arrive from the South-West and depart to the South-West.

Figure 2-5 illustrates these modes.

Each of these modes may or may not be available at any time, depending on meteorological conditions, particularly wind, the number of presenting aircraft, airspace management procedures (including any potential noise amelioration policies), and time of day. However, the assumed order for selection of the modes has a significant effect on the overall predicted noise impact from the proposed airport. Four strategies were considered in this report, as described below.

Figure 2-5 Initial Airport Development – Operating Modes



Strategy 1 – "Prefer 05"

- Mode 05 to be used unless wind conditions indicate the runway is unavailable, according to the Civil Aviation Safety Authority's Manual of Standards (MOS) Part 172. In this case, mode 23 will be adopted.
- If mode 23 is in use, the mode will revert to 05 under the following conditions:
  - the use of mode 05 has been allowed for at least 2 hours before the change time; and
  - the use of mode 05 will be allowed for at least 2 hours after the change time.

Strategy 2 – "Prefer 23"

- Mode 23 to be used unless wind conditions (as per MOS Part 172) indicate the runway is unavailable, in which case mode 05 will be adopted.
- If mode 05 is in use, the mode will revert to 23 under the following conditions:
  - the use of mode 23 has been allowed for at least 2 hours before the change time; and
  - the use of mode 23 will be allowed for at least 2 hours after the change time.

Strategy 3 – "Prefer 05 with Head-to-Head"

- As per "Prefer 05" except that during the night hours of 10pm and 7am, Head-to-Head mode will be used when:
  - there are no more than a total of 20 aircraft movements in the hour following the relevant time; and
  - wind conditions (as per MOS Part 172) allow the use of both runway directions.
- If mode 05 or mode 23 is in use during the night time period, the mode will revert to Head-to-Head under the following conditions:
  - the use of Head-to-Head has been allowed for at least 2 hours before the change time; and
  - the use of Head-to-Head will be allowed for at least 2 hours after the change time.

Strategy 4 – "Prefer 23 with Head-to-Head"

- As per "Prefer 05 with Head-to-Head" except that when Head-to-Head mode is not in use, the rules of "Prefer 23" apply rather than those of "Prefer 05"

The restriction that Head-to-Head mode can be used only when total movements are less than 20 per hour is based on advice from Airservices Australia.

The 2 hour "waiting period" before changing to a higher-priority mode represents a relatively conservative model of decision making by Air Traffic Control. A more "aggressive" regime would allow the higher-priority mode to be used for longer periods.

2.7.2 Longer Term Development

In assessment year 2063, only modes 05 and 23 are considered. These are illustrated in Figure 2-6. A number of alternative modes would be possible, including "head-to head" and the use of a single runway for arrivals or departures, which may have advantages in terms of noise impact. However, rules for the use of such modes are not expected to be developed until closer to parallel runway operations. Hence, predictions of noise impact for this assessment year should be treated as strategic, and probably conservative.

The "Prefer 05" and "Prefer 23" strategies for this assessment year are defined exactly as described above for the 2030 and 2050 strategies.

Figure 2-6 Longer Term Airport Development – Operating Modes



2.8 Meteorological Data

As described above, the mode of operation of the airport depends primarily on meteorological conditions and also for a given mode, different approach tracks may be assigned depending on whether visual or instrument meteorological conditions apply.

Meteorological data were collated from both the Bureau of Meteorology (BOM) site at Badgerys Creek and the site at Camden Airport for the period 26 August 2010 through 3 March 2015 (approximately 4.5 years). Data from Badgerys Creek gives mean wind speed, maximum wind gust, mean wind direction and rainfall over the 15 minutes before the time of the reading. This allows determination of whether various operating modes are available. Data from Camden Airport includes cloud cover and visibility, and allows determination of whether instrument or visual meteorological conditions apply. (Camden was chosen as the nearest representative site to Badgerys Creek with available data).

Together, these two data sets allow determination of the modes and flight tracks that would have applied for each 15-minute period of the sample period. This can be combined with the synthetic flight schedules for various assessment years to predict numbers of operations by track.

2.9 Calculation of Aircraft Noise Levels

The INM aircraft noise prediction program, produced by the U.S. Federal Aviation Administration, was used to predict noise levels from each of the 22 aircraft types on each of the 346 flight tracks (245 tracks for the initial development and 101 tracks for the longer term development). INM Version 7d was used, as this was the latest available version at the time of performing the calculations.

Parameters used in the calculations are:

- temperature: 20 °C (reasonable and conservative value for most operations at the site);
- atmospheric pressure: 1017.2 hPa (standard, and typical);
- average headwind: 0 kts. This conservative setting was determined based on low average headwinds at the site, meaning that on most occasions, the actual headwind would be determined by the airport's mode priority; and
- topography: 10 m contours covering the area of interest – at least 25 NM to the north, east, south and west of the airport centre.

Predicted noise levels are not very sensitive to any of the above parameters – for example, reducing the temperature to 10 °C, increasing atmospheric pressure to 1030 hPa or increasing the average headwind to 5 kts all result in a change of less than 1 dB in the calculated noise level from typical operations.

The INM model does not allow for calculation of the effect of atmospheric conditions such as wind and temperature inversions on sound propagation. These factors are known to have a strong influence on noise generated at ground level. However, for sources that are significantly elevated, such as an aircraft in flight, their influence on sound propagation is much lower, and has not been as thoroughly studied. In many cases, the major impact of adverse wind and temperature gradient conditions on noise from ground level sources comes through the removal of intervening barriers. This can result in very significant enhancement of noise at the receiver location. However, this effect is obviously not relevant for noise from a source such as an aircraft in flight.

As described in Section 2.3, INM's "standard" height-vs-distance profiles were used for all departures, while a "continuous descent approach" was used for all arrivals. Departures by most aircraft types are defined for several "stage lengths", representing different distances to the destination, and hence different assumed fuel loads. Noise levels on departure were initially calculated for all possible stage lengths for each aircraft type.

For each aircraft type, each track and (for departures) each possible stage length, custom-designed software was used to control INM's operation, calculating noise levels at each point on a grid of size 185 m x 185 m, covering the area of interest. The unit that was calculated is L_{Amax} – the maximum noise level during the overflight in dBA, which is used in calculating N70 and similar units. The results from this calculation form the "library of noise levels" referred to in Figure 2-2.

For N70 and similar units, this library is then interrogated to determine the number of events at each grid point exceeding the relevant L_{Amax} threshold, and the results used to produce contours using standard procedures.

Unlike N70 and similar units, both ANEC and units derived from L_{Aeq} can be calculated directly in INM. These descriptors were calculated in this way, based on the average number of events per day during the relevant time periods, calculated as described above.

2.10 Sensitive Receivers and Noise Exposure Calculation

Noise-sensitive receivers in the area around the proposed airport include residences, schools and other educational facilities, and hospitals and other health care facilities. In this report, the potential impact of the proposal on these receivers is assessed in terms of a number of descriptors of noise exposure, as set out in Section 2.1. One indicator of impact is the number of receivers experiencing a given level of noise exposure, measured by the various descriptors.

Existing and forecast population estimates were developed by GHD, based on the September 2014 release of the NSW Bureau of Transport Statistics population forecasts. These forecasts take into account metropolitan planning development forecasts for future land use in Sydney as well as NSW Department of Planning and Environment population forecasts. The limit of these forecasts is currently 2041; therefore, in order to project to 2063 and beyond, Series B population growth rates estimates used by the Australian Bureau of Statistics in their long-term population forecasts were applied.

The forecast of existing and future populations potentially exposed to different levels of noise from the proposed airport utilised GIS databases and was developed by GHD. The databases were developed based on the above population forecasts and address point data provided by NSW Land and Property Information.

The address point dataset provided a set of co-ordinates for each registered address point within the area covered by the data and was therefore used to represent the spatial distribution of population. The address point data was then divided into subareas based on statistical local area (SLA) boundaries developed for the Census. By matching the population estimates and address points to a common SLA, a population per SLA and average population per address point was calculated.

The noise contours generated by this study were then overlaid with the address point population for each forecast year enabling a count of future population potentially affected by each airport operational scenario.

2.11 Sources of Key Information

Table 2-6 summarises the sources of all key data discussed above and used in the calculation of noise descriptors for this report.

Table 2-6 Sources of Key Information Used

Information	Source
Forecast future annual aircraft movements and synthetic flight schedule	LEK
Current aircraft types used to represent future types	LEK
Selection of representative INM aircraft types	Wilkinson Murray
Indicative aircraft flight tracks	Airservices Australia
Rules for availability of runways by meteorology	Airservices Australia
Maximum possible movements in “Head-to-Head” mode	Airservices Australia
Historical meteorological records at Badgerys Creek and Camden Airport	Bureau of Meteorology (BoM)
Allocation of operations on a runway to flight tracks	Wilkinson Murray in consultation with Airservices Australia
Co-ordinates of runway ends and runway thresholds	Landrum and Brown/GHD
Heights of runway ends	Landrum and Brown/GHD
Meteorological conditions used in noise modelling	Wilkinson Murray, based on BoM data
Population exposure forecasts	GHD

3 ASSESSMENT OF INITIAL AIRPORT DEVELOPMENT

3.1 Development Overview

The initial stage (Stage 1) of the proposed Western Sydney Airport project would involve construction and operation of a single runway, approximately 3700 m long and additional landside and airside infrastructure sufficient to facilitate air travel by approximately 10 million passengers per annum. The airport is proposed to operate without a curfew, and projected air traffic volumes include operations throughout the night. An important component of the initial stage noise impact assessment is the acknowledgement that demand for air travel will grow over time following opening of the airport.

The assessment of the initial airport development is the key focus of this report as it is the location which has been referred under the EPBC Act. Subsequent stages of airport development would be subject to their own separate approvals processes as required by the relevant legislation.

3.2 Single-Event Noise Contours

Single-event noise contours indicate the maximum (L_{Amax}) noise level resulting from a single operation of a specific aircraft type on a specific flight track. In this section, composite single-event contours are shown indicating the outer envelope of L_{Amax} noise level contours for a specific aircraft operation on all possible tracks.

In the INM modelling program, departures are defined for several 'stage lengths', representing different distances to the destination, and hence different assumed fuel loads. Noise levels on departure can be calculated for various stage lengths for each aircraft type. Table 3-1 presents the various INM departure stage lengths.

Table 3-1 INM Aircraft Departure Stage Lengths – Nautical Miles

Stage Length	From	To
1	0	500
2	501	1000
3	1001	1500
4	1501	2500
5	2501	3500
6	3501	4500
7	4501	5500
8	5501	6500
9	over 6500	

Figure 3-1 shows single-event L_{Amax} noise level contours for the loudest noise event predicted to occur at the airport under this scenario – a 747 departure with INM stage length 5, corresponding to a departure for Singapore. According to the nominal schedule, these events would occur once per day. They may occur on any of a number of tracks. However, note that although contours are shown for these events on tracks heading south from the airport, it is very unlikely that a Stage 5 departure would occur on these tracks as there are no destinations for which this would be a preferred departure direction. Figure 3-1 is in a scale so that all contours in this report can be easily compared. Figure 3-2 shows the same contours in a larger scale and it is clear from these contours that the noise of the aircraft whilst on the runway is included.

At the most-affected residences, close to the airport, L_{Amax} noise levels from these events would be in the range 80 – 90 dBA. There are less than 10 existing residences within the 85 dBA L_{Amax} contour for these events, located to the south-west of the airport.

When these events occur on the track leading north in the 05 direction, L_{Amax} noise levels exceeding 70 dBA can be expected over densely-populated areas around St Marys, with levels above 75 dBA in some parts of Erskine Park.

Figure 3-3 and Figure 3-4 show L_{Amax} noise levels from a 747 arrival on any track. In this case, noise levels of 60 – 70 dBA can be expected over sections of Erskine Park and St Marys, extending to parts of Blacktown. Noise levels from this event also reach 60 dBA at Blaxland, beneath the “merge point” for arrivals. In 2030, there are expected to be five such arrivals per day.
Figure 3-4 exhibits the characteristic contour bulge around the runway as a result of reverse thrust.

Figure 3-5 to Figure 3-10 show L_{Amax} noise levels from much more common events – departures (Stage 4 and Stage 1) and arrivals by A320 and similar aircraft types. Stage 3 or 4 departures by A320 aircraft (on any track) are predicted to occur 12 times per day in 2030. When these events occur to the north in the 05 direction, maximum noise levels in parts of St Marys would be up to 64 dBA. For Stage 1 or 2 departures (for example, to Brisbane or Melbourne), the maximum noise level over built-up areas is not predicted to exceed 60 dBA.

Arrivals by A320 aircraft, when they occur in the 23 direction, are predicted to produce L_{Amax} noise levels exceeding 60 dBA over areas between Erskine Park, St Marys and Blacktown, and also (when they occur in the 05 direction) over areas in the Blue Mountains National Park and GBMWHA.

Figure 3-1 Combined Single Event B747 Departure – Stage 5 (Macro Scale)

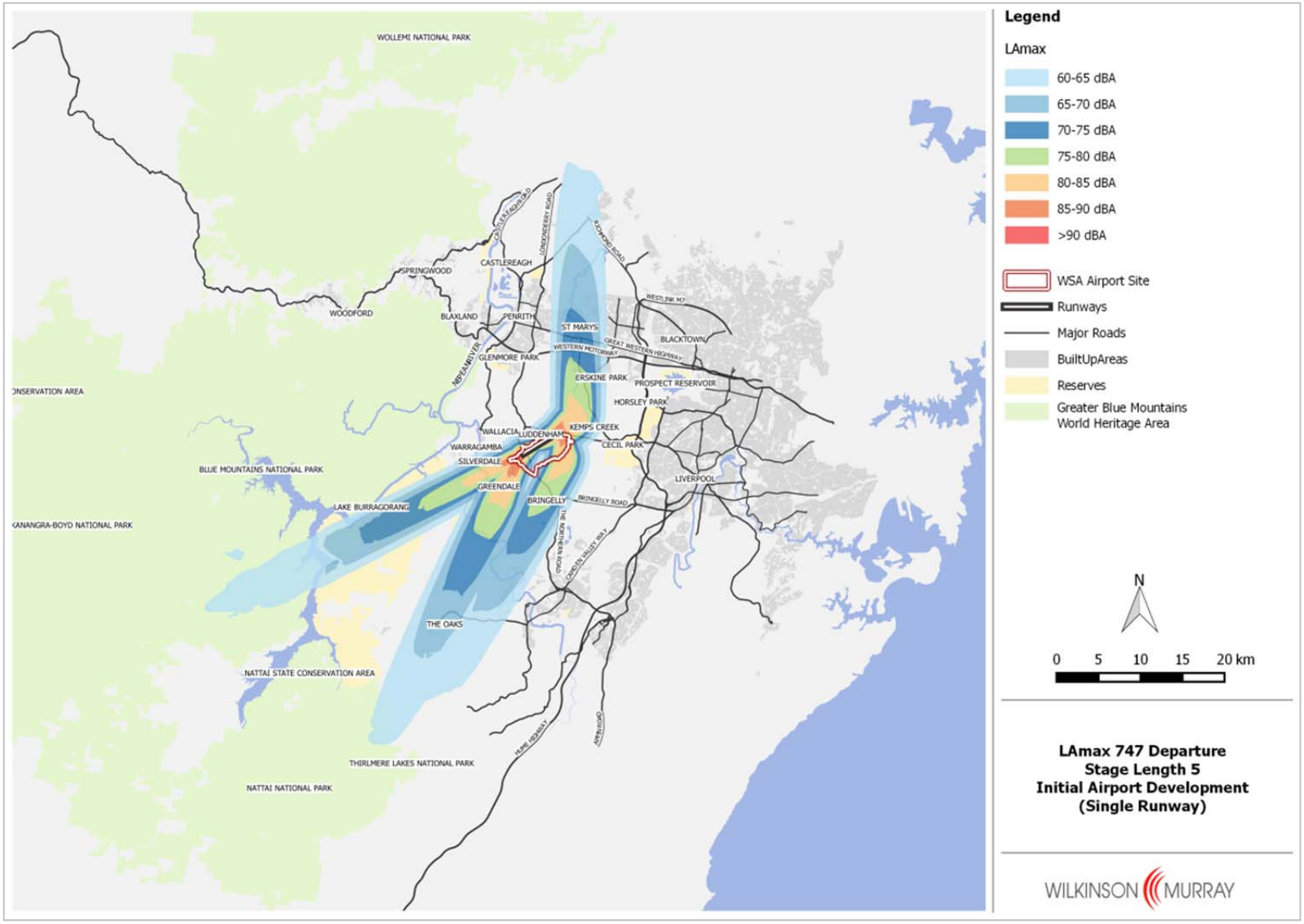


Figure 3-2 Combined Single Event B747 Departure – Stage 5 (Meso Scale)

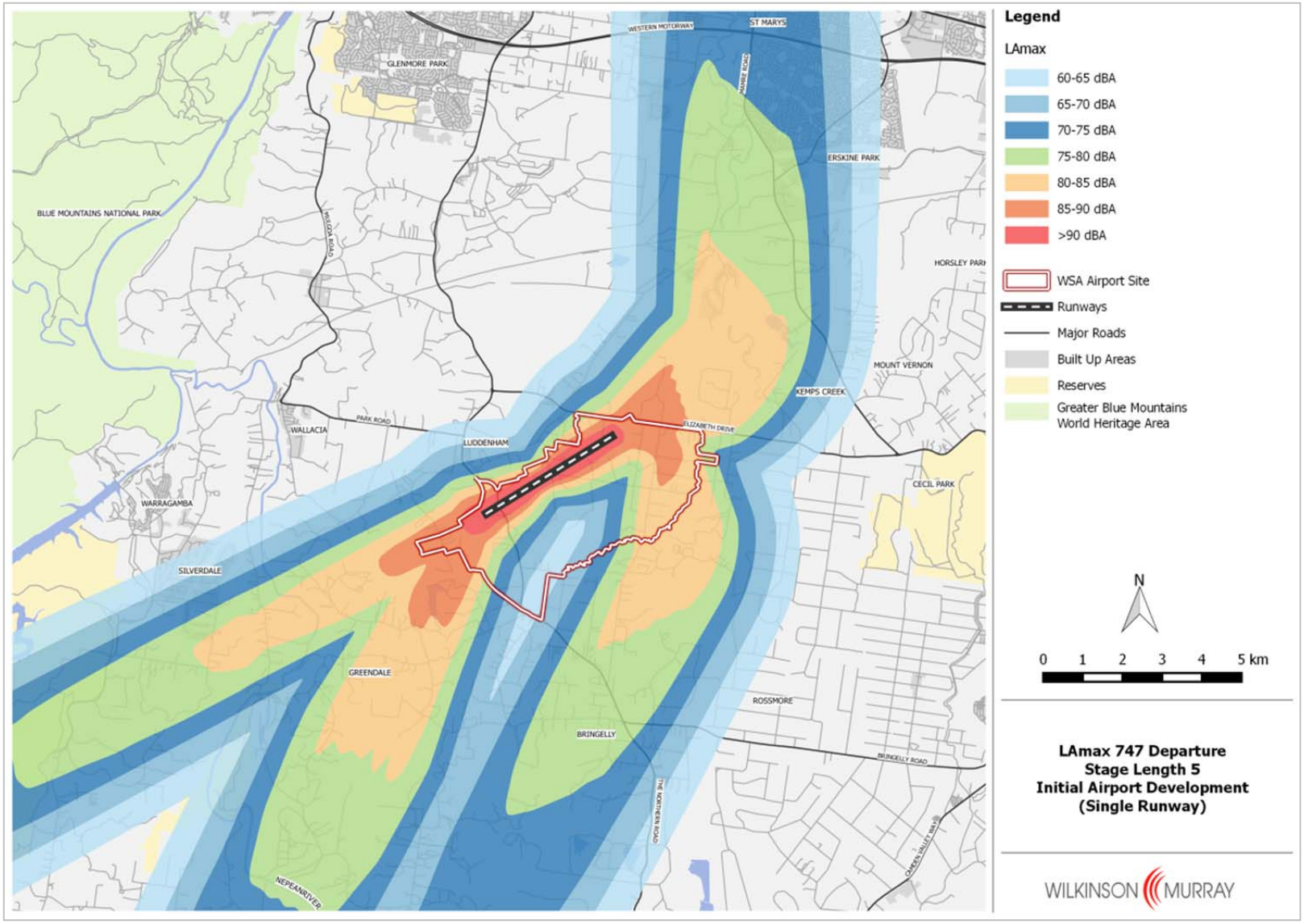


Figure 3-3 Combined Single Event B747 Arrival (Macro Scale)

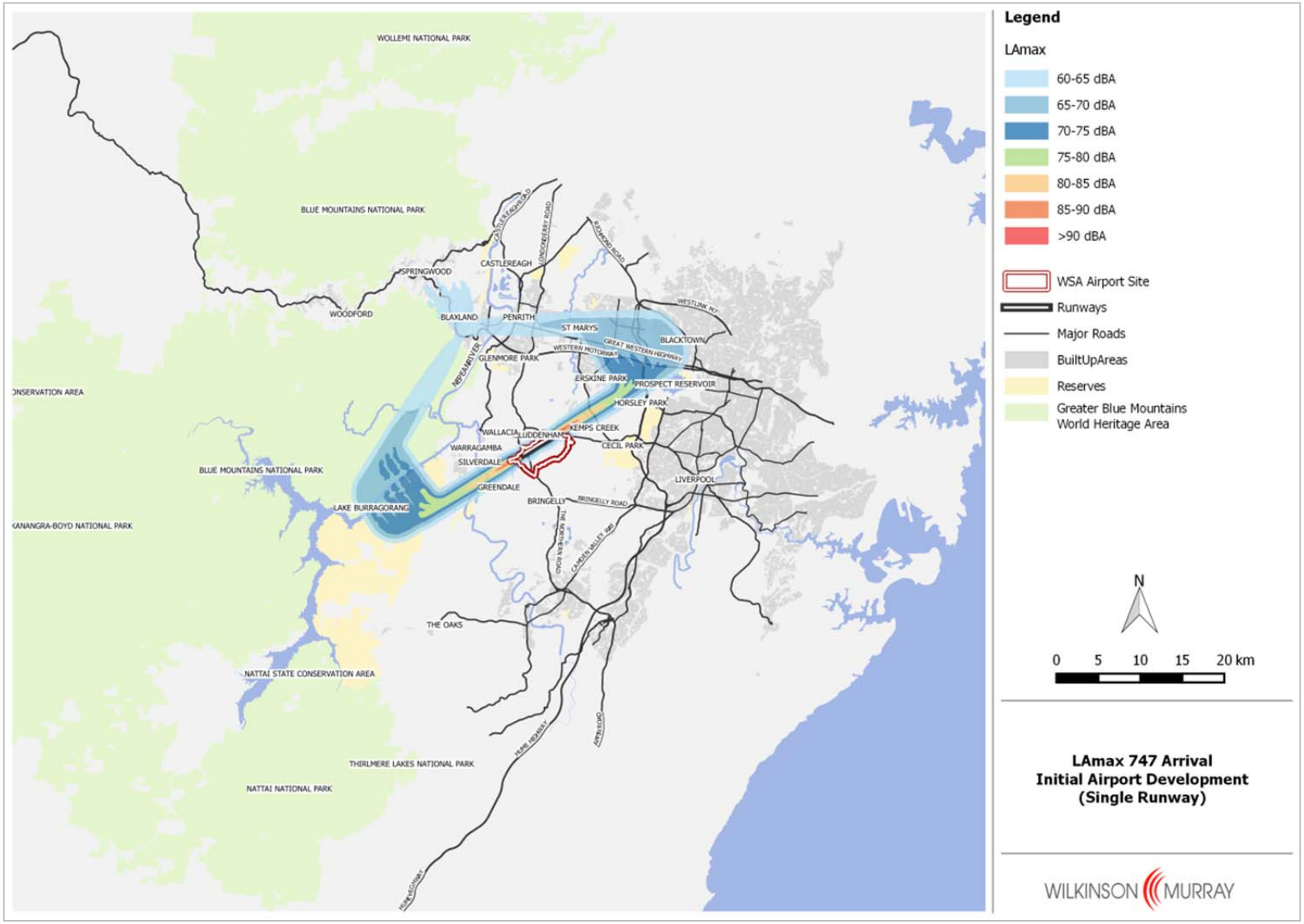


Figure 3-4 Combined Single Event B747 Arrival (Meso Scale)

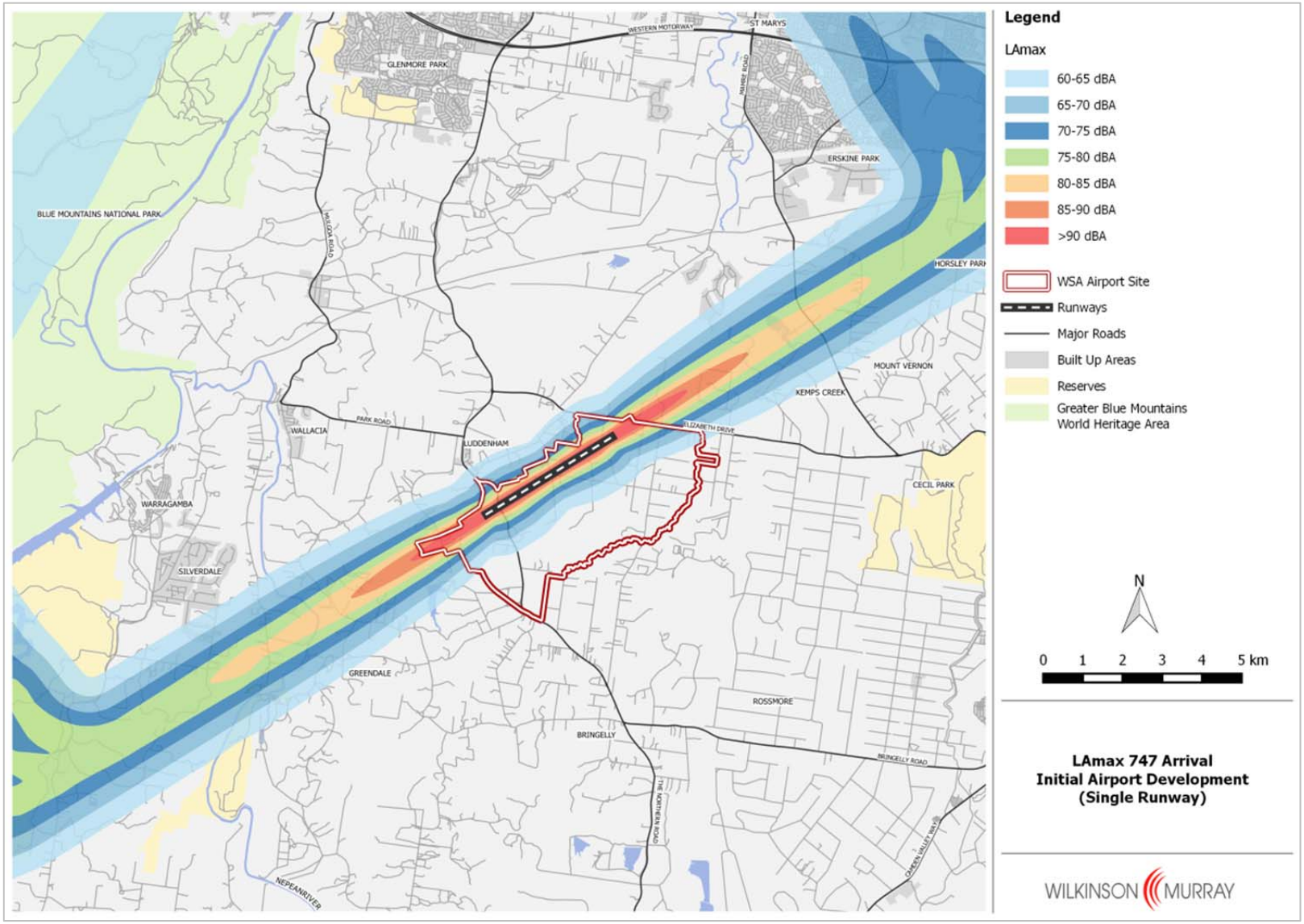


Figure 3-5 Combined Single Event A320 Departure – Stage 4 (Macro Scale)

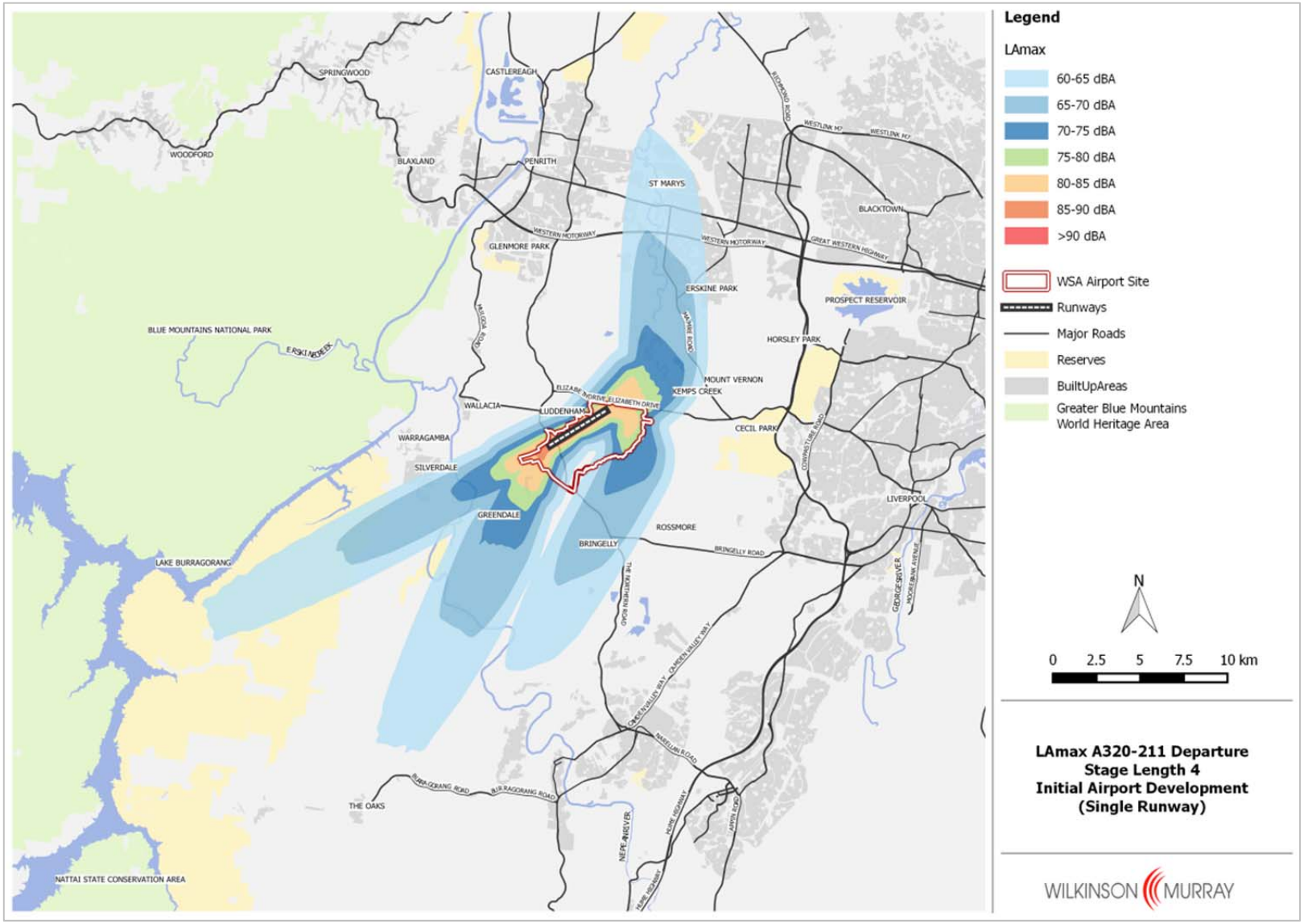


Figure 3-6 Combined Single Event A320 Departure – Stage 4 (Meso Scale)

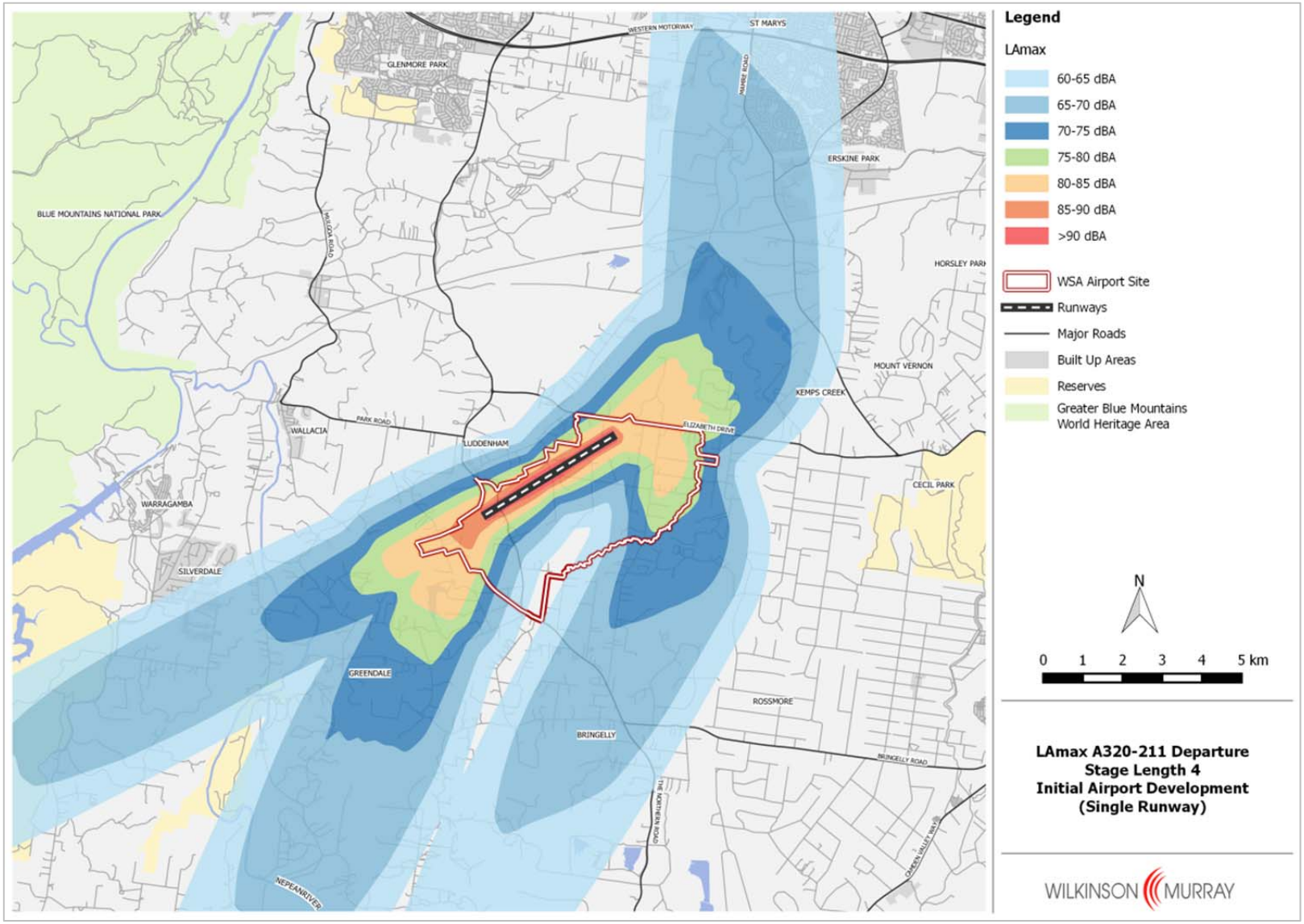


Figure 3-7 Combined Single Event A320 Departure – Stage 1 (Macro Scale)

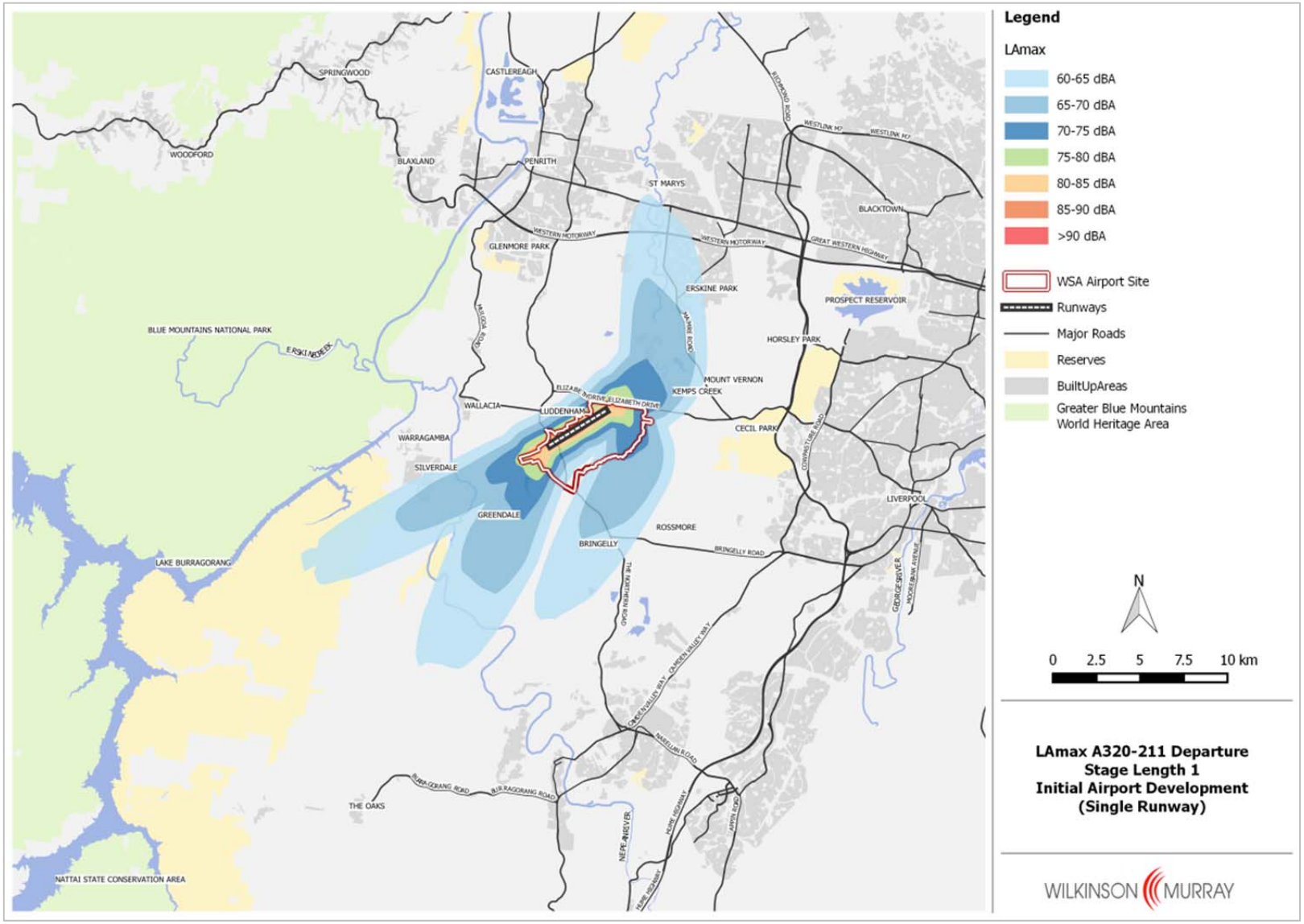


Figure 3-8 Combined Single Event A320 Departure – Stage 1 (Meso Scale)

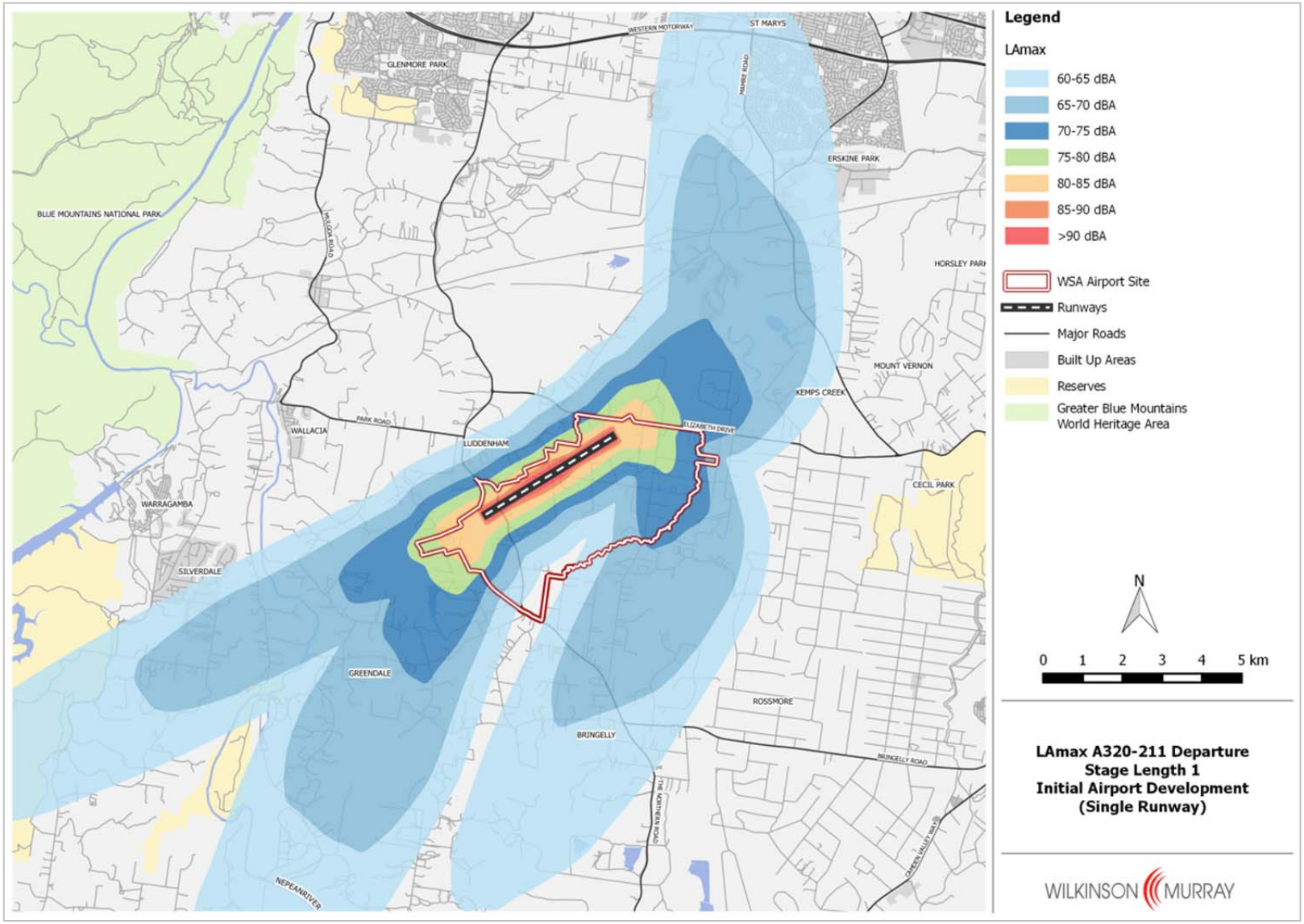


Figure 3-9 Combined Single Event A320 Arrival (Macro Scale)

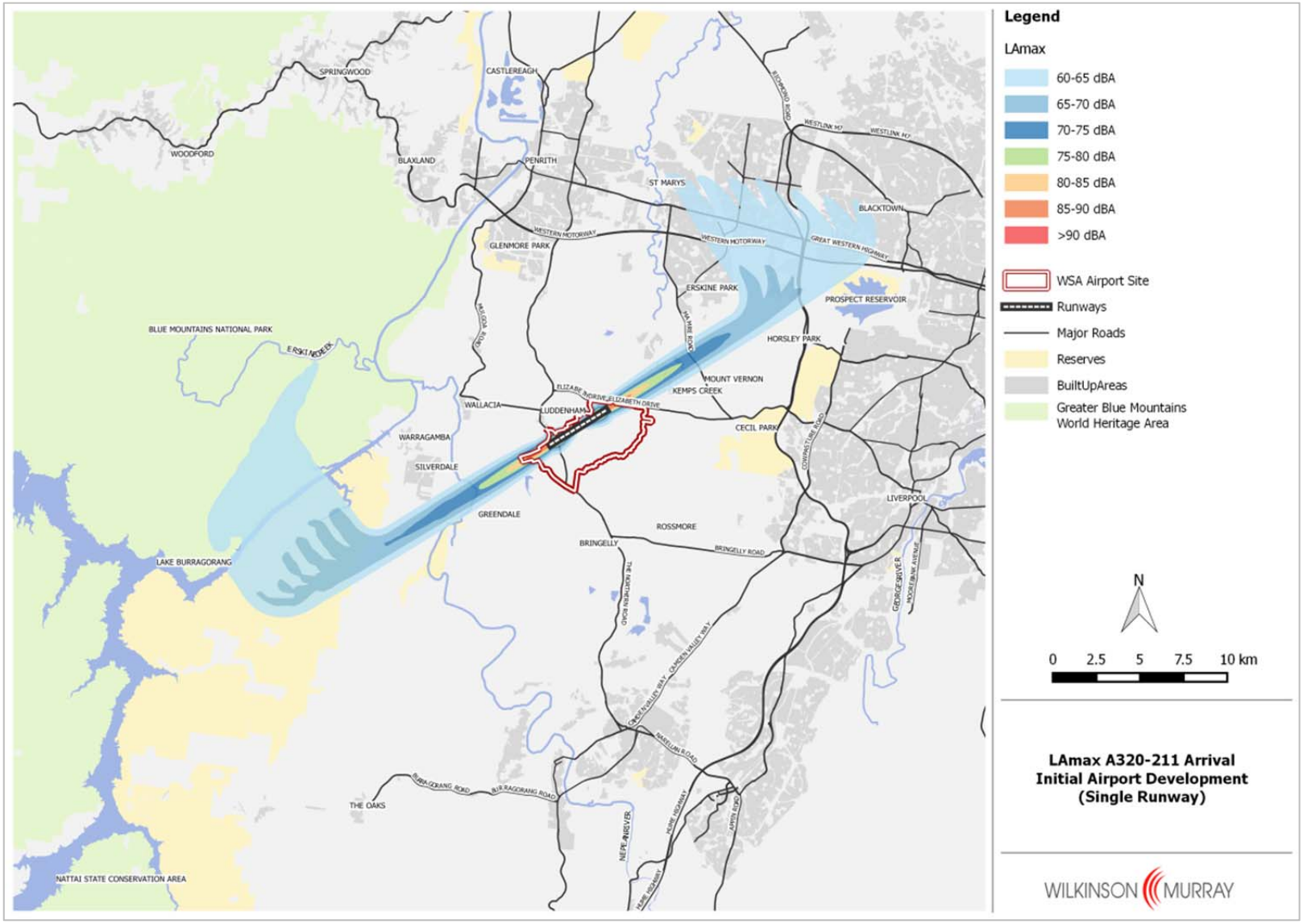
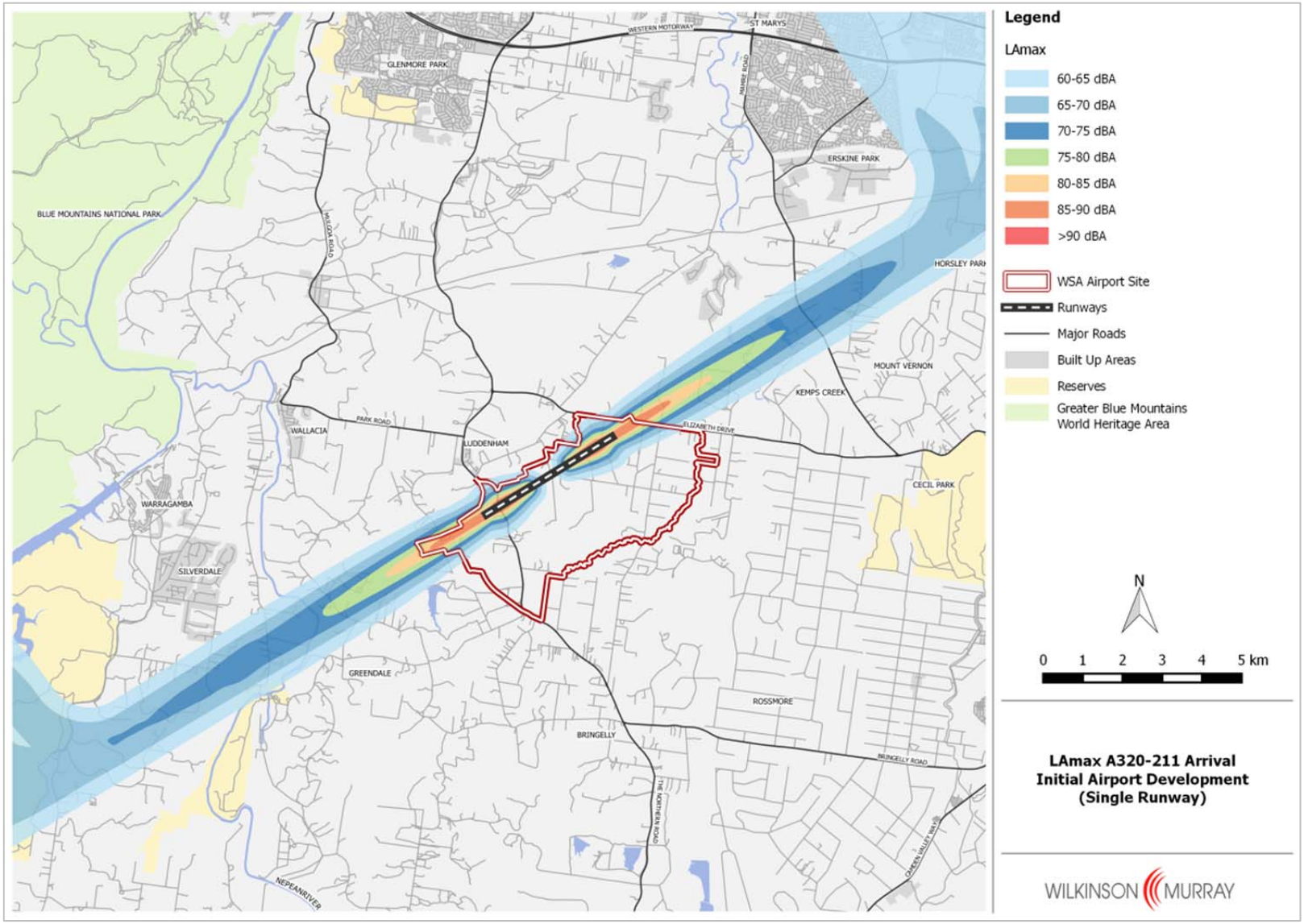


Figure 3-10 Combined Single Event A320 Arrival (Meso Scale)



3.3 Summer and Winter Operations

For noise metrics that respond to the number of noise events, including N70 and N60, there will potentially be a difference between values in the summer and winter periods due to differing meteorological conditions (wind strength and direction, visibility etc). This difference was investigated, and Appendix C shows N70 and N60 contours for summer, winter and annual movements for different assessment years.

However, as seen in Appendix C, differences between results for different seasons are relatively minor, and do not influence the overall noise assessment to any significant extent. For this reason, noise level contours shown in the body of this report are all based on annual values of the relevant noise descriptor.

It should be noted that ANEC contours are defined to represent annual average noise levels (except under special circumstances that do not apply here) and hence in this case, comparison between seasons is not relevant.

3.4 Noise Levels Over 24 Hours

3.4.1 N70 Results

Aircraft noise impact over a full day can be described by the number of noise events exceeding 70 dBA, or N70. Calculated N70 noise contours for each of the four airport operating strategies described in Section 2.7.1, and for nominal year 2030, are presented in Figure 3-11 to Figure 3-14. These represent the predicted annual average number of movements per day with L_{Amax} noise levels exceeding 70 dBA. While N70 charts typically show numbers of events down to 10 events per day, this report shows N70 contours down to 5 events per day, to allow lower level impacts to be better understood.

The analysis shows that there are differences between noise impacts from different airport operating strategies. In particular, the Prefer 05 strategy results in greater impact on residents to the north-east of the airport. However, in 2030 no densely-populated residential areas are predicted to experience more than five events per day above 70 dBA. In addition, only very limited areas within the Blue Mountains National Park and GBMWHA are predicted to experience this level of noise impact.

Inclusion of a “Head-to-Head” mode at night makes an almost imperceptible difference to overall N70 values. This is because night time operations are only a small fraction of total operations. The importance of this mode will be seen below in results that focus only on night time noise.

Figure 3-11 N70 Contours – 2030 – Prefer 05

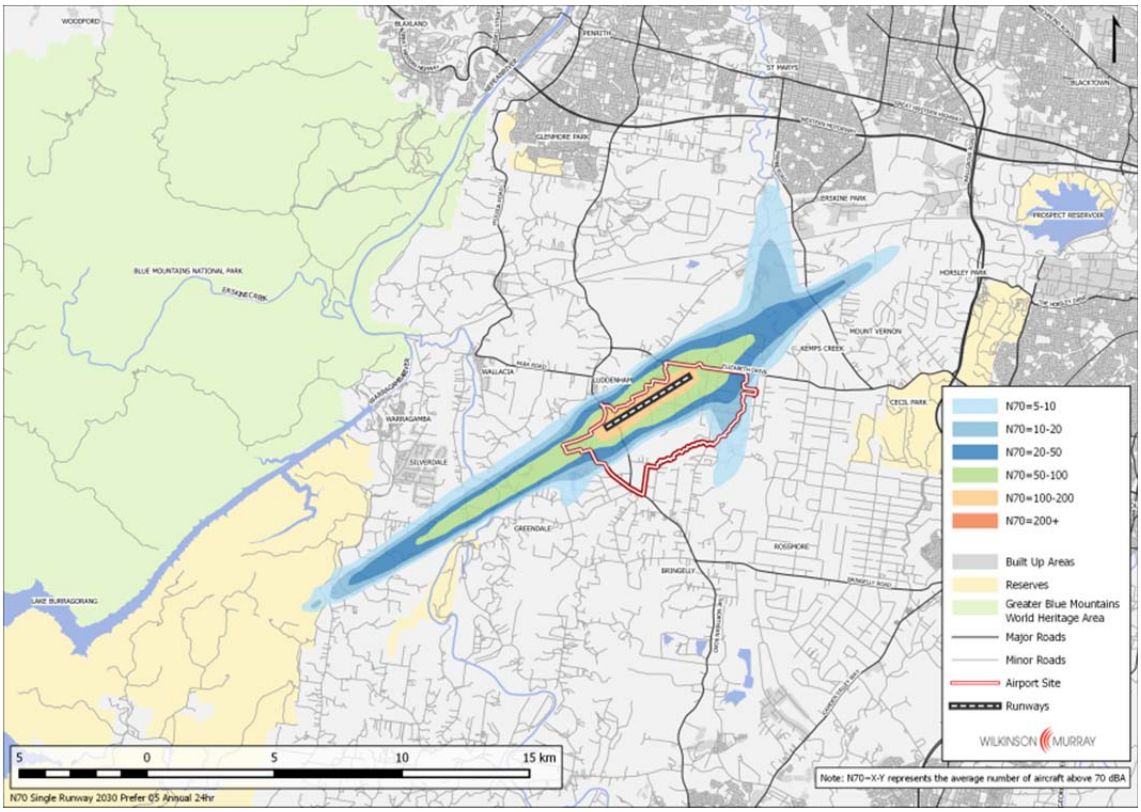


Figure 3-12 N70 Contours – 2030 – Prefer 23

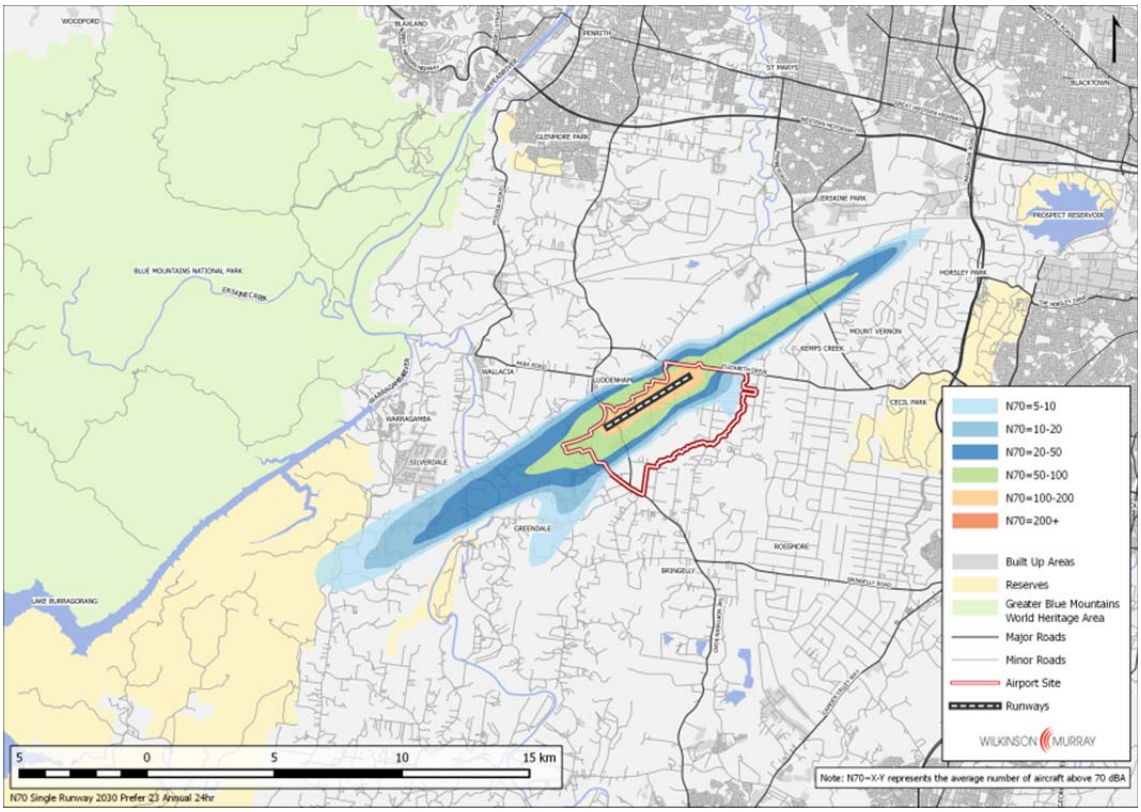


Figure 3-13 N70 Contours – 2030 – Prefer 05 with Head-to-Head

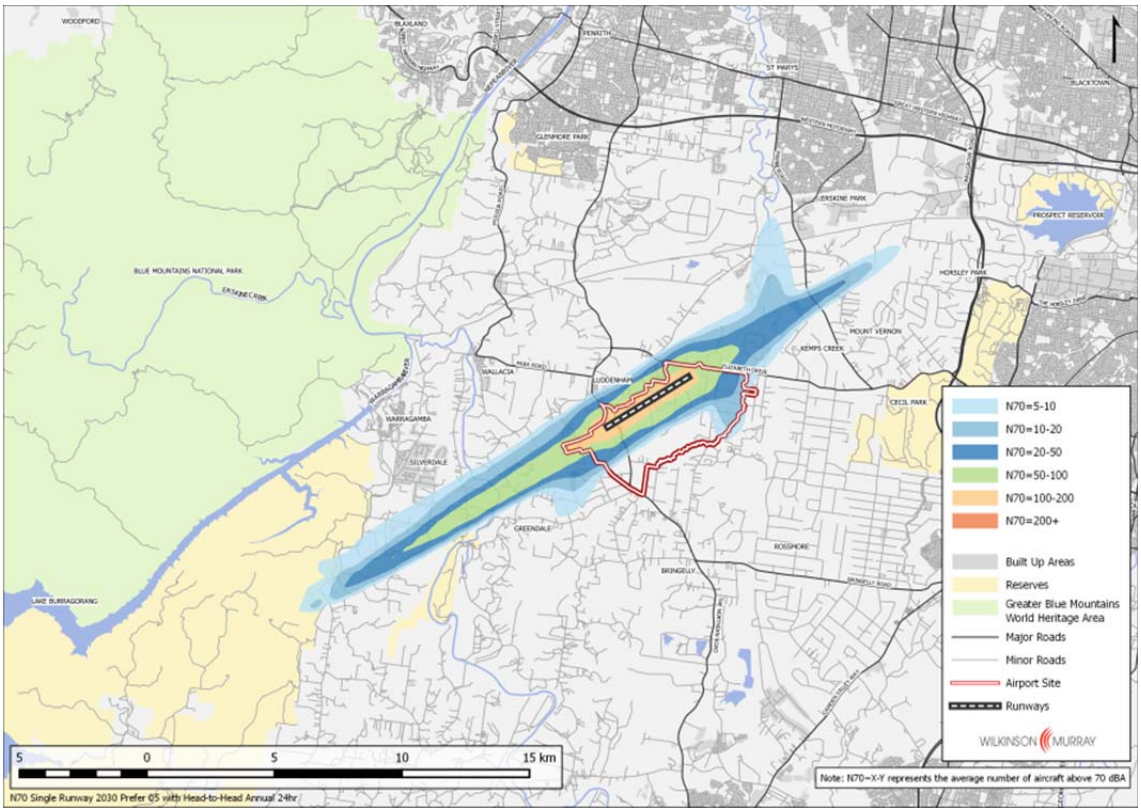
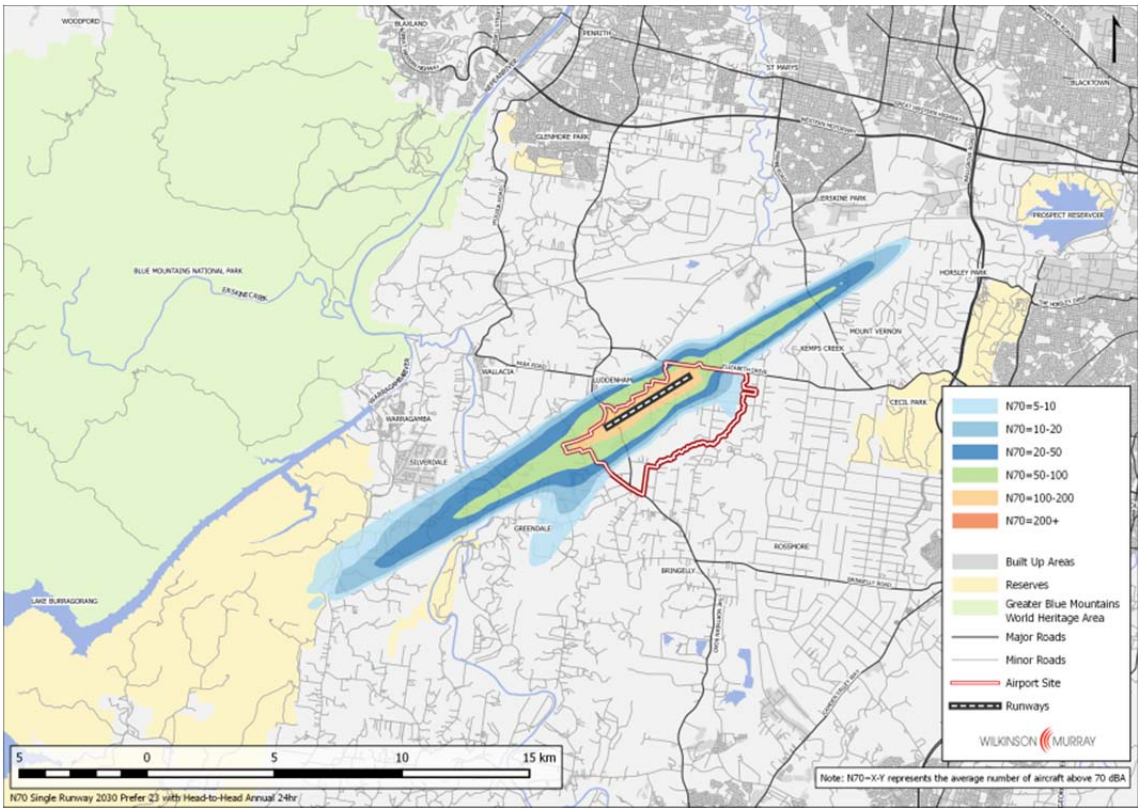


Figure 3-14 N70 Contours – 2030 – Prefer 23 with Head-to-Head



3.4.2 90th Percentile N70 Results

Figure 3-15 and Figure 3-16 show 90th percentile values of N70 calculated over all days – that is, the number of daily aircraft noise events over 70 dBA that would be exceeded on only 10% of days. This can be thought of as a "typical worst-case" day. Values are shown for 2030, Prefer 05 and Prefer 23. (Head-to-Head strategies are not shown as this mode makes very little difference to the results.) The figures also show the "average day" N70 values as depicted in the figures above.

The most noticeable feature of these figures is that generally, the difference between predicted noise impact on "average" and "typical worst-case" days is not large. This is due to the relatively low and consistent wind speeds at the site, which mean that the airport's "preferred" mode of operation can be selected over 80% of the time.

Figure 3-15 Mean & 90th Percentile N70 Contours – 2030 – Prefer 05

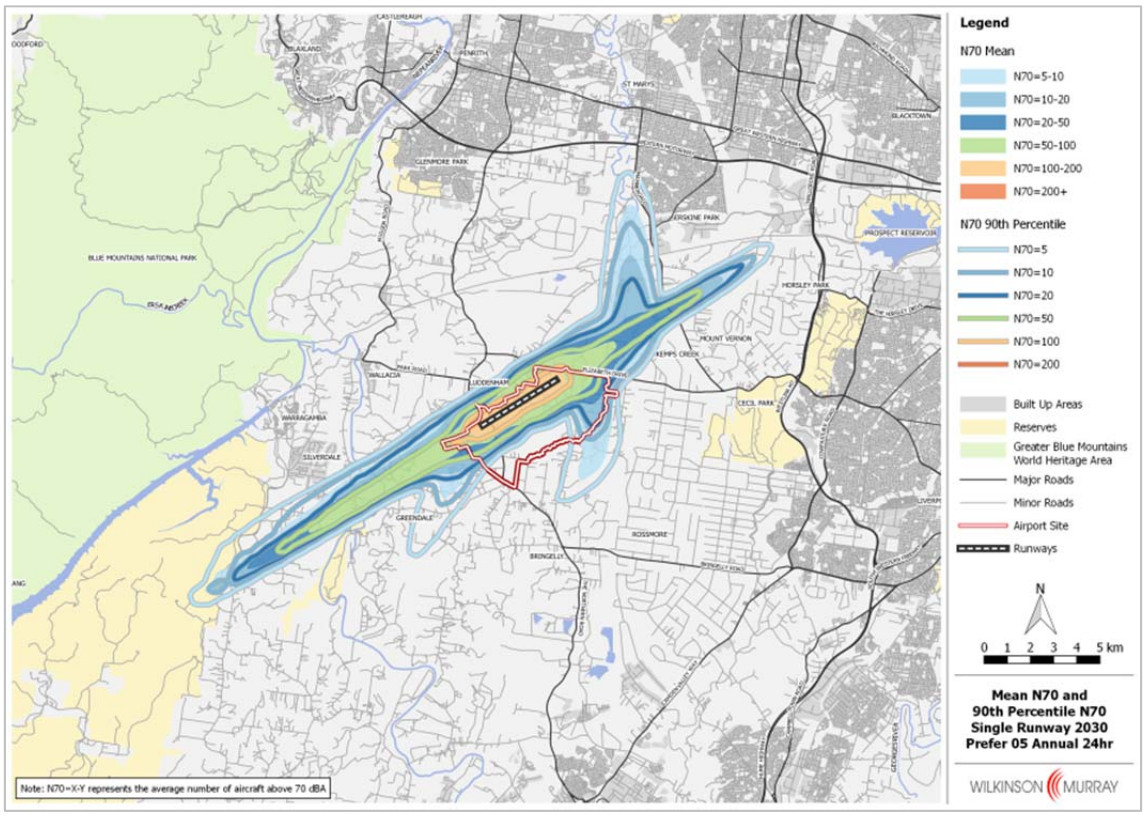
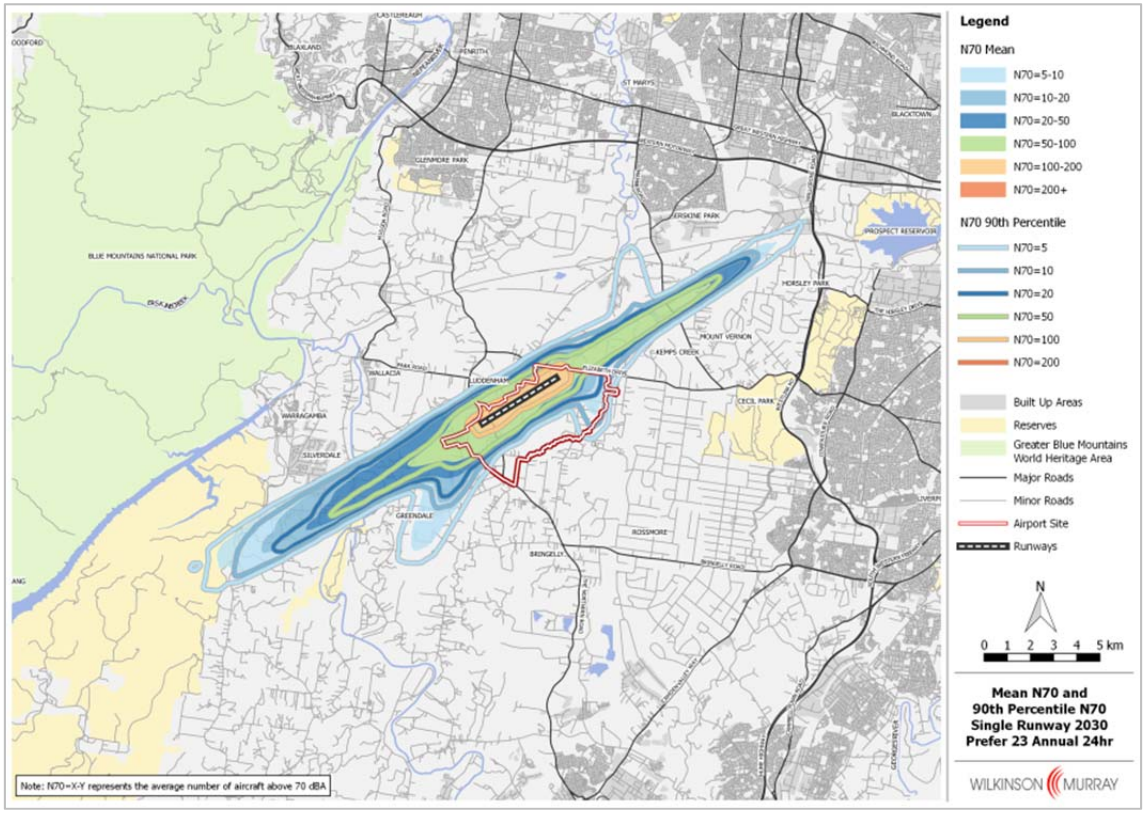


Figure 3-16 Mean & 90th Percentile N70 Contours – 2030 – Prefer 23



3.4.3 Population Exposure Estimates

The future population experiencing various levels of daytime noise impact has been estimated using procedures described in Section 2.9. Results for an "annual average day" are shown in Table 3-2.

Table 3-2 Estimated Population within N70 Contours – 2030

N70	Operating Strategy			
	Prefer 05	Prefer 23	Prefer 05 + H_2H*	Prefer 23 + H_2H*
5-10	563	399	852	405
10-20	581	450	326	439
20-50	192	426	258	431
50-100	152	192	167	178
100-200	5	0	10	10
>200	0	0	0	0
Total	***1,493***	***1,467***	***1,613***	***1,463***

Note: * H2H = "Head-to-Head"
Population figures in this table are estimates only and are valid for comparisons between modes

In assessment year 2030, the number of people predicted to experience five or more aircraft noise events per day above 70 dBA would be roughly 1,500 – 1,600. This outcome depends very little on the operating strategy adopted. The Prefer 23 operating strategy results in fewer people being affected at lower noise levels (generally to the north of the airport), but this is offset by more people being affected at higher noise levels – generally in rural residential areas to the south and west of the airport.

3.5 Night Time Noise

3.5.1 N60 Results

The number of noise events exceeding 60 dBA is often used to describe the impact of noise at night. In this report, predicted N60 values are shown for the standard night time period 10pm-7am. Figure 3-17 to Figure 3-20 show these values for the four operating strategies considered, for assessment year 2030. Calculations are shown down to a value of five events per night.

The difference between Prefer 05 and Prefer 23 strategies is significant, with Prefer 05 having greater impact on built-up areas around St Marys while Prefer 23 has a greater impact on rural residential areas around Greendale. In 2030, with Prefer 05, large areas with significant population density are predicted to experience more than five noise events per night exceeding 60 dBA. With Prefer 23, this level of impact would be experienced only in rural residential areas and a small area to the south of Blacktown.

This night time noise impact can be mitigated by use of the "Head-to-Head" mode where

available. As demonstrated in Figure 3-19 and Figure 3-20, this results in no built-up residential areas being exposed to more than five events per night above 60 dBA.

It is notable that in 2030, the impact for “Prefer 05 with Head-to-Head” is exactly the same as for “Prefer 23 with Head-to-Head”. This is because in 2030, Head-to-Head mode can be used throughout the night, unless wind conditions dictate otherwise, because the number of operations per hour never exceeds 20. If wind conditions dictate that “Head-to-Head” cannot be used, then the mode used would be determined based on wind direction, and would not depend on whether 05 or 23 is preferred.

Figure 3-17 N60 Contours – 2030 – Prefer 05

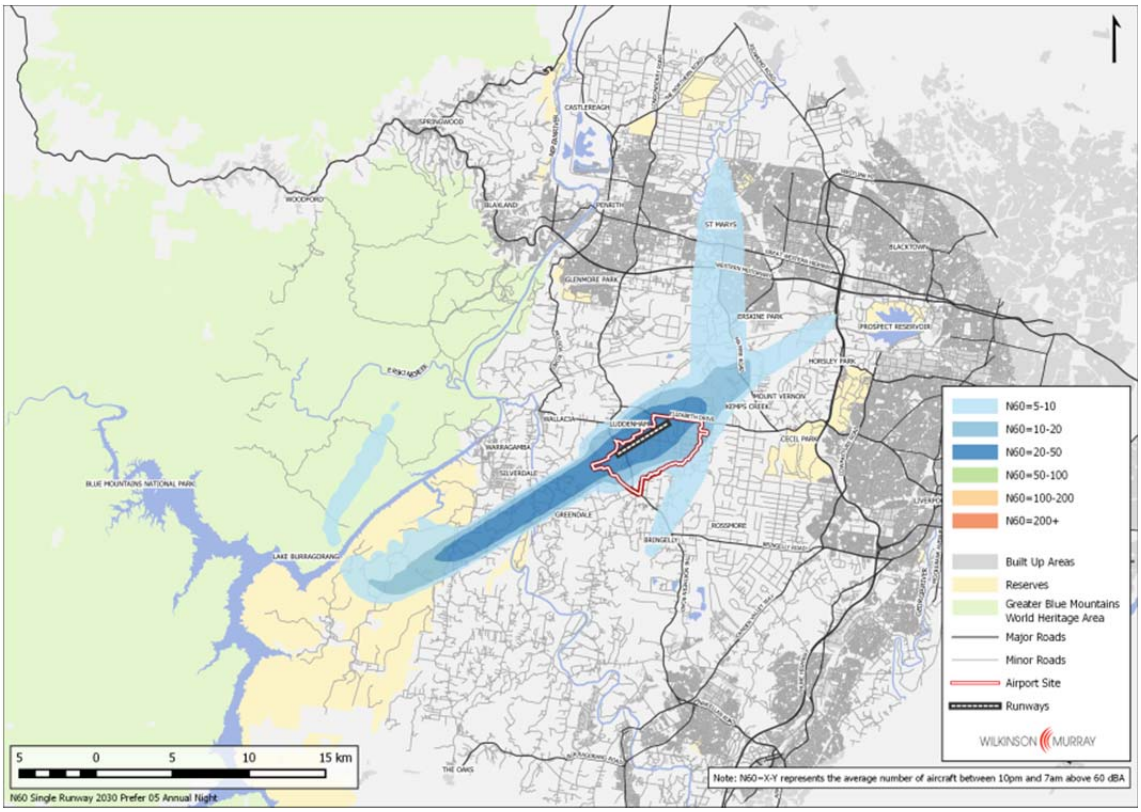


Figure 3-18 N60 Contours – 2030 – Prefer 23

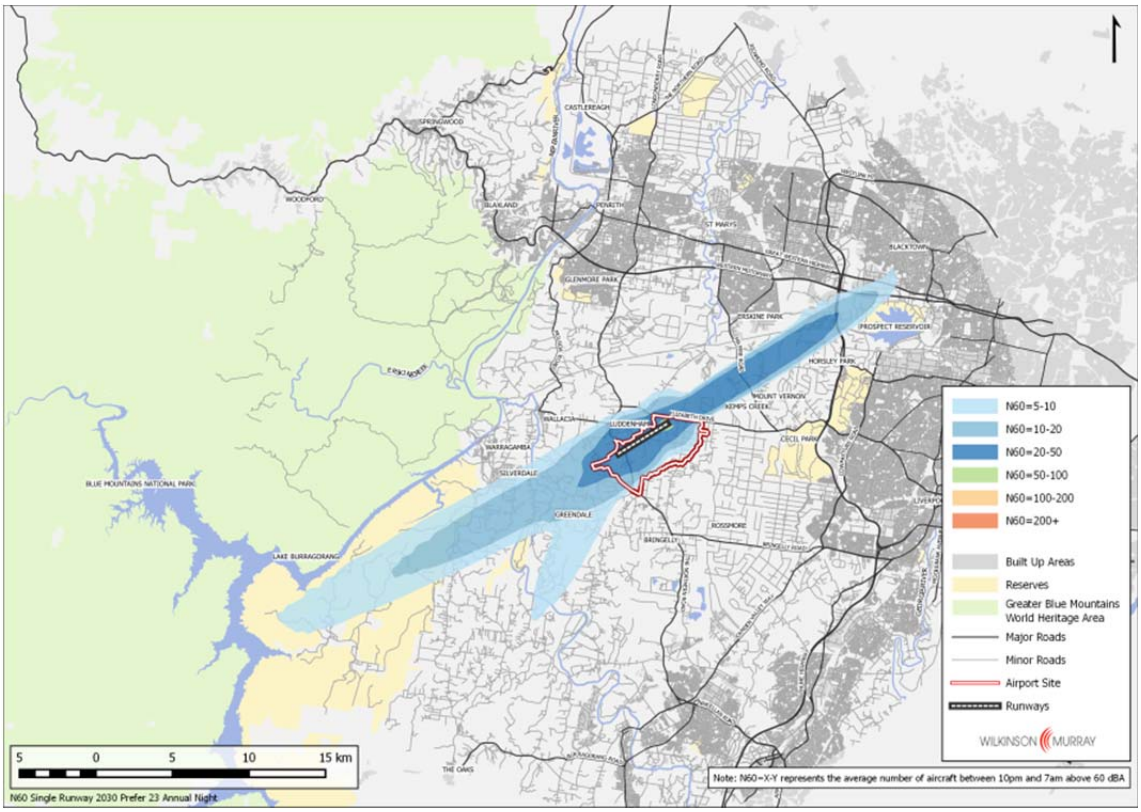


Figure 3-19 N60 Contours – 2030 – Prefer 05 with Head-to-Head

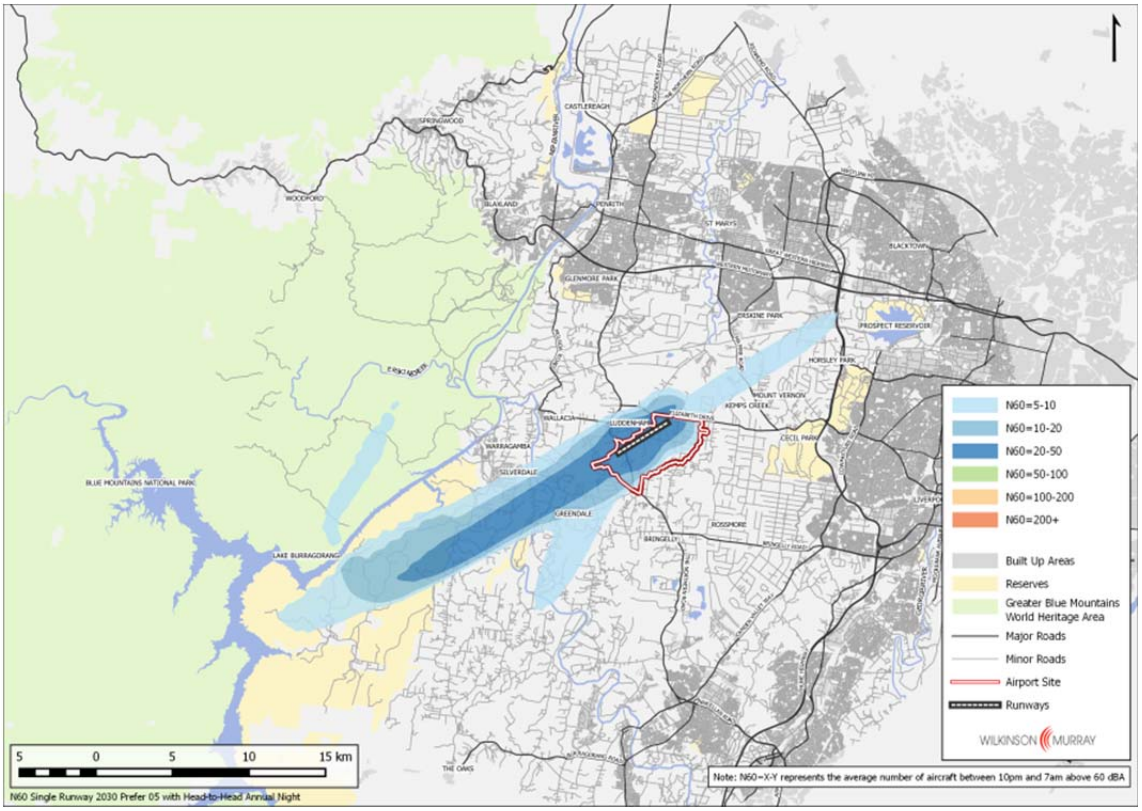
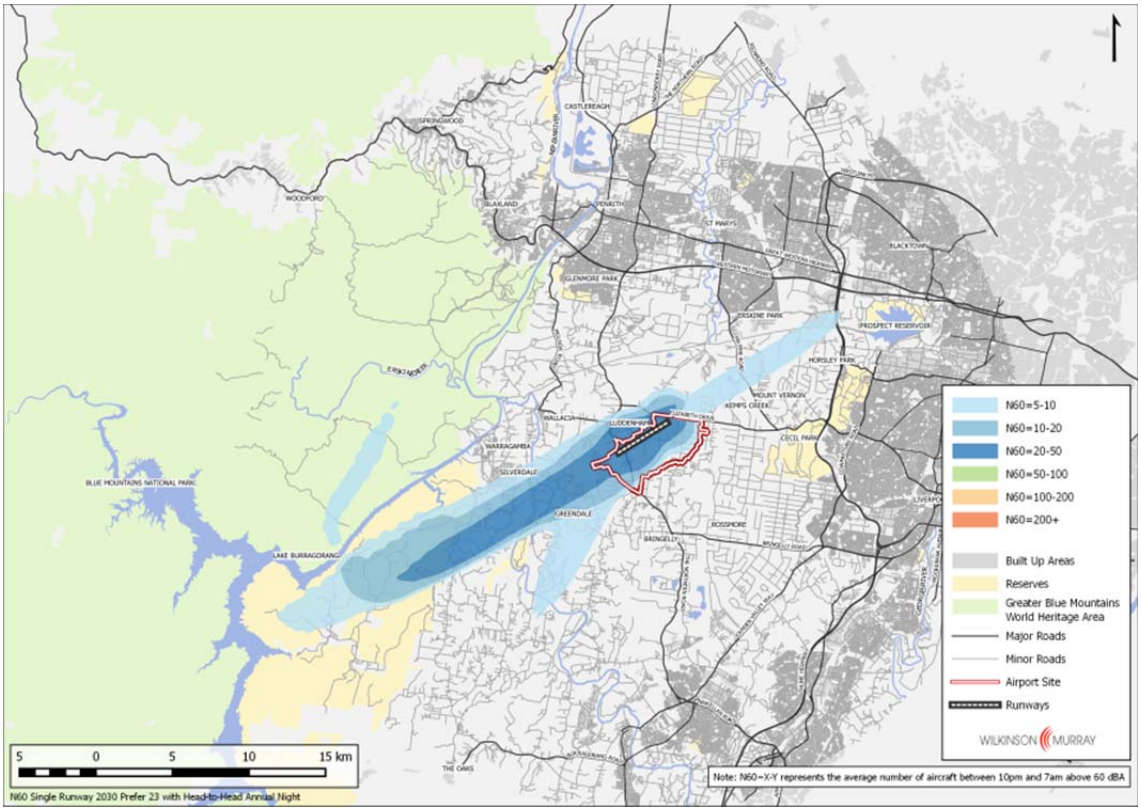


Figure 3-20 N60 Contours – 2030 – Prefer 23 with Head-to-Head



3.5.2 90th Percentile N60 Results

As for N70 values, 90th percentile night time N60 values give an indication of the number of events per night exceeding 60 dBA on a "typical worst-case" night. These are shown in Figure 3-21 to Figure 3-24.

Once again, differences between "average" and "typical worst-case" days are generally not large.

Figure 3-21 Mean & 90th Percentile N60 Contours – 2030 – Prefer 05

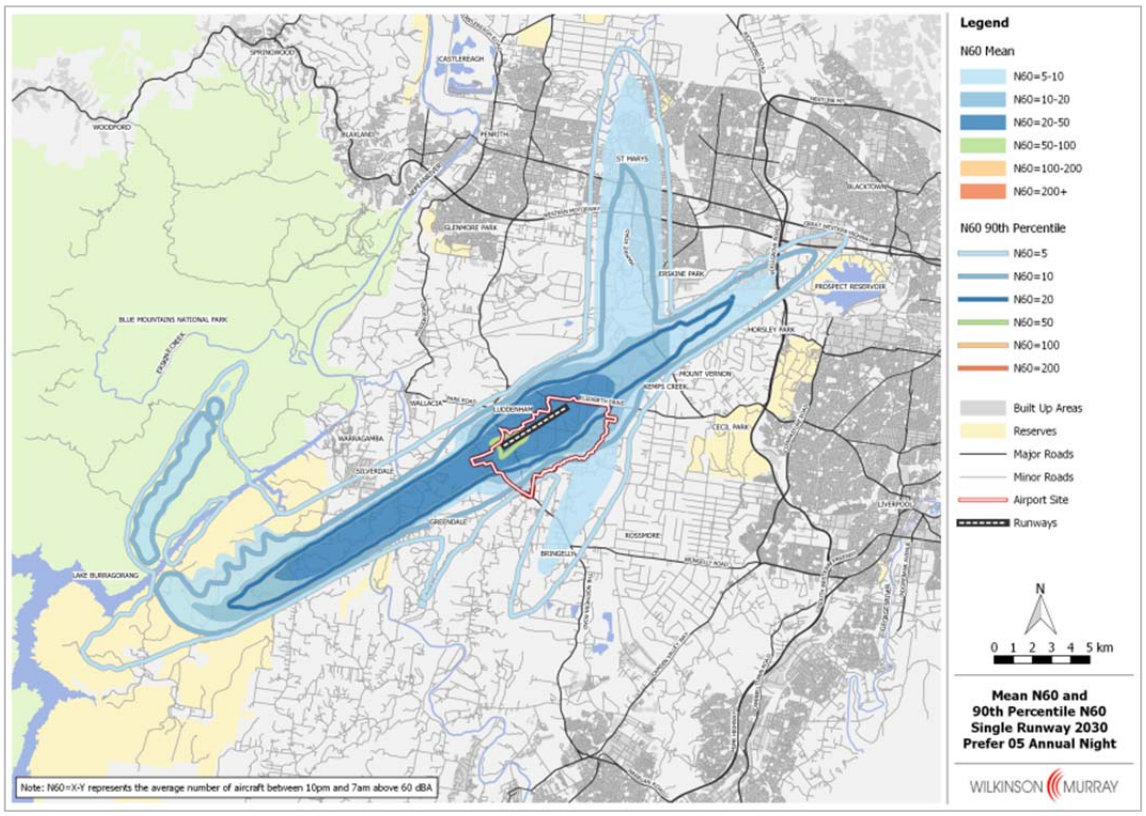


Figure 3-22 Mean & 90th Percentile N60 Contours – 2030 – Prefer 23

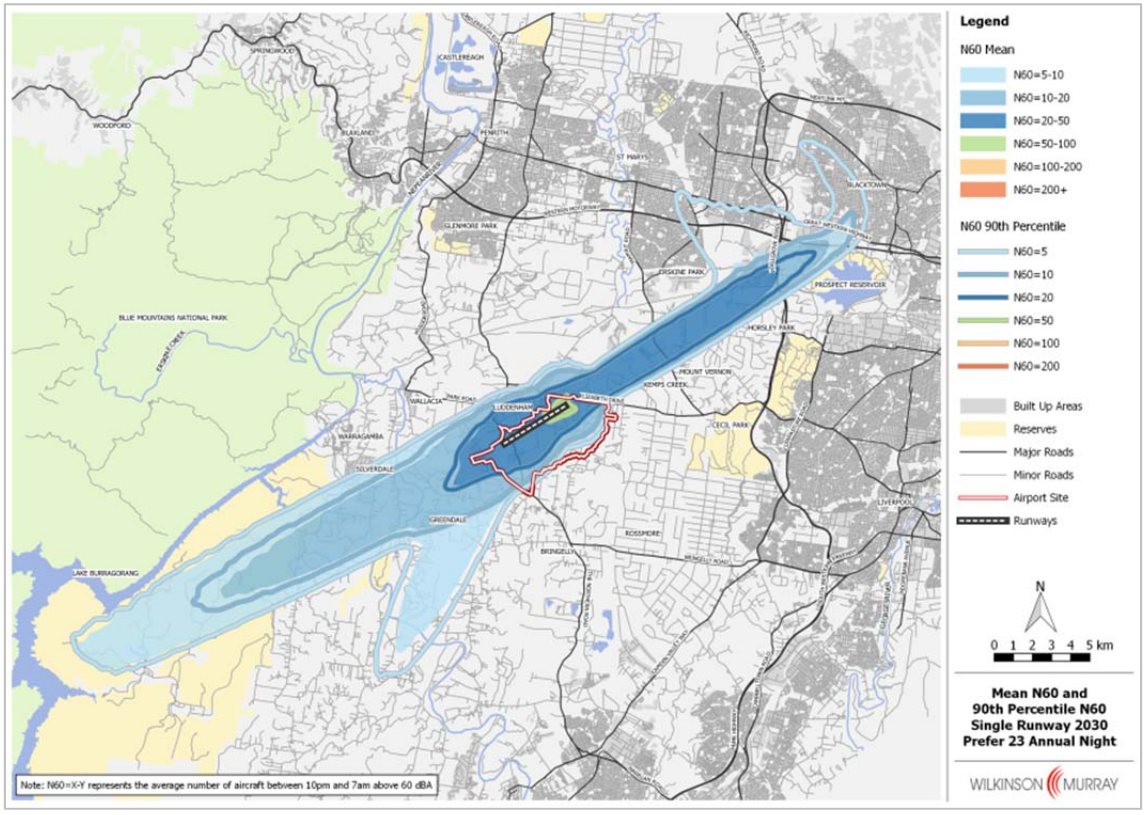


Figure 3-23 Mean & 90th Percentile N60 Contours – 2030 – Prefer 05 with Head-to-Head

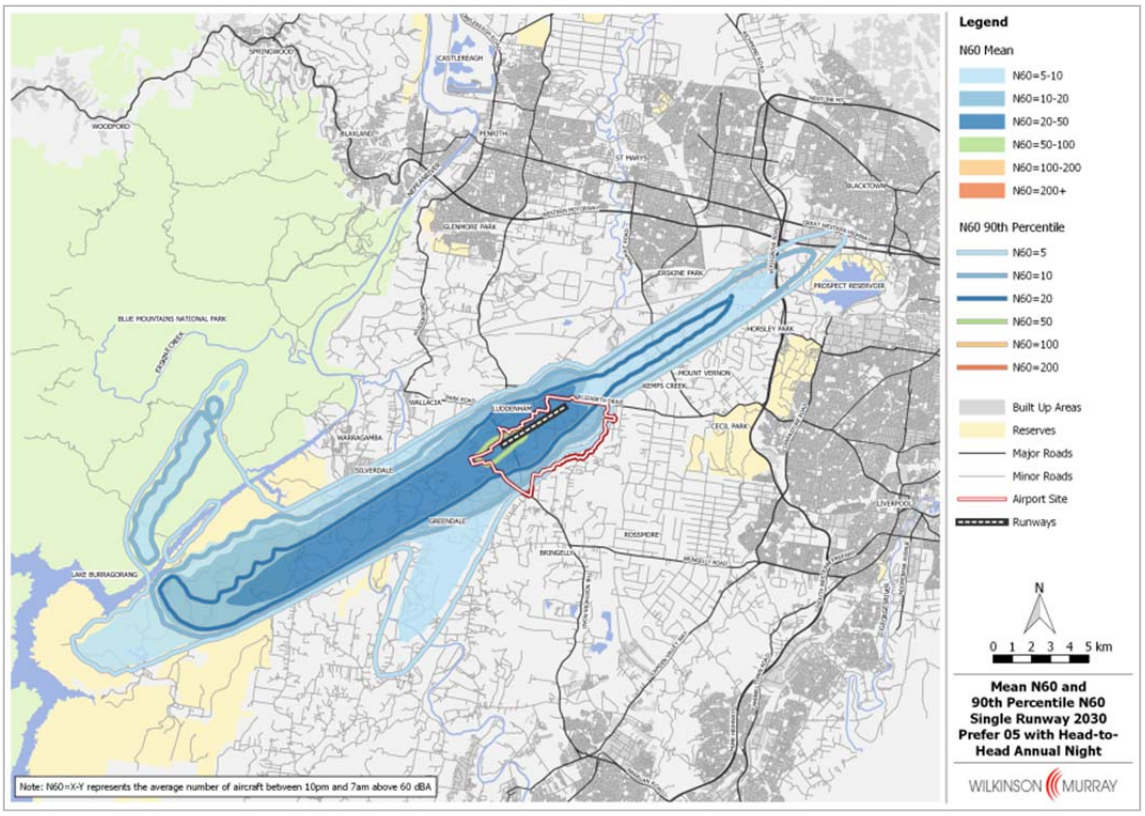
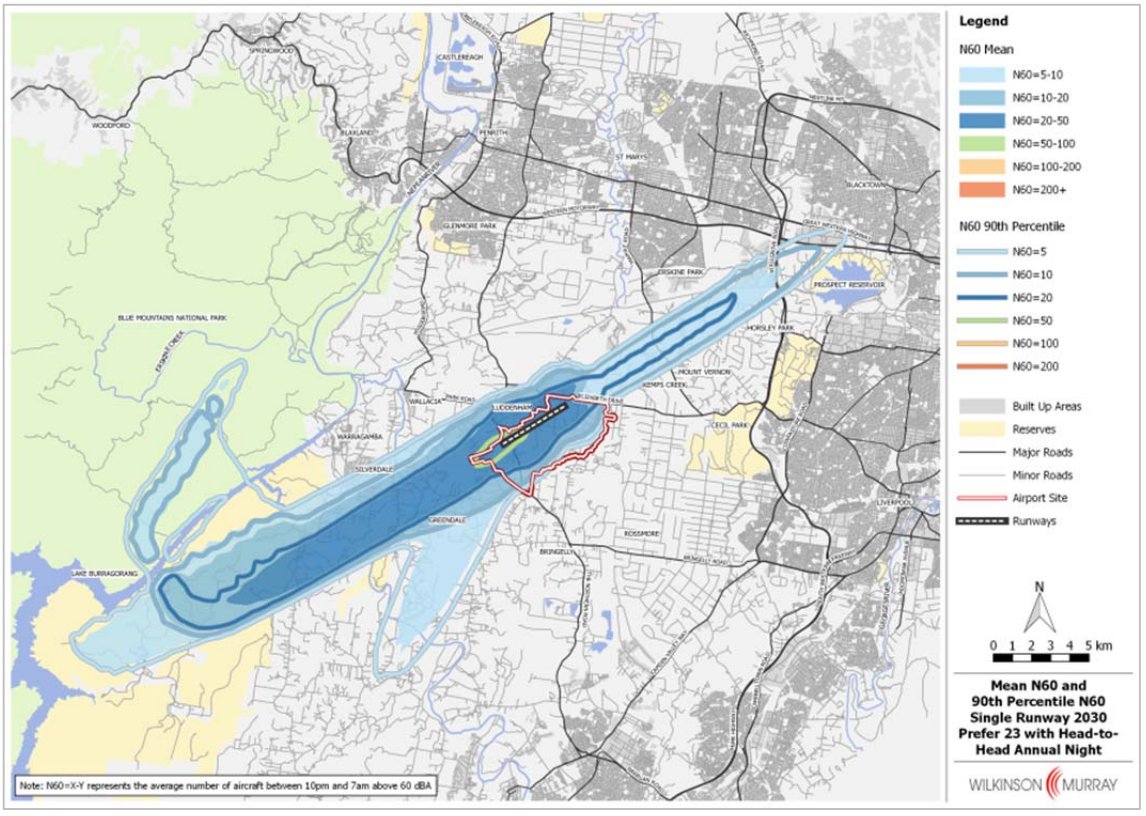


Figure 3-24 Mean & 90th Percentile N60 Contours – 2030 – Prefer 23 with Head-to-Head



3.5.3 Population Exposure Estimates

The future population experiencing various levels of night time noise impact has been estimated using procedures described in Section 2.9. Results are shown in Table 3-3.

Table 3-3 Estimated Population within N60 Contours – 2030

N60	Operating Strategy			
	Prefer 05	Prefer 23	Prefer 05 + H_2H*	Prefer 23 + H_2H*
5-10	46731	3436	2245	2287
10-20	1065	1474	841	844
20-50	609	1269	1200	1200
50-100	0	0	0	0
>100	0	0	0	0
Total	***48405***	***6179***	***4286***	***4331***

Note: * H2H = "Head-to-Head"
Population figures in this table are estimates only and are valid for comparisons between modes

- In assessment year 2030, a "Prefer 05" operating strategy at night would result in an estimated 48,000 people experiencing more than five events above 60 dBA at night. This is reduced to approximately 6,000 with a "Prefer 23" operating strategy, or 4,000 if a "Head-to-Head" mode is included. However, as for daytime noise, "Prefer 23" or "Head-to-Head" result in slightly more people experiencing higher noise impacts (i.e. a larger number of significant noise events). Once again these will be residents in rural residential areas to the south and west of the airport.
- It is also notable that night time noise impacts over some areas of the Blue Mountains National Park and GBMWHA are significantly higher with "Prefer 23" and "Head-to-Head" operating strategies. These impacts are described in more detail in Section 7 of this report.

3.6 Land Use Planning Impacts

3.6.1 ANEC Contours

Figure 3-25 to Figure 3-28 show the ANEC contours calculated for the year 2030, for the four operating strategies considered above. Calculations are for the 2030 assessment year.

As for N70 contours, it is notable that while there are differences between “Prefer 05” and “Prefer 23”, the introduction of “Head-to-Head” operations at night does not greatly influence the contours. This is because even with a heavier weighting for night time noise events, as included in the ANEF formula, overall noise exposure is still dominated by daytime events.

The 20 ANEF contour represents the area outside which new residential development is described as “acceptable” under Australian Standard 2021. Between 20 and 25 ANEF, the Standard recommends that new residential development is “conditionally acceptable” and should incorporate acoustic insulation to meet certain maximum internal noise levels, while in areas inside the 25 ANEF contour new residential development is described as “unacceptable”.

As seen in Figure 3-25 to Figure 3-28, the area enclosed by the 20 ANEC contour for 2030 is largely rural residential in nature, under all operating strategies.

The estimated population within these contours in 2030 is shown in Table 3-4. The total population within the 20 ANEC contour is similar for all operating strategies, although the exact areas represented are slightly different.

Figure 3-25 ANEC Contours – 2030 – Prefer 05

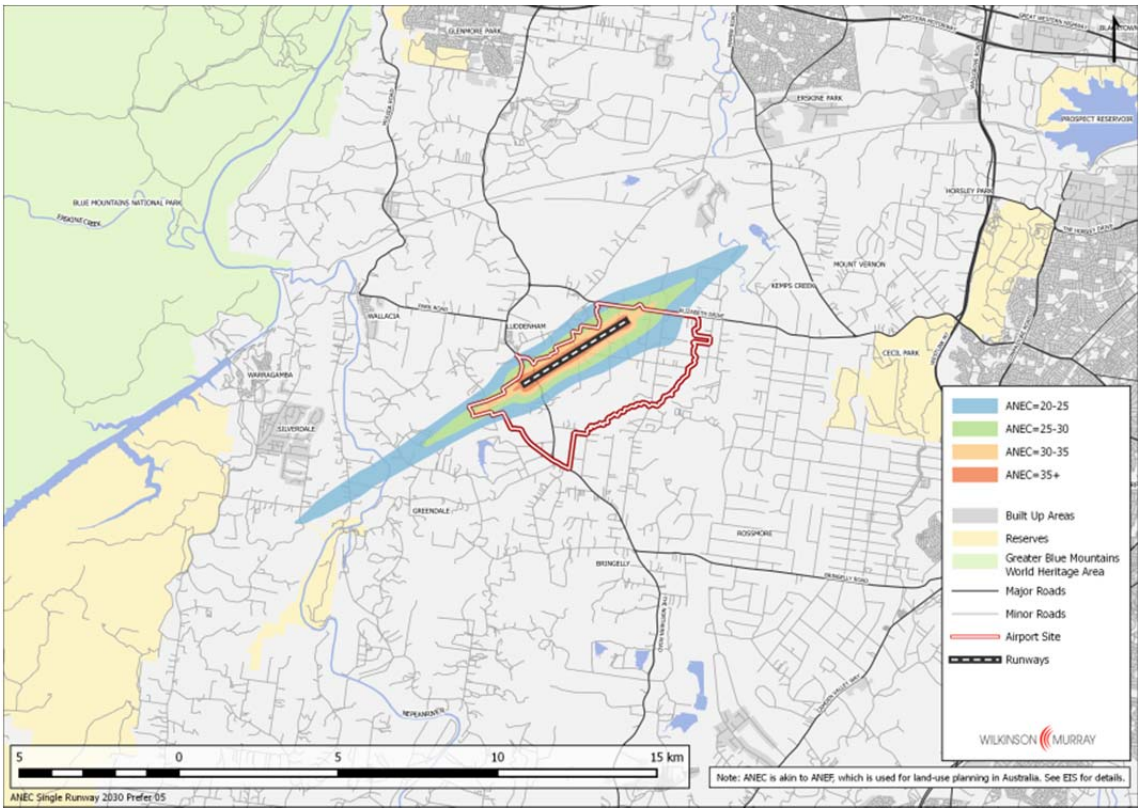


Figure 3-26 ANEC Contours – 2030 – Prefer 23

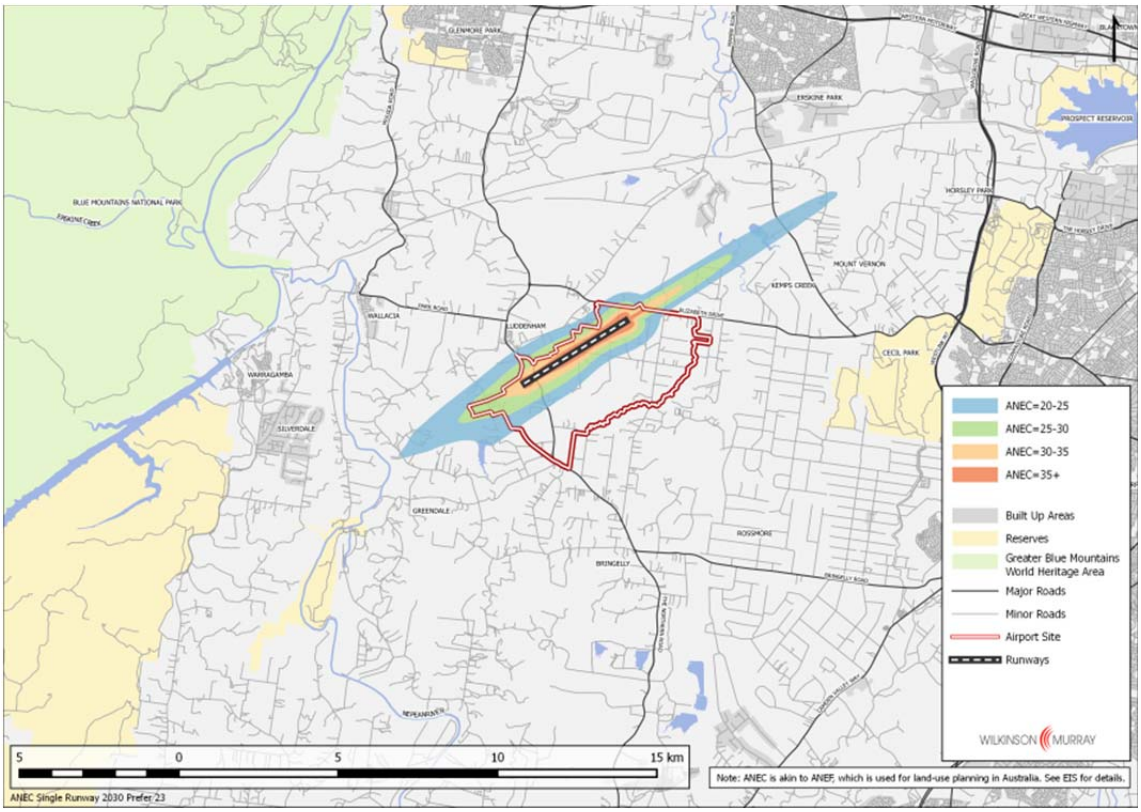


Figure 3-27 ANEC Contours – 2030 – Prefer 05 with Head-to-Head

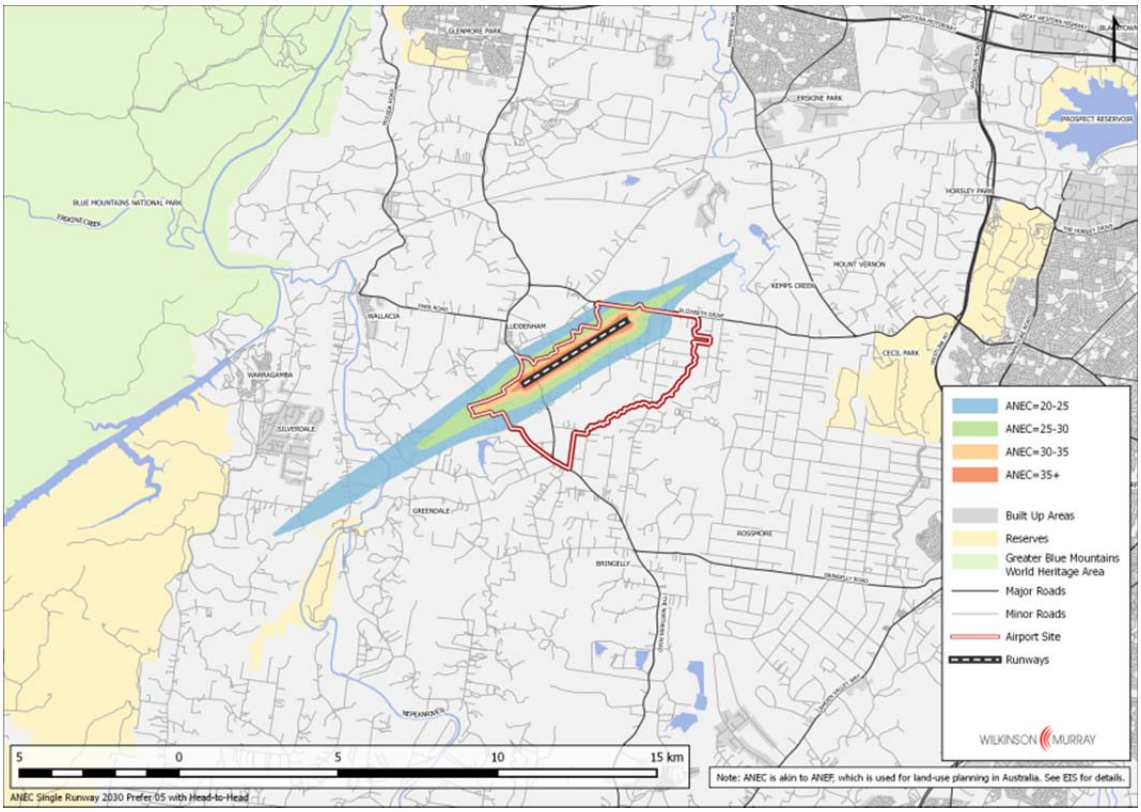


Figure 3-28 ANEC Contours – 2030 – Prefer 23 with Head-to-Head

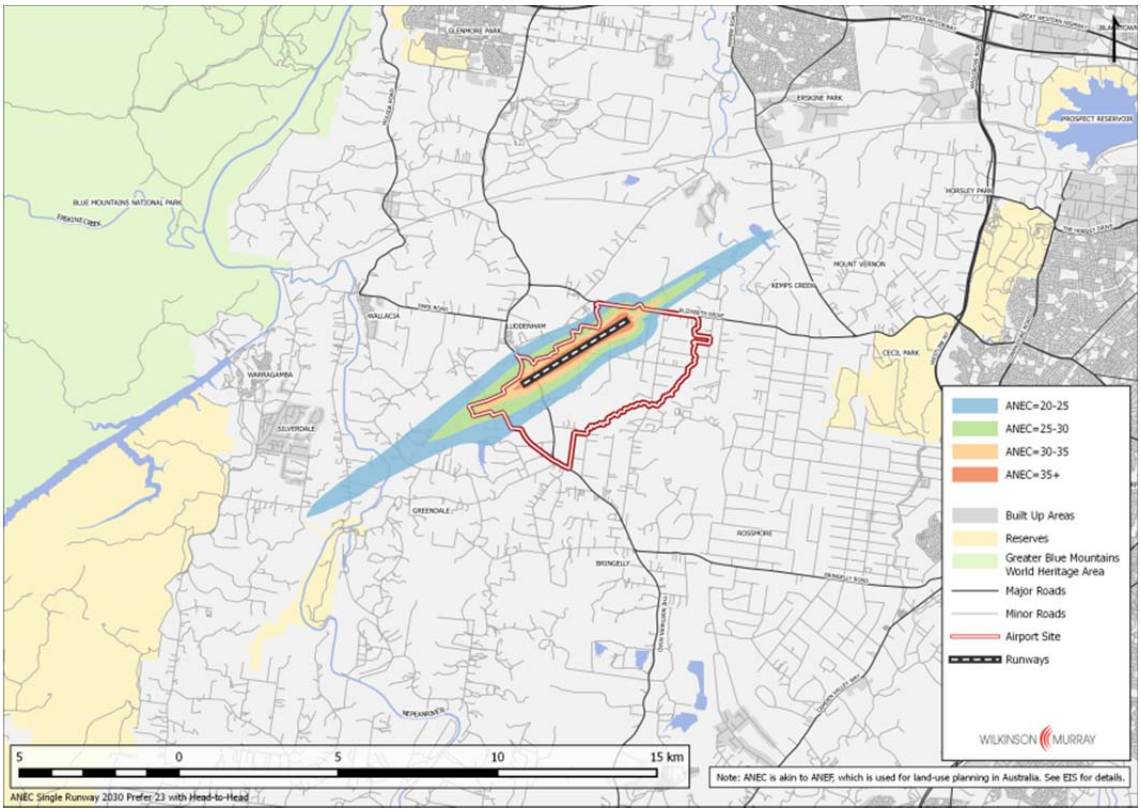


Table 3-4 Estimated Population within ANEC Contours – 2030

ANEC Band	Operating Strategy			
	Prefer 05	Prefer 23	Prefer 05 + H_2H*	Prefer 23 + H_2H*
20-25	198	228	235	224
25-30	13	39	28	30
30-35	0	0	0	3
>35	0	0	0	0
Total	***211***	***266***	***264***	***258***

Note: * H2H = "Head-to-Head"
Population figures in this table are estimates only and are valid for comparisons between modes

3.7 Aircraft Noise Levels in Recreational Areas

The Blue Mountains National Park and GBMWHA is an area used for recreational purposes that is located some distance from the proposed airport. The impact of aircraft overflights in these areas is considered in Section 7 of this report.

A number of smaller recreational areas, located closer to the proposed airport, have been identified within the area potentially affected by aircraft overflight noise. These range from sports areas used for activities such as horse riding, bowling or golf to nature reserves which may be used for more passive pursuits, including camping.

As for residences, the impact of aircraft noise in these areas can be quantified by the number of events per day with maximum noise levels exceeding 60 dBA, and exceeding 70 dBA. Where a noise level exceeds 60 dBA, a person may need to raise their voice to be properly heard in conversation. This magnitude of noise would be unlikely to cause disruption to active sporting pursuits. However, the noise would be noticeable, and could impact on the acoustic amenity of areas used for passive recreation, for the duration of the aircraft overflight.

Noise levels above 70 dBA would require increased voice effort (although not shouting) for conversation to be understood, and would certainly be considered to be acoustically intrusive in passive recreation areas, for the duration of the aircraft overflight.

Table 3-5 and Table 3-6 shows the identified recreation areas, and the predicted values of N60 and N70 for the Prefer 05 and Prefer 23 operating strategies. The values shown are for the period 7am-6pm, representing the times when these areas would most likely be used with the exception of Bents Basin State Conservation area which is also used for public camping.

Table 3-5 Average Number of Daily Noise Events with L_{Amax} Exceeding 70 dBA (N70) at Recreational Receivers

Recreational Receiver	2030	
	Prefer 05	Prefer 23
Bents Basin State Conservation Reserve & Gulguer Nature Reserve	0	0
Kemps Creek Nature Reserve	0	0
Rossmore Grange	0	0
Horsley Park Reserve	0	0
Twin Creeks Golf & Country Club	5	1
Sydney International Equestrian Centre	0	0
Whalan Reserve, St Marys	0	0

Table 3-6 Average Number of Daily Noise Events with L_{Amax} Exceeding 60 dBA (N60) at Recreational Receivers

Recreational Receiver	2030	
	Prefer 05	Prefer 23
Bents Basin State Conservation Reserve & Gulguer Nature Reserve	7	13
Kemps Creek Nature Reserve	0	0
Rossmore Grange	3	1
Horsley Park Reserve	0	0
Twin Creeks Golf & Country Club	23	6
Sydney International Equestrian Centre	0	0
Whalan Reserve, St Marys	1	2

A review of the results presented in Table 3-5 and Table 3-6 indicates the following:

- Most of the identified recreational receivers would not be subjected to aircraft overflight noise events with maximum levels exceeding 70 dBA – or their exposure would be significantly less than 1 event per day on average.
- **Twin Creeks Golf & Country Club** – Flyover noise levels from aircraft at this location would be noticeable out of doors and at times a raised voice effort would be required for effective communication. However it is noted that the sensitivity of receivers at this location is likely to be lower due to the active use of the area.
- **Bents Basin State Conservation Reserve & Gulguer Nature Reserve** would be subject to a number of flyover event noise levels exceeding 60 dBA, which would be noticeable to passive users of this area. Bents Basin State Conservation Reserve is used for camping, and would be subject to less than five night time noise events exceeding 60
- At Twin Creeks Golf & Country Club, noise exposure would be significantly reduced under a Prefer 23 operating strategy. However, at Bents Basin State Conservation Reserve it would be lower under a Prefer 05 operating strategy.

4 ASSESSMENT OF ADDITIONAL CAPACITY SCENARIO

4.1 Development Overview

It is important to acknowledge that following the initial stage of airport development, which is the proposal referred under the EPBC Act, demand for air travel will grow. This noise assessment therefore includes a subsequent assessment scenario, notionally at the capacity of the first runway when total passenger demand is estimated to be approximately 37 million passengers per annum. This scenario provides an indication of potential noise impacts which reflects the forecast likely maximum number of aircraft operations associated with the single runway development.

4.2 Single-Event Noise Contours

The aircraft types used in modelling for this additional capacity scenario are generally the same as those used for the Initial Airport Development scenario (Chapter 0), and hence single-event noise contours will be the same as those shown in Section 3.2. However, one exception is that the synthetic schedule for the 2030 scenario included B747 (or equivalent) aircraft departures with a maximum stage length of 5 (corresponding to a departure for Singapore) whereas the Additional Capacity, or 2050, scenario includes Stage 9 departures (corresponding to departures for Los Angeles).

In the Extended Capacity scenario, Stage 9 departures by 747 aircraft are predicted to occur once every two days, on average, and may occur on any of a number of tracks. However, note that although contours are shown for these events on tracks heading south from the airport, it is very unlikely that a Stage 9 departure would occur on these tracks as there are no destinations for which this would be a preferred departure direction.

Maximum noise level contours for this additional event type are shown in Figure 4-1 and Figure 4-2. At the most-affected residences, close to the airport, L_{Amax} noise levels from these events would be in the range 85 – 95 dBA. There are less than 10 existing residences within the 90 dBA L_{Amax} contour for these events, located to the south-west of the airport Maximum noise levels in the most-affected areas are shown in greater detail in Chapter 6.

When these events occur on the track leading north in the 05 direction, L_{Amax} noise levels exceeding 75 dBA can be expected over densely-populated areas around St Marys, with levels above 80 dBA in some parts of Erskine Park.

Maximum noise levels from other aircraft operations would be as described in Section 3.2 for the Initial Airport Development scenario.

Figure 4-1 Combined Single Event B747 Departure – Stage 9 (Macro Scale)

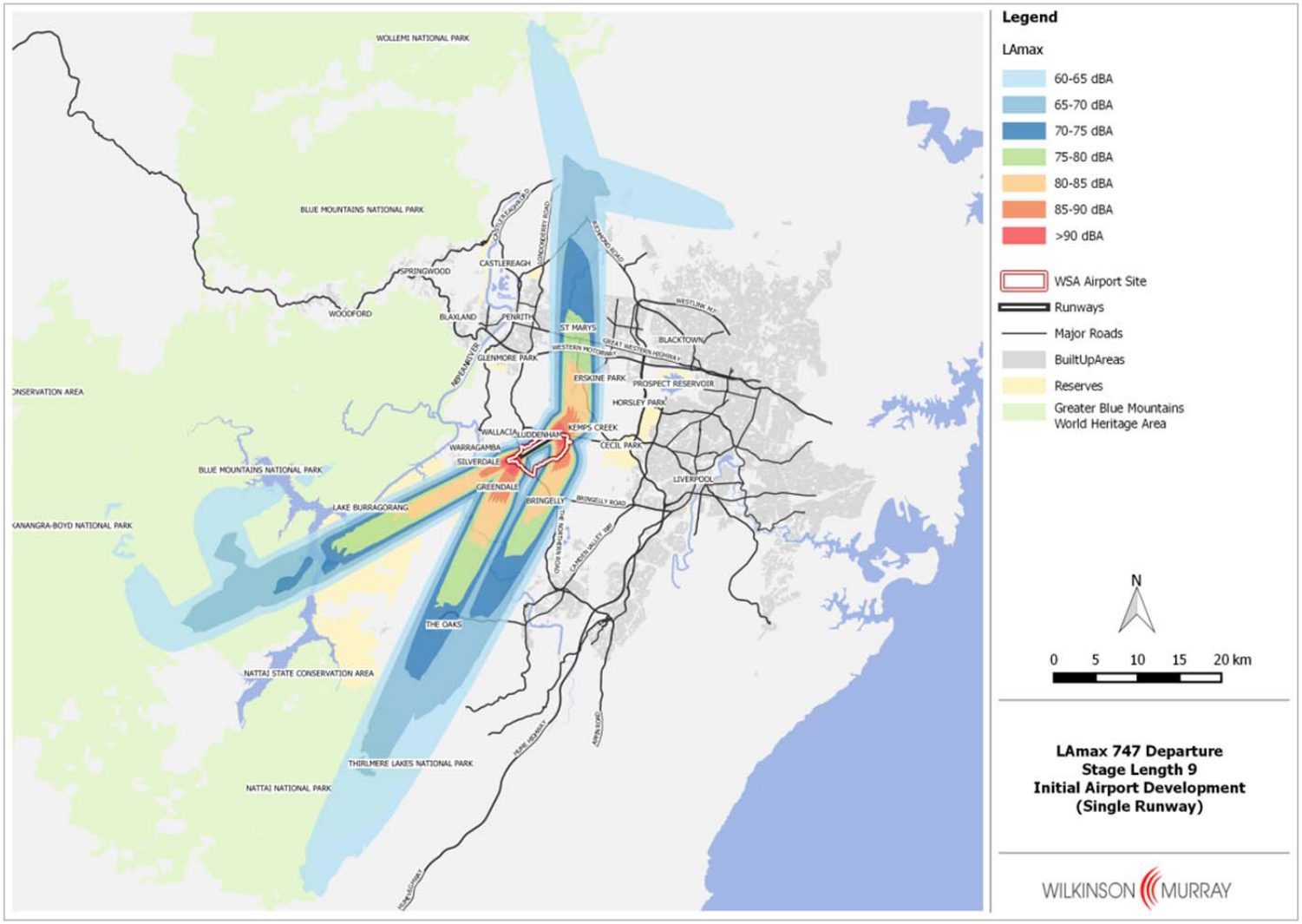
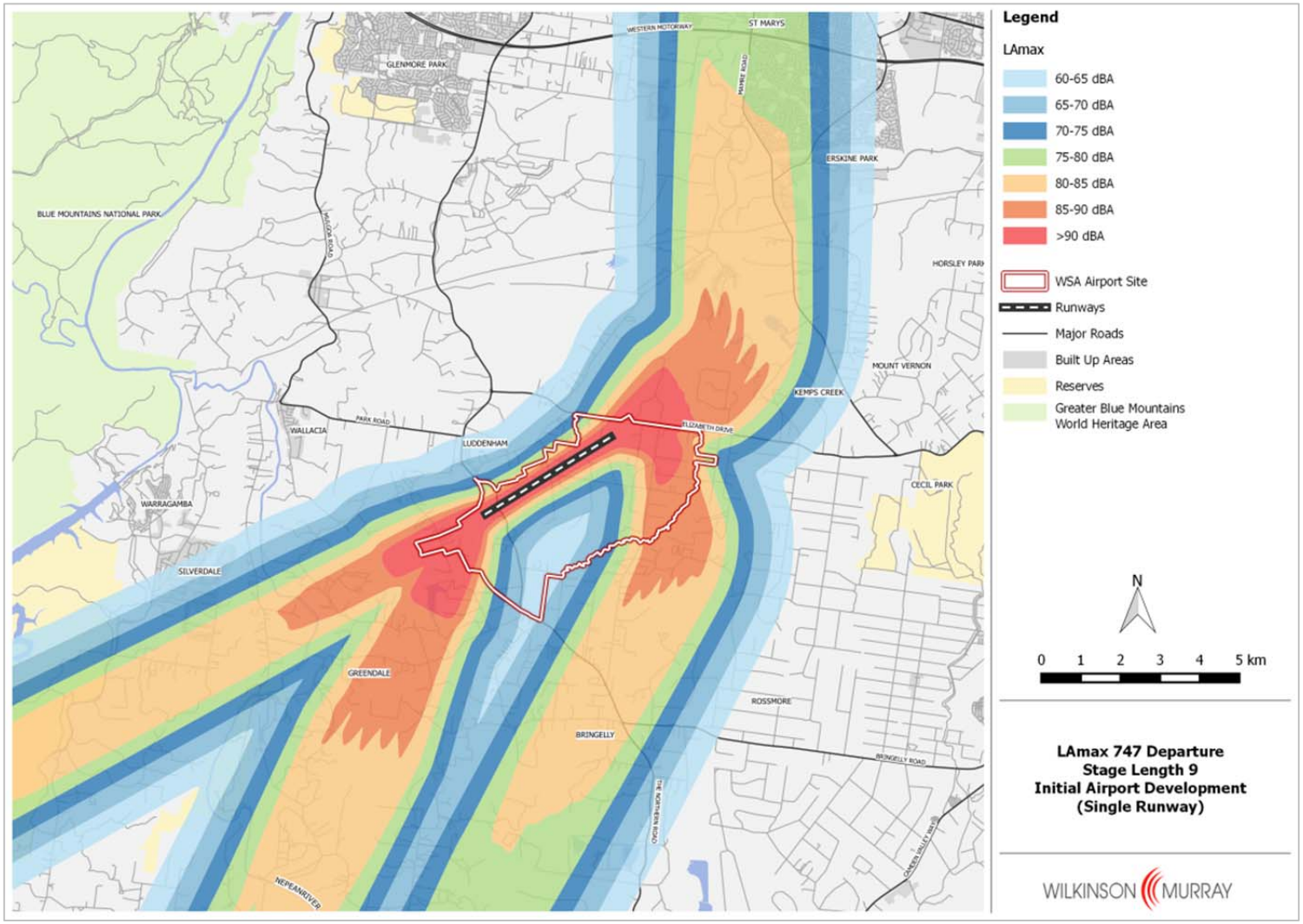


Figure 4-2 Combined Single Event B747 Departure – Stage 9 (Meso Scale)



4.3 Noise Levels Over 24 Hours

4.3.1 N70 Results

Aircraft noise impact over a full day can be described by the number of noise events exceeding 70 dBA, or N70. Calculated N70 noise contours for each of the four airport operating strategies described in Section 2.7.1, and for nominal year 2050, are presented in Figure 4-3 to Figure 4-6. These represent the predicted annual average number of movements per day with L_{Amax} noise levels exceeding 70 dBA.

Comparison with Figure 3-25 to Figure 3-28 indicates that impacts in assessment year 2030 are significantly lower than for year 2050. Impacts would be expected to increase gradually to the levels shown for 2050 as aircraft movements at the airport approach capacity for a single runway configuration.

As for 2030, there are significant differences between noise impacts from different airport operating strategies. In particular, the Prefer 05 strategy results in greater impact on residents in densely-populated areas the north-east of the airport – in 2050 there are predicted to be 5-10 events per day above 70 dBA over developed areas in St Marys, whereas in the Prefer 23 operating strategy, the impact is less than 5 events per day in all these areas. For Prefer 23, the impact is predicted to be greater in less densely populated areas to the north of Horsley Park, and also in rural residential areas around Greendale. Prefer 23 also results in somewhat greater impact in some parts of the Blue Mountains National Park and GBMWHA.

As in 2030, inclusion of a “Head-to-Head” mode at night makes an almost imperceptible difference to overall N70 values.

Figure 4-3 N70 Contours – 2050 – Prefer 05

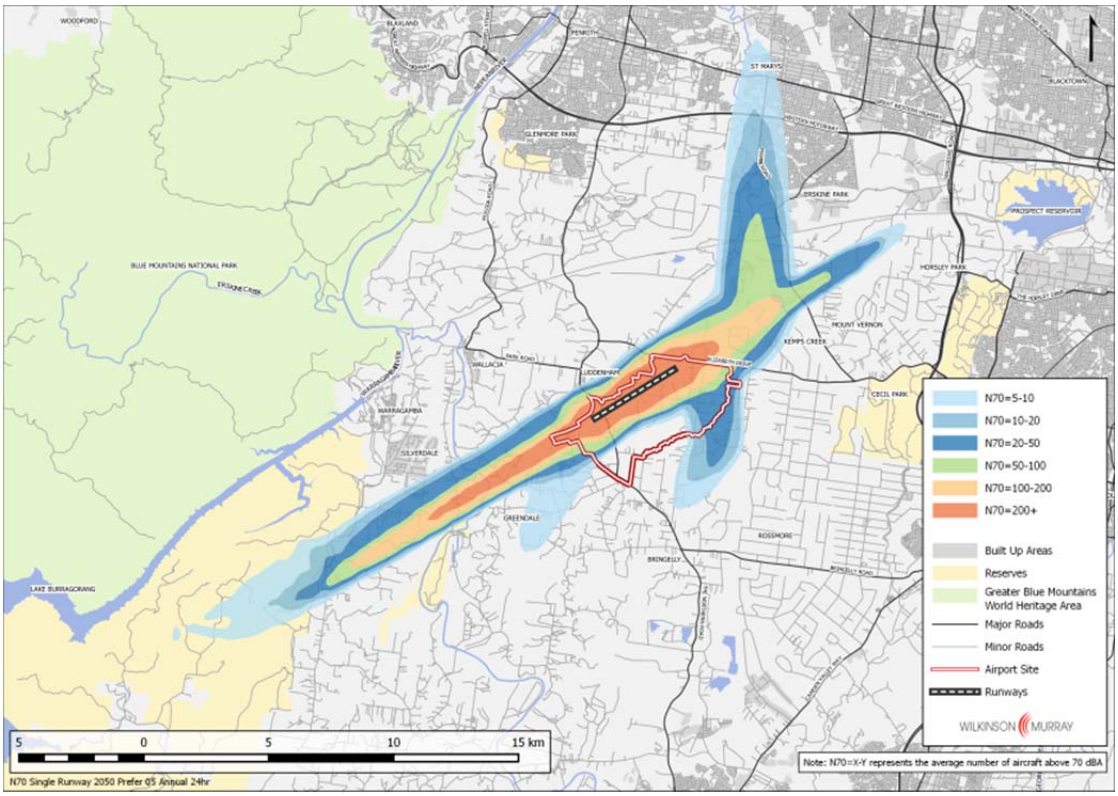


Figure 4-4 N70 Contours – 2050 – Prefer 23

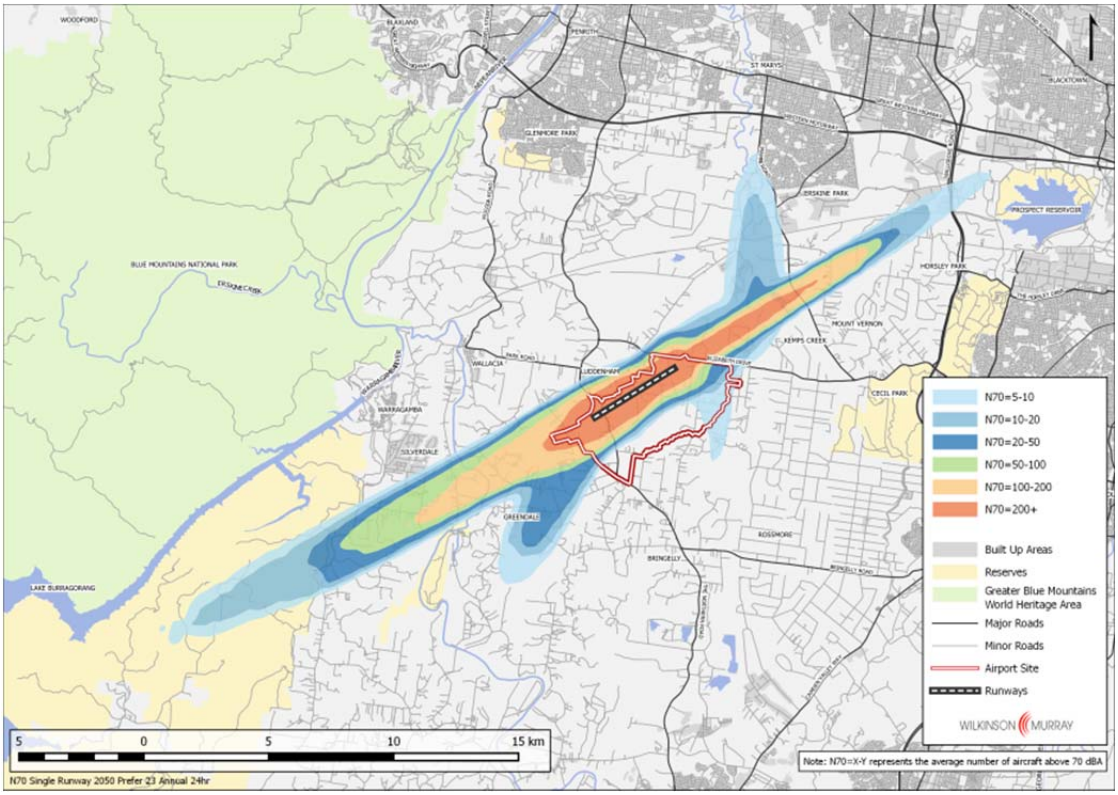


Figure 4-5 N70 Contours – 2050 – Prefer 05 with Head-to-Head

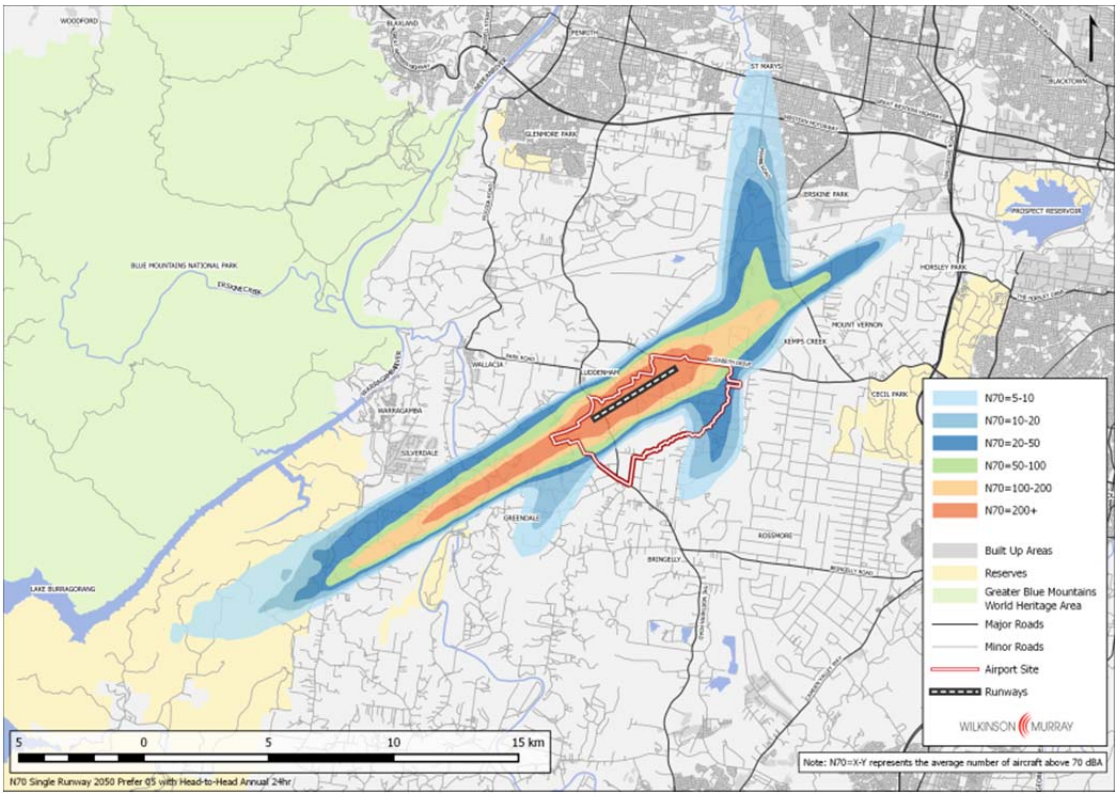
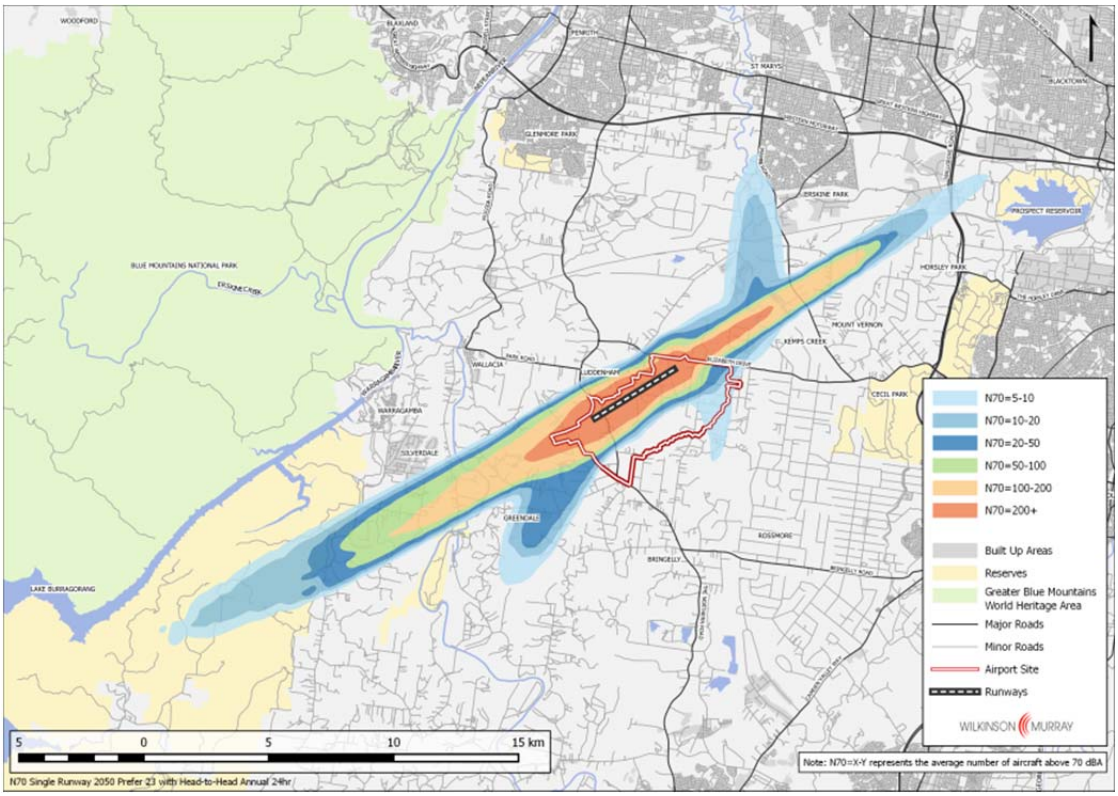


Figure 4-6 N70 Contours – 2050 – Prefer 23 with Head-to-Head



4.3.2 90th Percentile N70 Results

Figure 4-7 and Figure 4-8 show 90th percentile values of N70 calculated over all days – that is, the number of daily aircraft noise events over 70 dBA that would be exceeded on only 10% of days. This can be thought of as a "typical worst-case" day. Values are Prefer 05 and Prefer 23. (Head-to-Head strategies are not shown as this mode makes very little difference to the results.) The figures also show the "average day" N70 values as depicted in the figures above.

Generally, as for 2030, the difference between noise impact on "average" and "typical worst-case" days is not large. This is due to the relatively low and consistent wind speeds at the site, which mean that the airport's "preferred" mode of operation can be selected over 80% of the time.

The most important difference shown in these figures is for the Prefer 23 strategy. Figure 4-8 demonstrates that although established built-up areas do not experience more than five events per day over 70 dBA on an "average" day, there are areas to the south of St Marys that would do so on a "typical worst-case" day, and in fact, in these areas a "typical worst-case" day for the Prefer 23 operating strategy is similar to an "average day" for Prefer 05.

Figure 4-7 Mean and 90th Percentile N70 Contours – 2050 – Prefer 05

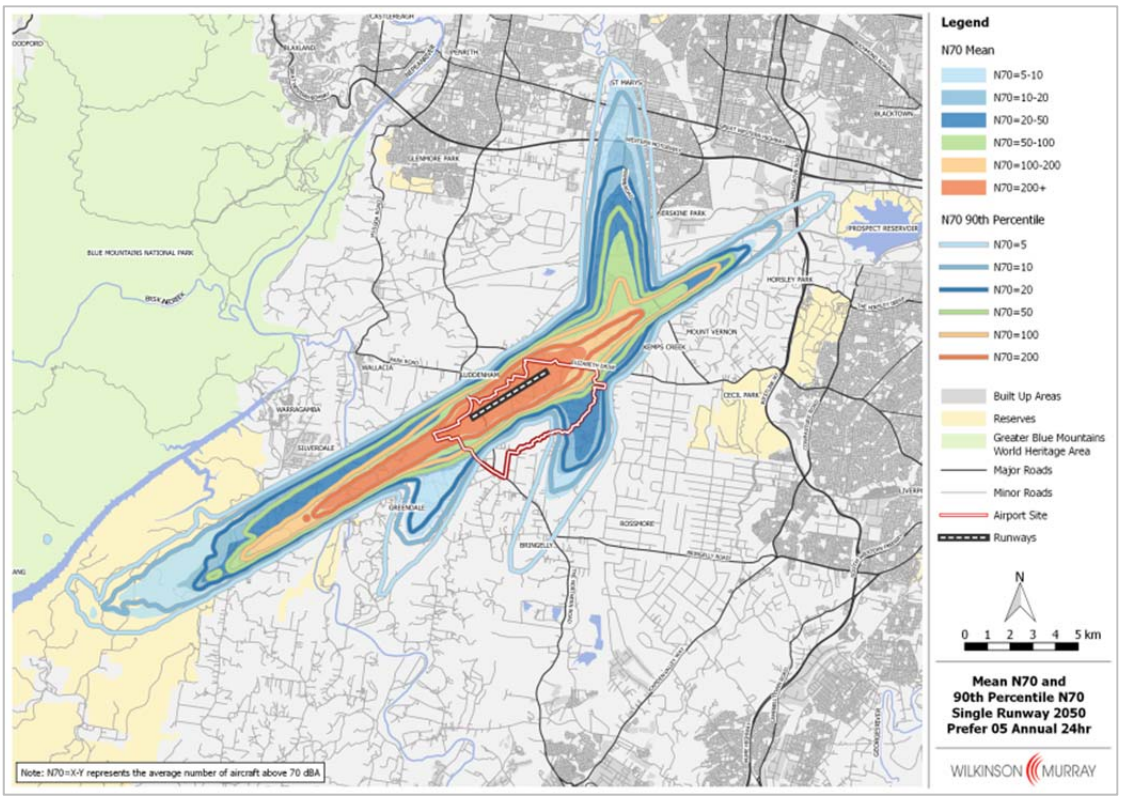
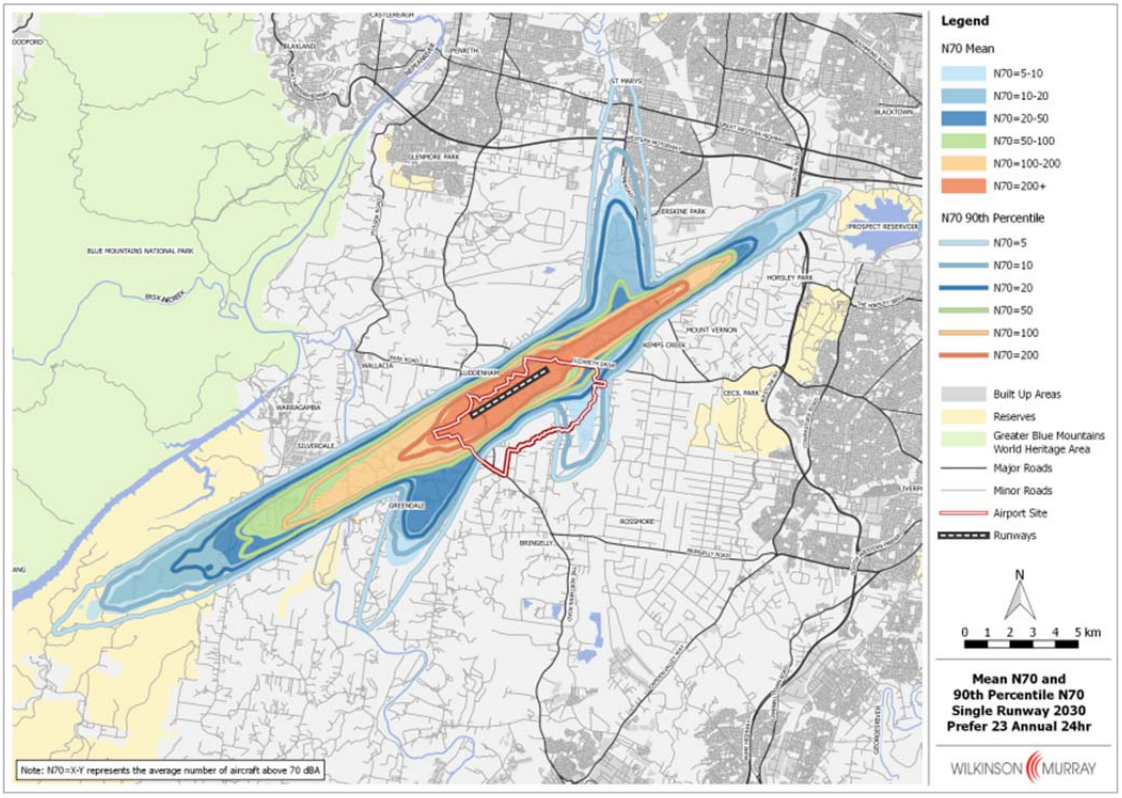


Figure 4-8 Mean and 90th Percentile N70 Contours – 2050 – Prefer 23



4.3.3 Population Exposure Estimates

The future population experiencing various levels of daytime noise impact has been estimated using procedures described in Section 2.9. Results for an "annual average day" are shown in Table 4-1.

Table 4-1 Estimated Population within N70 Contours – 2050

N70	Operating Strategy			
	Prefer 05	Prefer 23	Prefer 05 + H_2H*	Prefer 23 + H_2H*
5-10	20,193	2,232	17,358	2,262
10-20	7,101	1,024	5,425	992
20-50	1,448	636	1,392	649
50-100	767	590	685	594
100-200	265	662	228	665
>200	139	145	180	141
Total	***29,913***	***5,289***	***25,268***	***5,303***

Note: * H2H = "Head-to-Head"
Population figures in this table are estimates only and are valid for comparisons between modes

Compared with assessment year 2030, in 2050 noise impacts at the lower levels have spread into areas of greater residential development. With the Prefer 05 operating strategy, this results in approximately 30,000 people being exposed to at least five noise events per day above 70 dBA, compared with 1,600 in 2030. In Prefer 23, this number is predicted to be dramatically lower at approximately 5,000 people. However, it is notable that Prefer 23 still results in greater impact at higher noise levels – generally in rural residential areas to the south and west of the airport.

4.4 Night Time Noise

4.4.1 N60 Results

Figure 4-9 to Figure 4-12 show the predicted number of noise events per night (10pm – 7am) exceeding 60 dBA for the four operating strategies considered, for the assessment year 2050. Calculations are shown down to a value of five events per night.

Once again, the difference between Prefer 05 and Prefer 23 strategies is significant, with Prefer 05 predicted to have greater impact on built-up areas around St Marys while Prefer 23 has a greater impact on rural residential areas around Greendale. By 2050, with Prefer 05, large areas with significant population density are predicted to experience over 20 noise events per night exceeding 60 dBA. With Prefer 23, large areas of residential development would also experience night time noise impact, but at a lower level of 5-10 events per night.

This night time noise impact can be mitigated by use of the "Head-to-Head" mode where available. As demonstrated in Figure 4-12, with "Prefer 23 Plus Head-to Head" this results in almost no built-up residential areas being exposed to more than five events per night above 60 dBA, even in 2050.

Figure 4-9 N60 Contours – 2050 – Prefer 05

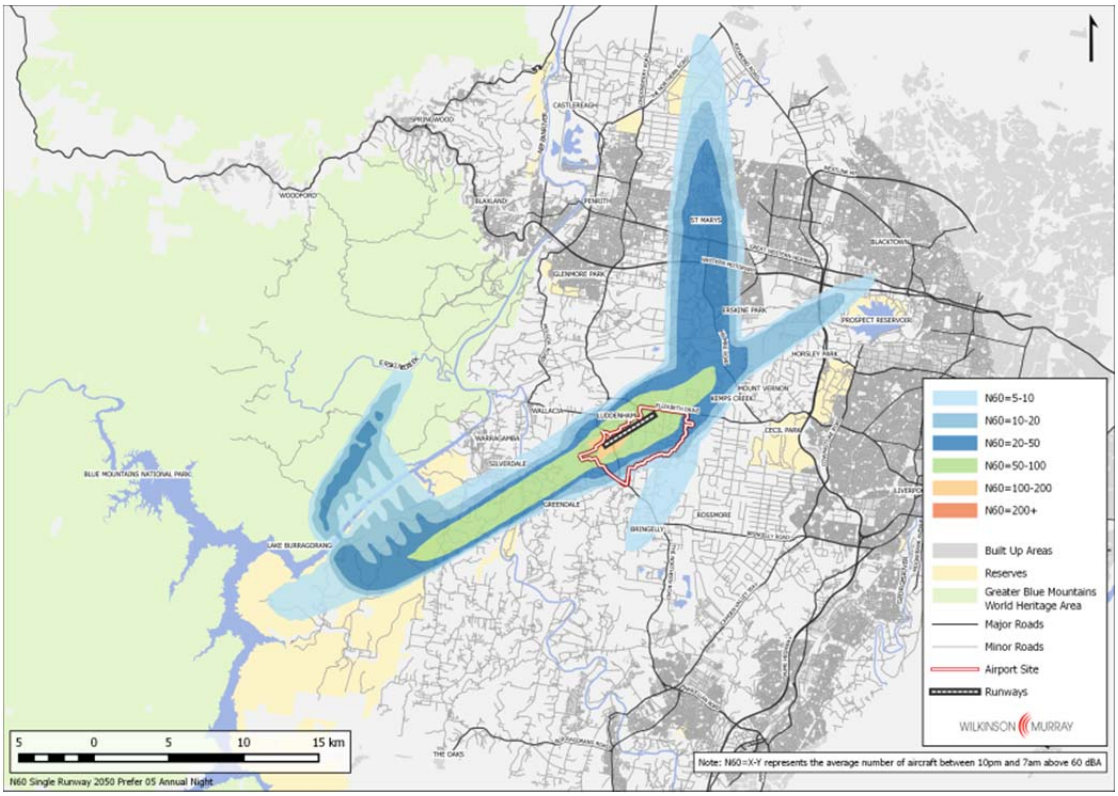


Figure 4-10 N60 Contours – 2050 – Prefer 23

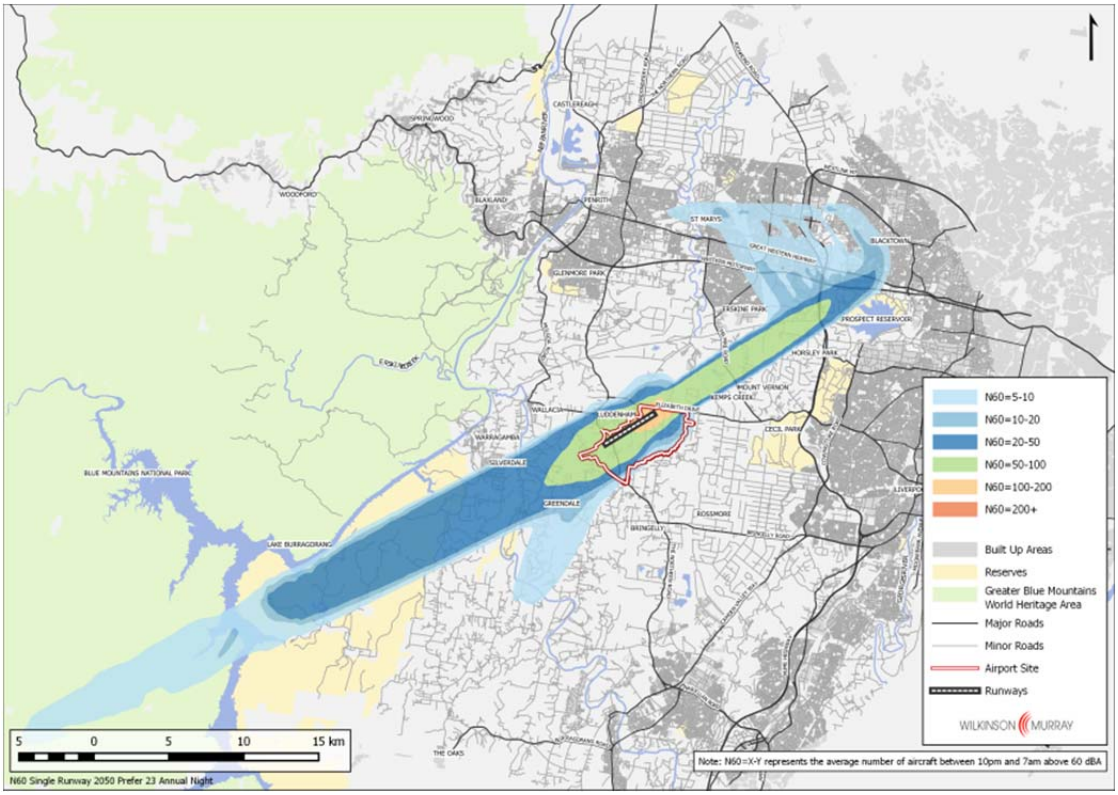


Figure 4-11 N60 Contours – 2050 – Prefer 05 with Head-to-Head

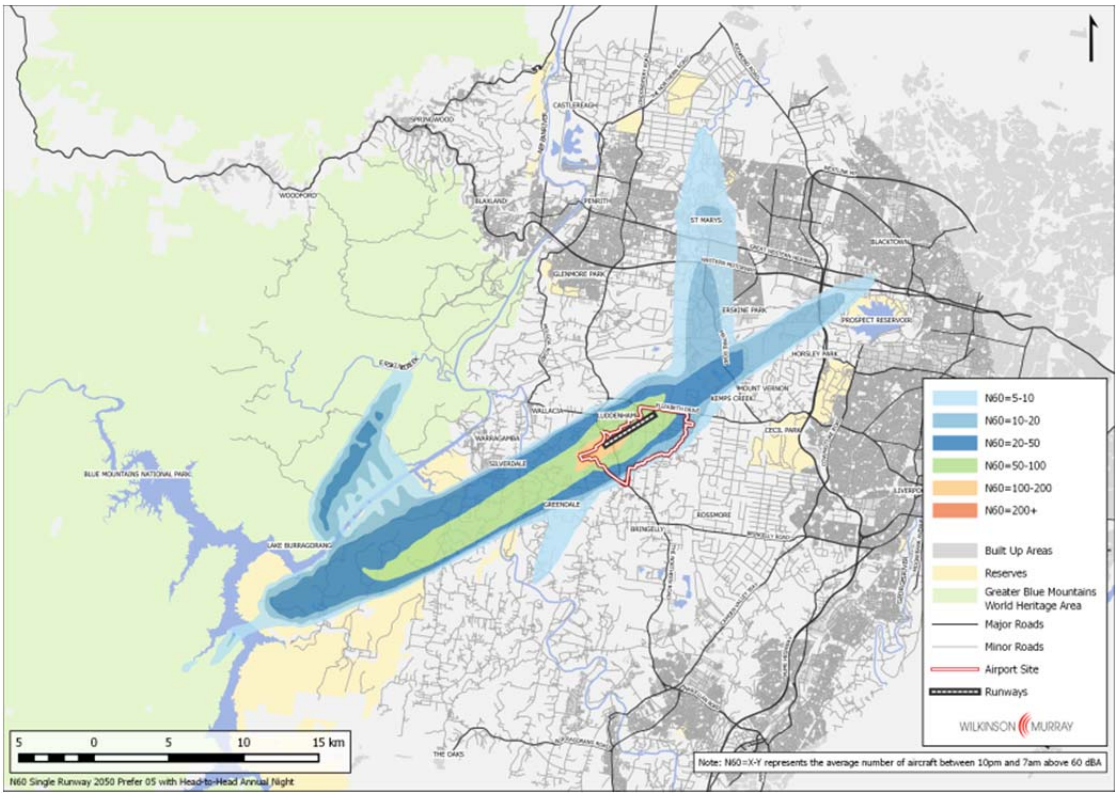
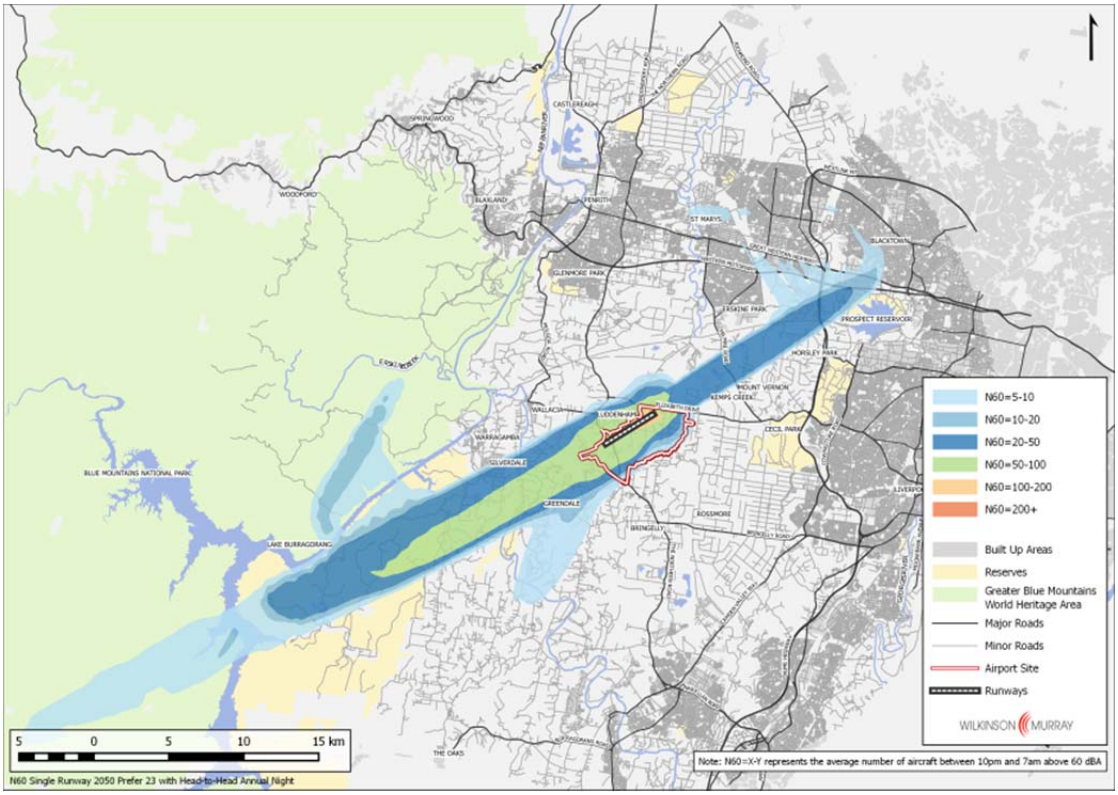


Figure 4-12 N60 Contours – 2050 – Prefer 23 with Head-to-Head



4.4.2 90th Percentile N60 Results

As for N70 values, 90th percentile night time N60 values give an indication of the number of events per night exceeding 60 dBA on a "typical worst-case" night. These are shown in Figure 4-13 to Figure 4-16.

In 2050, and particularly with "Head-to-Head" mode, significant developed residential areas are predicted to be exposed to more than five events per night on a "typical worst-case" night but not on an "average" night.

Figure 4-13 Mean and 90th Percentile N60 Contours – 2050 – Prefer 05

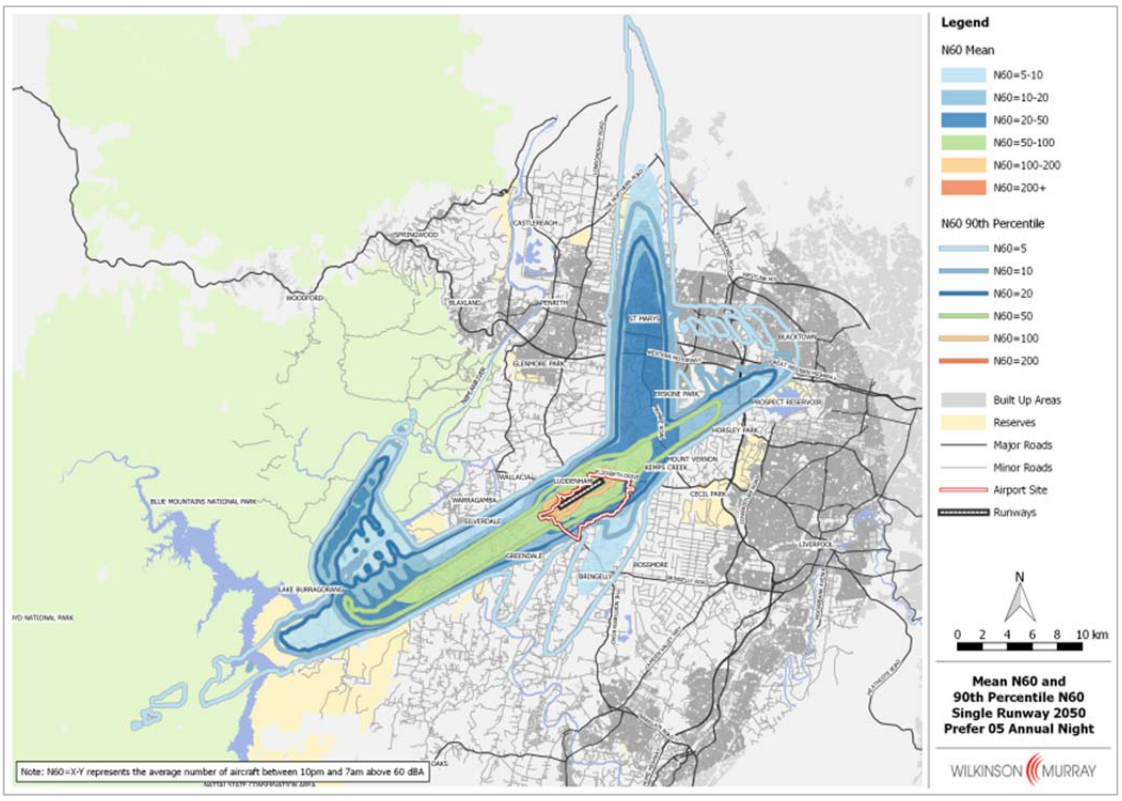


Figure 4-14 Mean and 90th Percentile N60 Contours – 2050 – Prefer 23

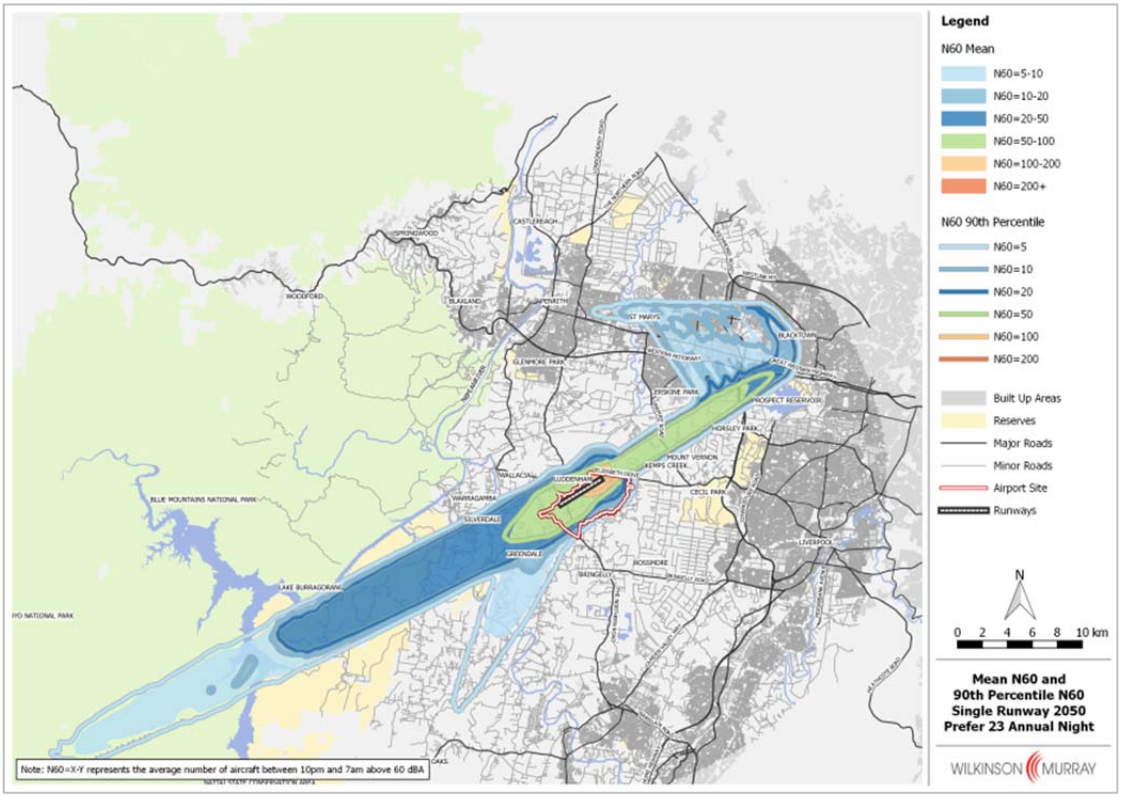


Figure 4-15 Mean and 90th Percentile N60 Contours – 2050 – Prefer 05 with Head-to-Head

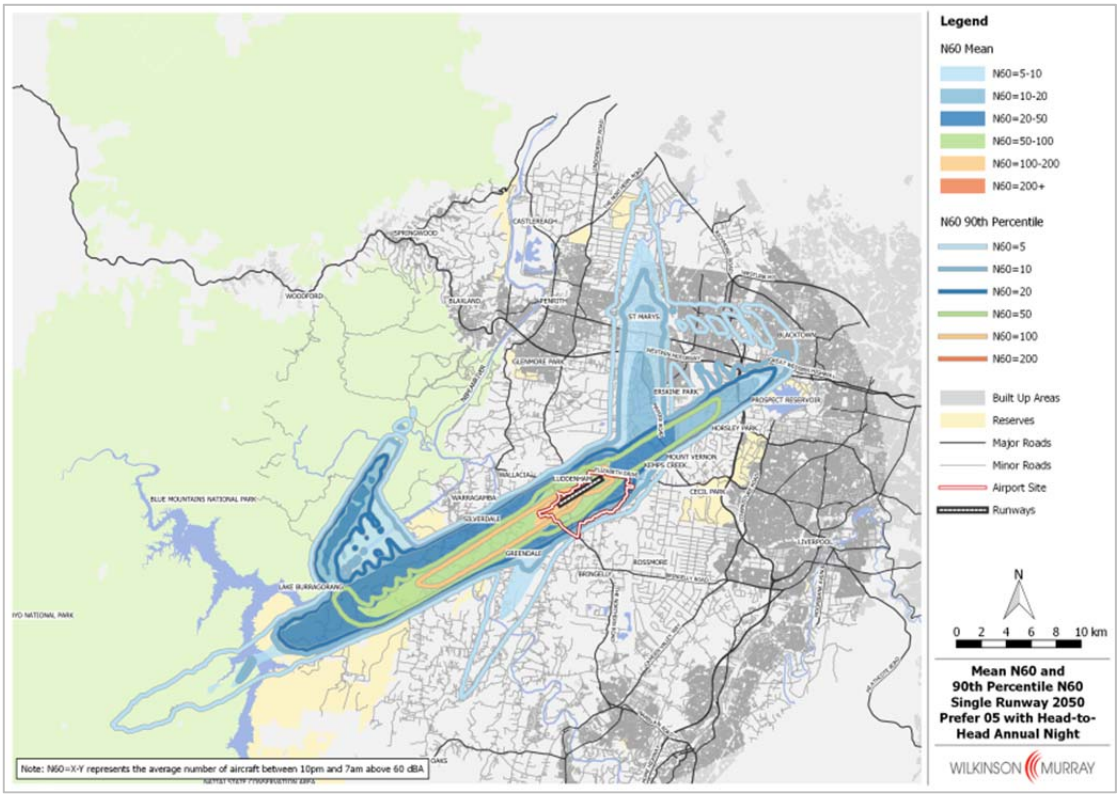
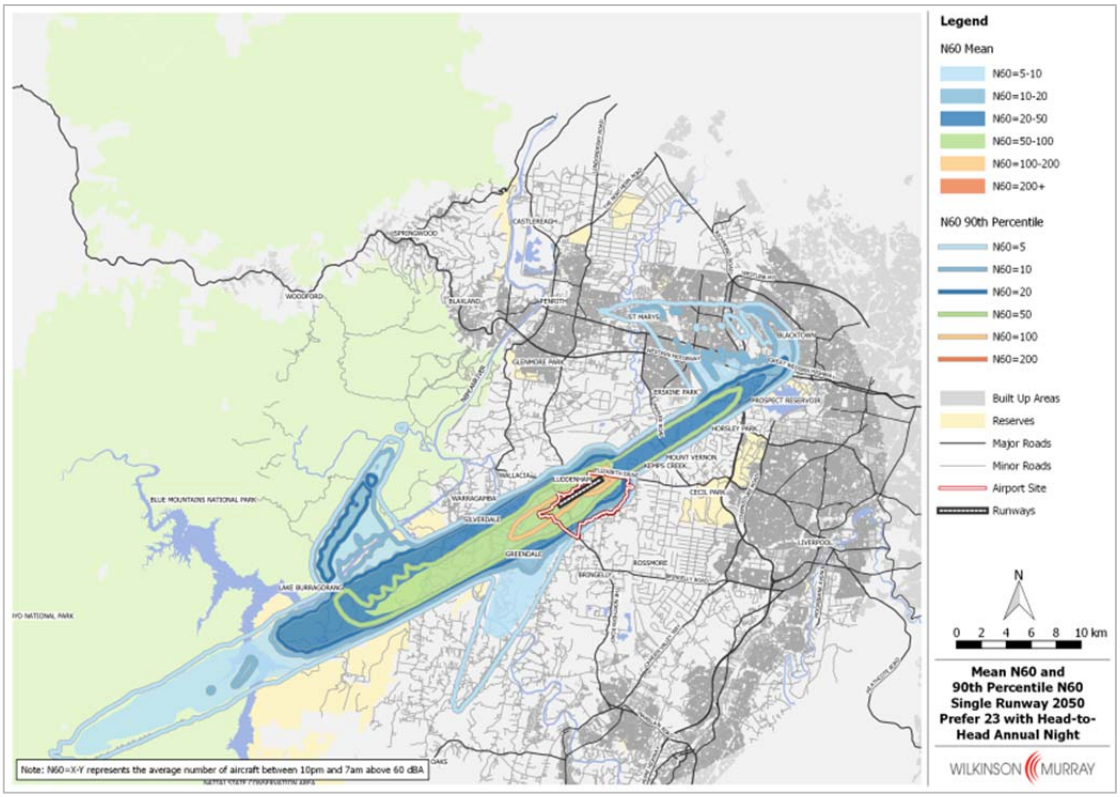


Figure 4-16 Mean and 90th Percentile N60 Contours – 2050 – Prefer 23 with Head-to-Head



4.4.3 Population Exposure Estimates

The future population experiencing various levels of night time noise impact has been estimated using procedures described in Section 2.9. Results are shown in Table 4-2.

Table 4-2 Estimated Population within N60 Contours – 2050

N60	Operating Strategy			
	Prefer 05	Prefer 23	Prefer 05 + H_2H*	Prefer 23 + H_2H*
5-10	29,128	143,827	81,187	30,560
10-20	34,552	18,211	15,513	1,987
20-50	72,138	4,953	3558	4,111
50-100	1,600	3,395	2,664	3,440
>100	13	5	144	0
Total	***137,431***	***170,391***	***103,066***	***40,098***

Note: * H2H = "Head-to-Head"
Population figures in this table are estimates only and are valid for comparisons between modes

By assessment year 2050, the population experiencing night time noise impacts at some level is predicted to expand. At this stage, the use of "Prefer 23 with Head-to-Head" offers clear benefits in terms of the population exposed to night time noise.

It is also evident that predicted number of night time noise events exceeding 60 dBA over parts of the Blue Mountains National Park and GBMWHA is notably higher with "Prefer 23" and "Head-to-Head" operating scenarios. This impact is described in more detail in Section 7 of this report.

4.5 Land Use Planning Impacts

4.5.1 ANEC Contours

Figure 4-17 to Figure 4-20 show the ANEC contours calculated for the year 2050, for the four operating strategies considered above. Calculations are for the 2050 assessment year because these contours are more likely to be representative of noise contours to be used for planning purposes and represent aircraft overflight noise impacts when the first runway is approaching its maximum capacity.

As for N70 contours, it is notable that while there are differences between "Prefer 05" and "Prefer 23", the introduction of "Head-to-Head" operations at night does not greatly influence the contours. This is because even with a heavier weighting for night time noise events, as included in the ANEF formula, overall noise exposure is still dominated by daytime events.

The 20 ANEF contour represents the area outside which new residential development is described as "acceptable" under Australian Standard 2021. Between 20 and 25 ANEF, the Standard recommends that new residential development is "conditionally acceptable" and should incorporate acoustic insulation to meet certain maximum internal noise levels, while in areas inside the 25 ANEF contour new residential development is described as "unacceptable".

The estimated population within these contours in 2050 is shown in Table 4-3. As in 2030, the

total population within the 20 ANEC contour is similar for all operating strategies, although the exact areas represented are slightly different.

Figure 4-17 ANEC Contours – 2050 – Prefer 05

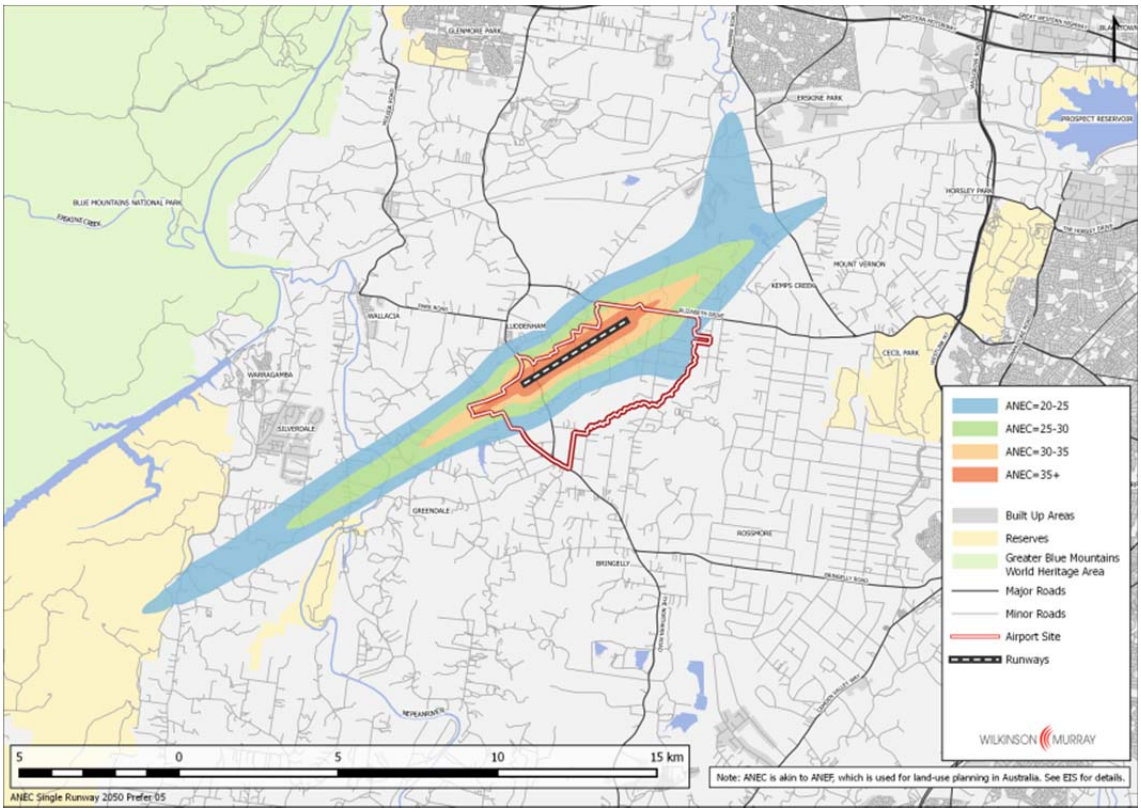


Figure 4-18 ANEC Contours – 2050 – Prefer 23

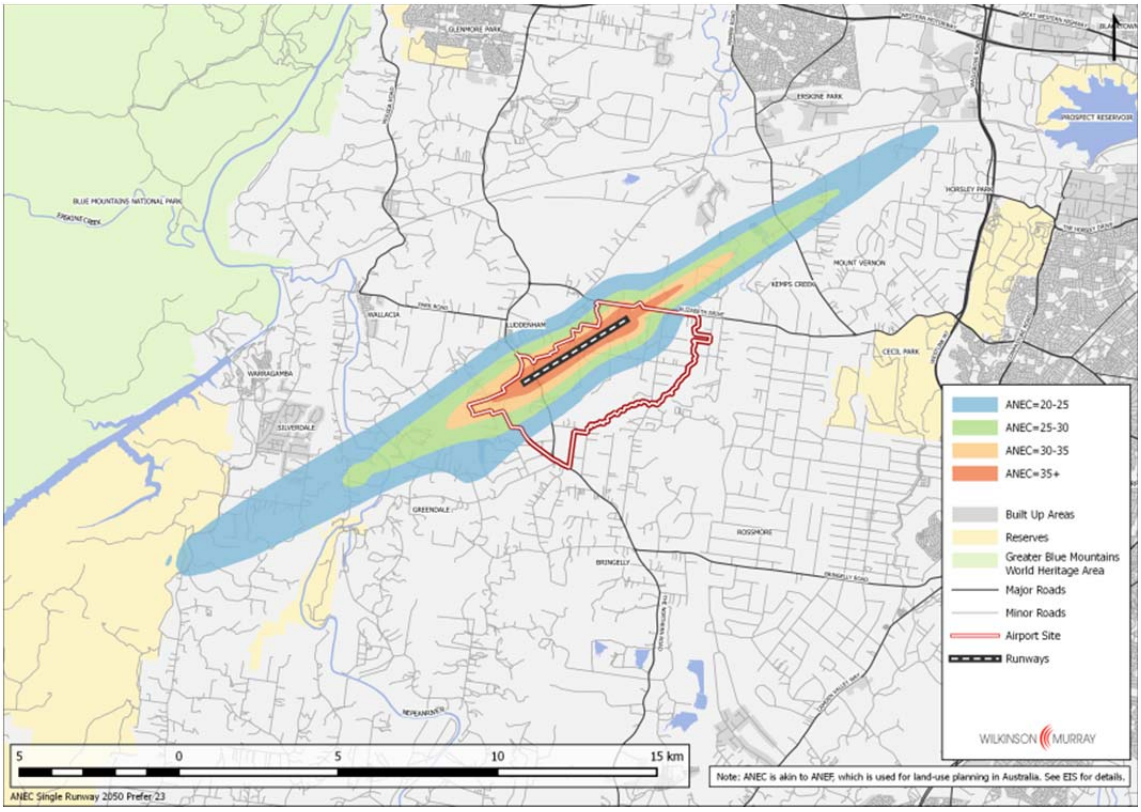


Figure 4-19 ANEC Contours – 2050 – Prefer 05 with Head-to-Head

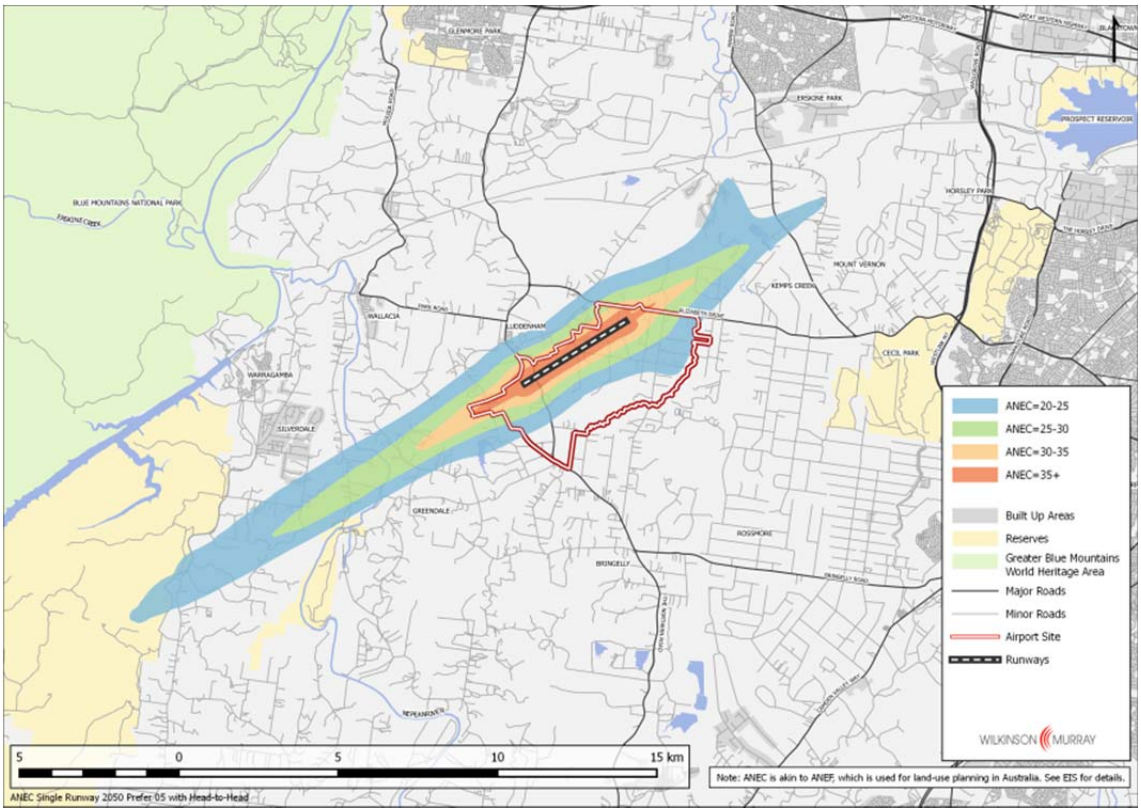


Figure 4-20 ANEC Contours – 2050 – Prefer 23 with Head-to-Head

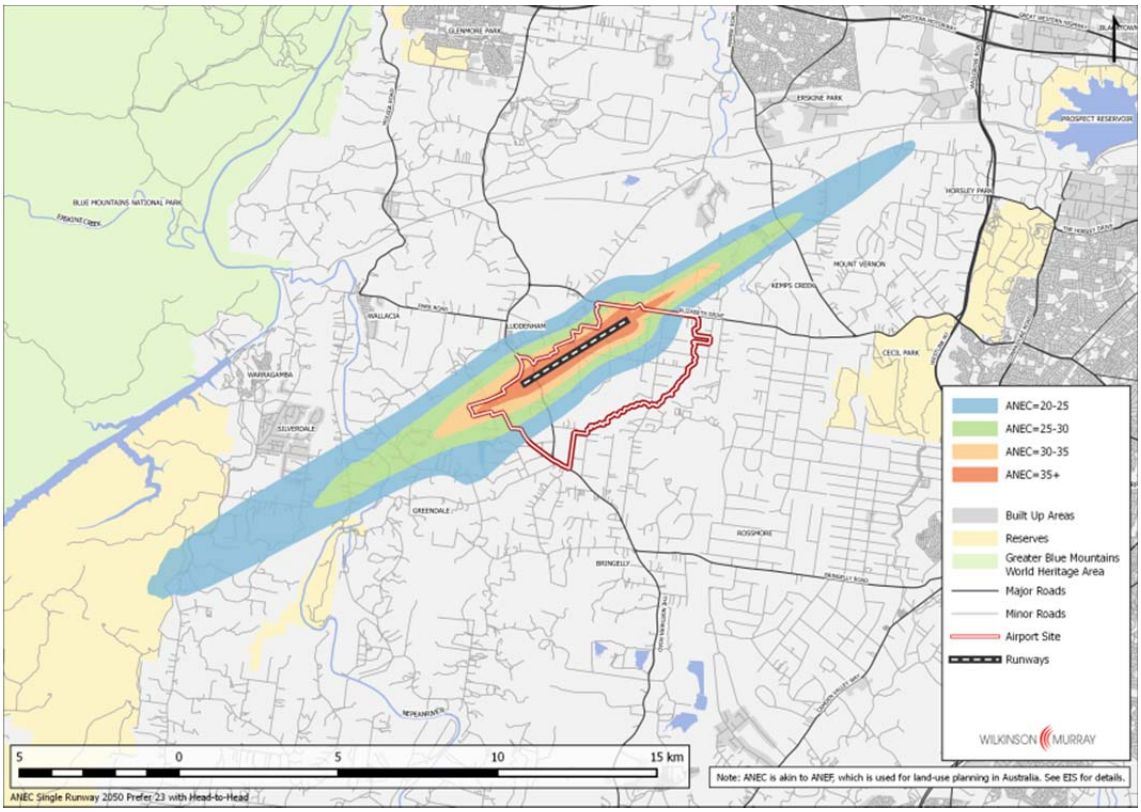


Table 4-3 Estimated Population within ANEC Contours – 2050

ANEC Band	Operating Strategy			
	Prefer 05	Prefer 23	Prefer 05 + H_2H*	Prefer 23 + H_2H*
20-25	1502	1645	1367	1672
25-30	295	390	353	379
30-35	34	77	38	77
>35	0	4	0	4
Total	***1831***	***2116***	***1758***	***2132***

Note: * H2H = "Head-to-Head"
Population figures in this table are estimates only and are valid for comparisons between modes

4.6 Aircraft Noise Levels in Recreational Areas

The Blue Mountains National Park and GBMWHA is an area used for recreational purposes that is located some distance from the proposed airport. The impact of aircraft overflights in these areas is considered in Section 7 of this report.

As noted in Section 3.7, a number of smaller recreational areas, located closer to the proposed airport, have been identified within the area potentially affected by aircraft overflight noise. These range from sports areas used for activities, such as horse riding, bowling or golf to nature reserves which may be used for more passive pursuits, including camping.

Table 4-4 and Table 4-5 show the identified recreation areas, and the predicted values of N70 and N60 for the Prefer 05 and Prefer 23 operating strategies. The values shown are for the period 7am – 6pm, representing the times when these areas would most likely be used.

Table 4-4 Average Number of Daily Noise Events with L_{Amax} Exceeding 70 dBA (N70) at Recreational Receivers

Recreational Receiver	2050	
	Prefer 05	Prefer 23
Bents Basin State Conservation Reserve & Gulguer Nature Reserve	0	0
Kemps Creek Nature Reserve	0	0
Rossmore Grange	0	0
Horsley Park Reserve	0	0
Twin Creeks Golf & Country Club	28	11
Sydney International Equestrian Centre	0	0
Whalan Reserve, St Marys	0	0

Table 4-5 Average Number of Daily Noise Events with L_{Amax} Exceeding 60 dBA (N60) at Recreational Receivers

Recreational Receiver	2050	
	Prefer 05	Prefer 23
Bents Basin State Conservation Reserve & Gulguer Nature Reserve	24	49
Kemps Creek Nature Reserve	0	0
Rossmore Grange	11	2
Horsley Park Reserve	0	0
Twin Creeks Golf & Country Club	78	27
Sydney International Equestrian Centre	0	0
Whalan Reserve, St Marys	4	10

A review of the results presented in Table 4-4 and Table 4-5 indicates the following:

- Most of the identified recreational receivers would not be subjected to aircraft overflight noise events with maximum levels exceeding 70 dBA – or their exposure would be significantly less than 1 event per day on average.
- **Twin Creeks Golf & Country Club** – Flyover noise levels from aircraft at this location would be noticeable out of doors and at times a raised voice effort would be required for effective communication. However it is noted that the sensitivity of receivers at this location would likely to be lower due to the active use of the area.
- **Bents Basin State Conservation Reserve & Gulguer Nature Reserve** are predicted to be subject to a number of flyover event noise levels exceeding 60 dBA, which would be noticeable to passive users of these areas. Bents Basin State Conservation Reserve is used for camping, and would be subject to less than five night time noise events exceeding 60 dBA.
- At Twin Creeks Golf & Country Club, noise exposure are predicted to be significantly reduced under a Prefer 23 operating strategy. However, at Bents Basin State Conservation Reserve noise exposure would be lower under a Prefer 05 operating strategy.

5 ASSESSMENT OF LONGER TERM AIRPORT DEVELOPMENT

5.1 Development Overview

The longer term development of the proposed Western Sydney Airport could involve construction and operation of a second runway which would be the subject of a separate future environmental impact assessment. However, a preliminary assessment of noise impacts from this development has been included in this report to provide an indication of potential future noise impacts. These predicted impacts are based on operational projections, best estimates of likely flight path configurations, and conservative assumptions regarding noise emission from future aircraft.

As noted in Section 2.6, the tracks and procedures to be used by aircraft using the proposed airport (either for the single runway or the longer term two runway configuration) are indicative and are required to undergo further detailed consideration before being finalised. Acknowledgement of this uncertainty is particularly important in the case of the longer term development. Other sources of uncertainty in this scenario are noise emission levels from future aircraft types, and the role and pattern of movements at a dual runway airport.

As noted in Section 2.7.2, in the longer term scenario, a number of alternative airport operating modes may be available under conditions of low traffic volume, and these may result in reduced noise impacts. However, at the time of production of this report, it was not possible to accurately ascertain which modes would be possible at a time so far into the future, and their capacities. Hence, in this section of the assessment, only the two basic operating modes – 05 and 23 – are considered, with corresponding operating strategies Prefer 05 and Prefer 23.

Nevertheless, this section provides a strategic indication of potential noise impacts that may assist in developing land use and other long-term plans for surrounding areas.

Figure 5-1 to Figure 5-10 show composite, single-event L_{Amax} noise level contours for departures and approaches by B747 and A320 aircraft, based on nominal flight tracks for the indicative longer term airport development.

Comparison of Figure 4-1 with Figure 5-1 indicates that although the aircraft types are exactly the same in the two cases, noise events would be experienced over a wider area due to the additional flight tracks that are proposed (refer Appendix A and B). In particular, a B747 aircraft (or a future type with equivalent noise emission) operating on certain departure tracks would result in noise levels exceeding 60 dBA over a larger area of the Blue Mountains National Park, and in some areas, the maximum noise level would exceed 70 dBA.

Maximum noise levels from other operations would affect similar numbers of residents compared to the proposed initial development, but the pattern of exposure would be different. Large numbers of residents would be newly exposed to noise levels exceeding 60 dBA, and some, notably in Silverdale, would be newly exposed to noise events over 70 dBA from A320 departures.

Figure 5-1 Combined Single Event B747 Departure Longer Term Assessment Scenario – Stage 9 (Macro Scale)

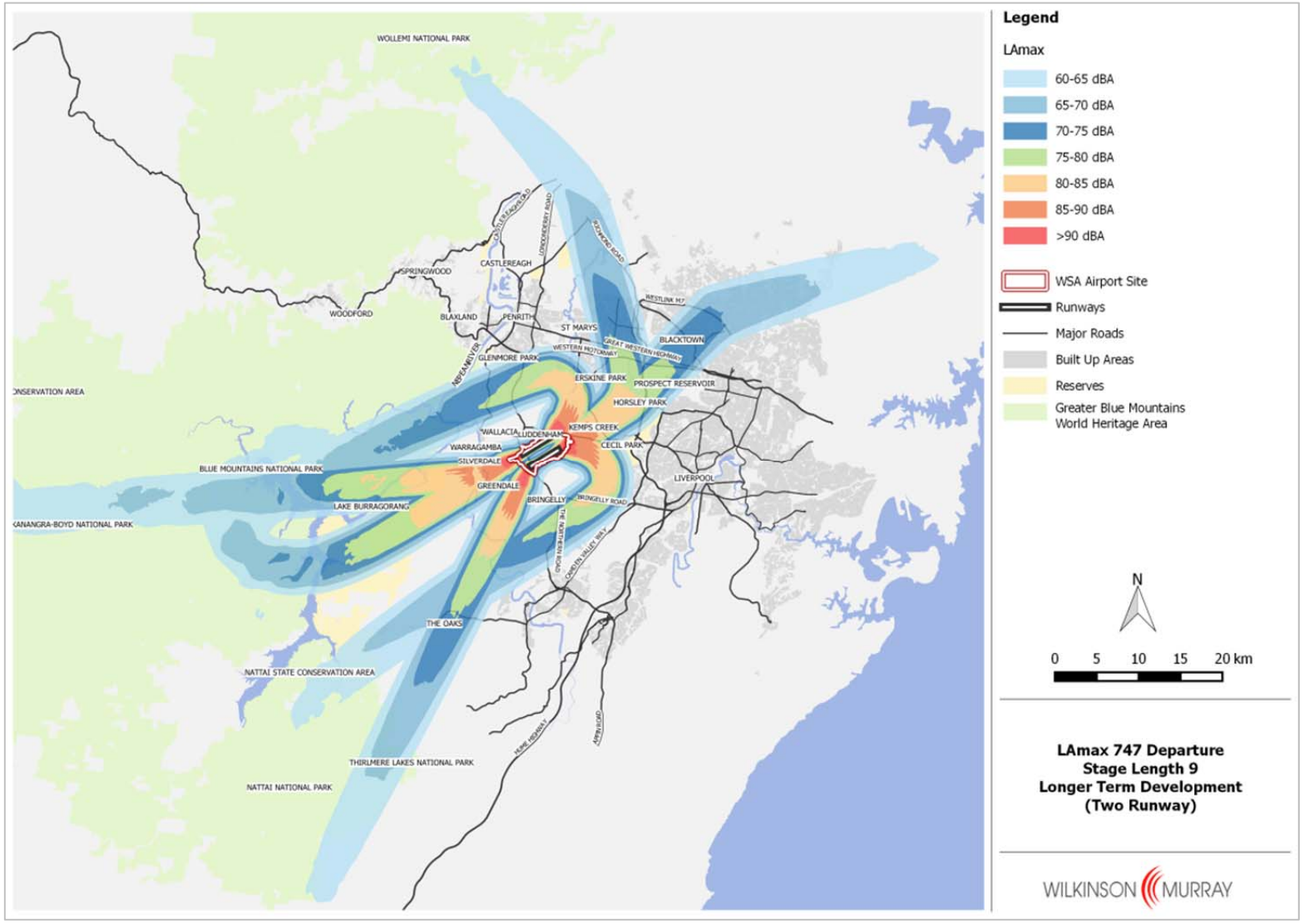


Figure 5-2 Combined Single Event B747 Departure Longer Term Assessment Scenario – Stage 9 (Meso Scale)

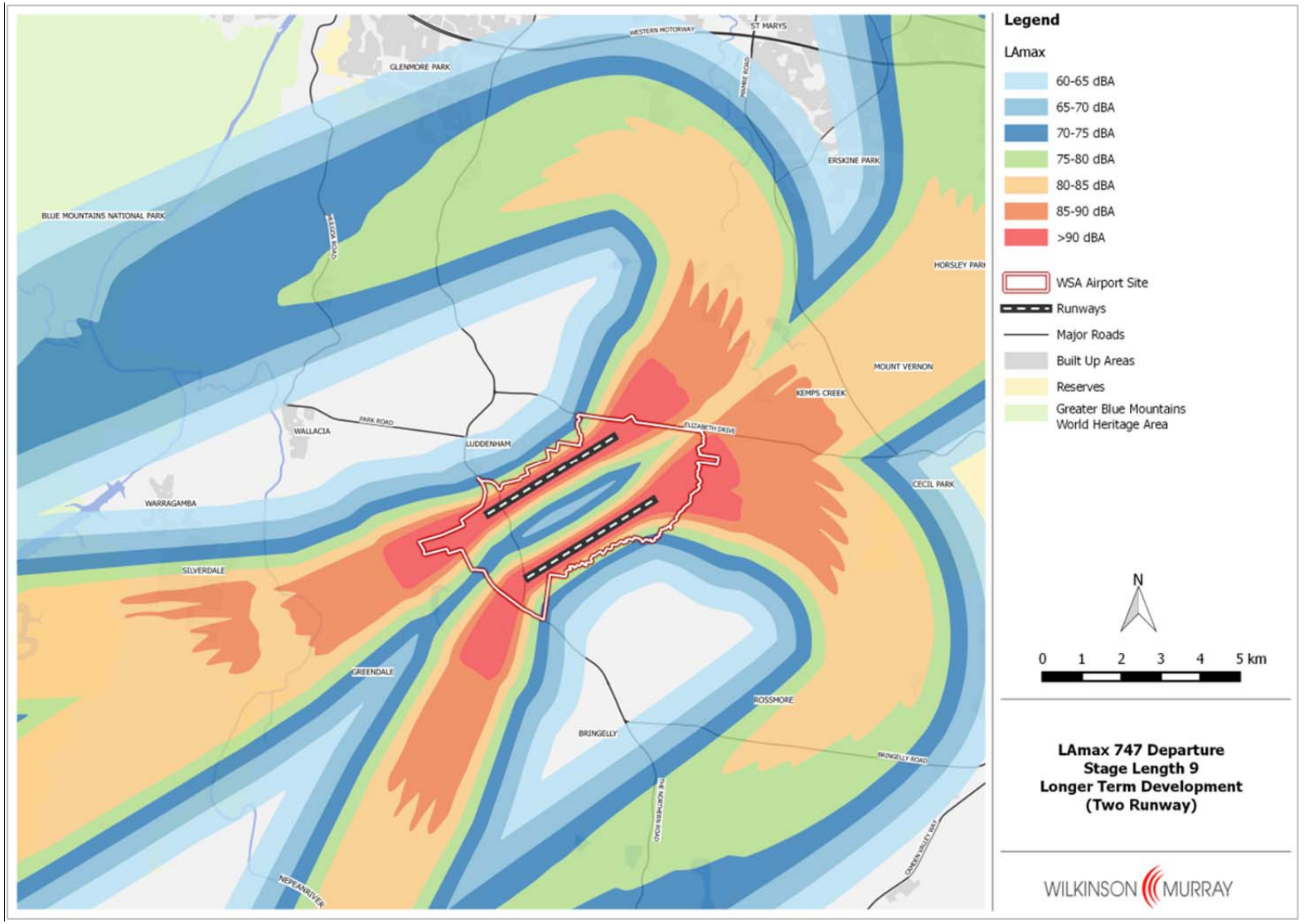


Figure 5-3 Combined Single Event B747 Arrival – Longer Term Assessment Scenario (Macro Scale)

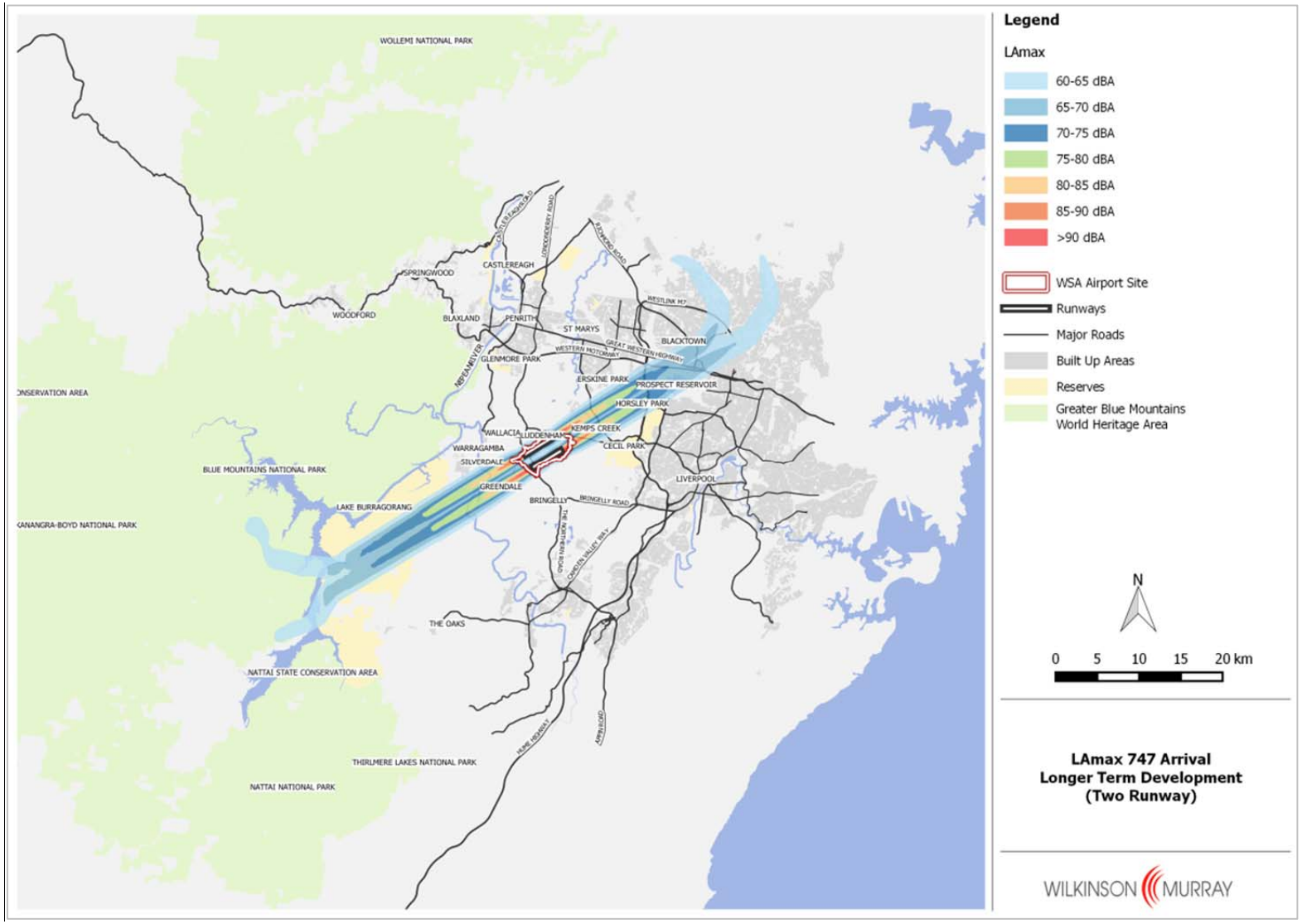


Figure 5-4 Combined Single Event B747 Arrival – Longer Term Assessment Scenario (Meso Scale)

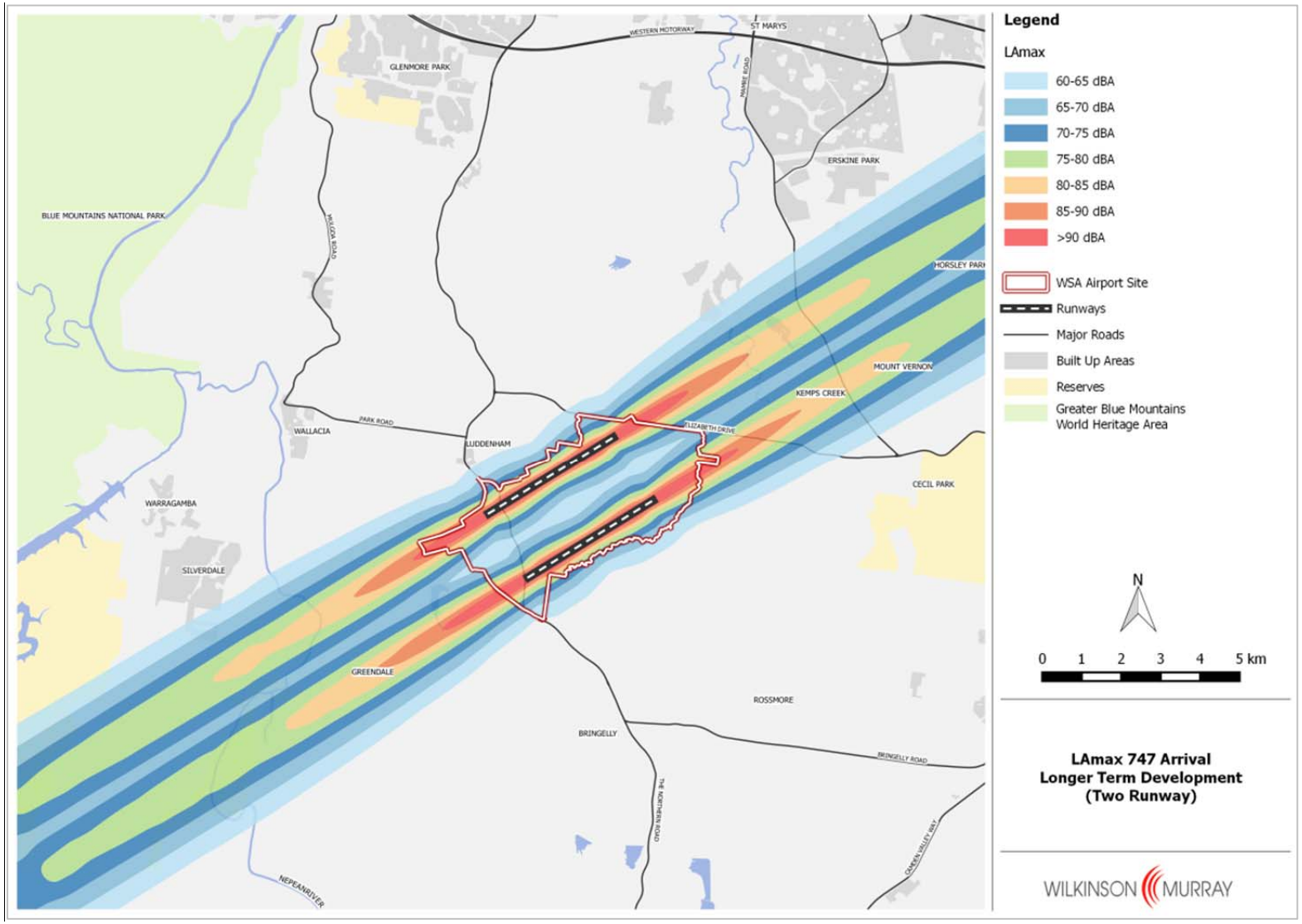


Figure 5-5 Combined Single Event A320 Departure – Stage 4 – Longer Term Assessment Scenario (Macro Scale)

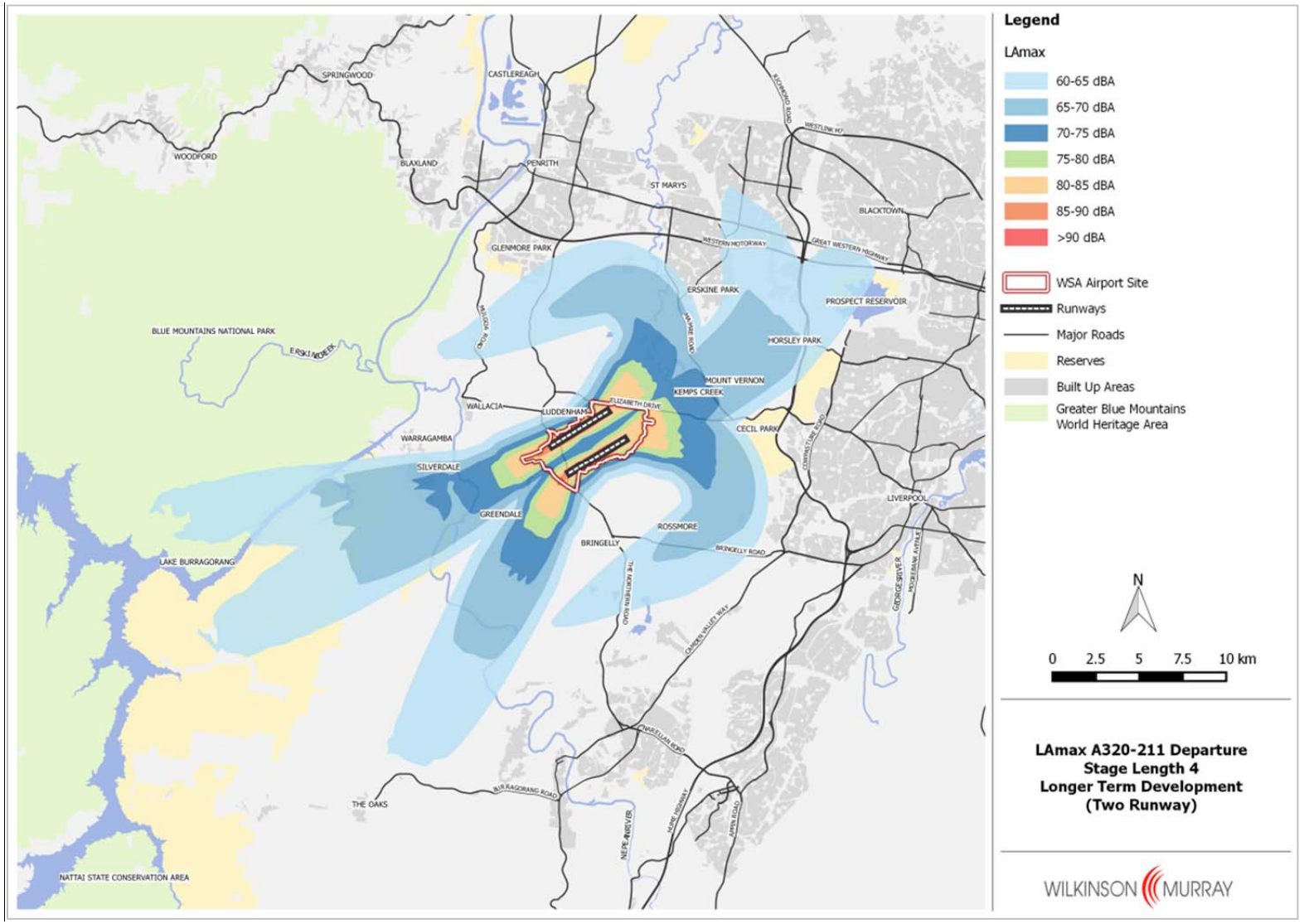


Figure 5-6 Combined Single Event A320 Departure – Stage 4 – Longer Term Assessment Scenario (Meso Scale)

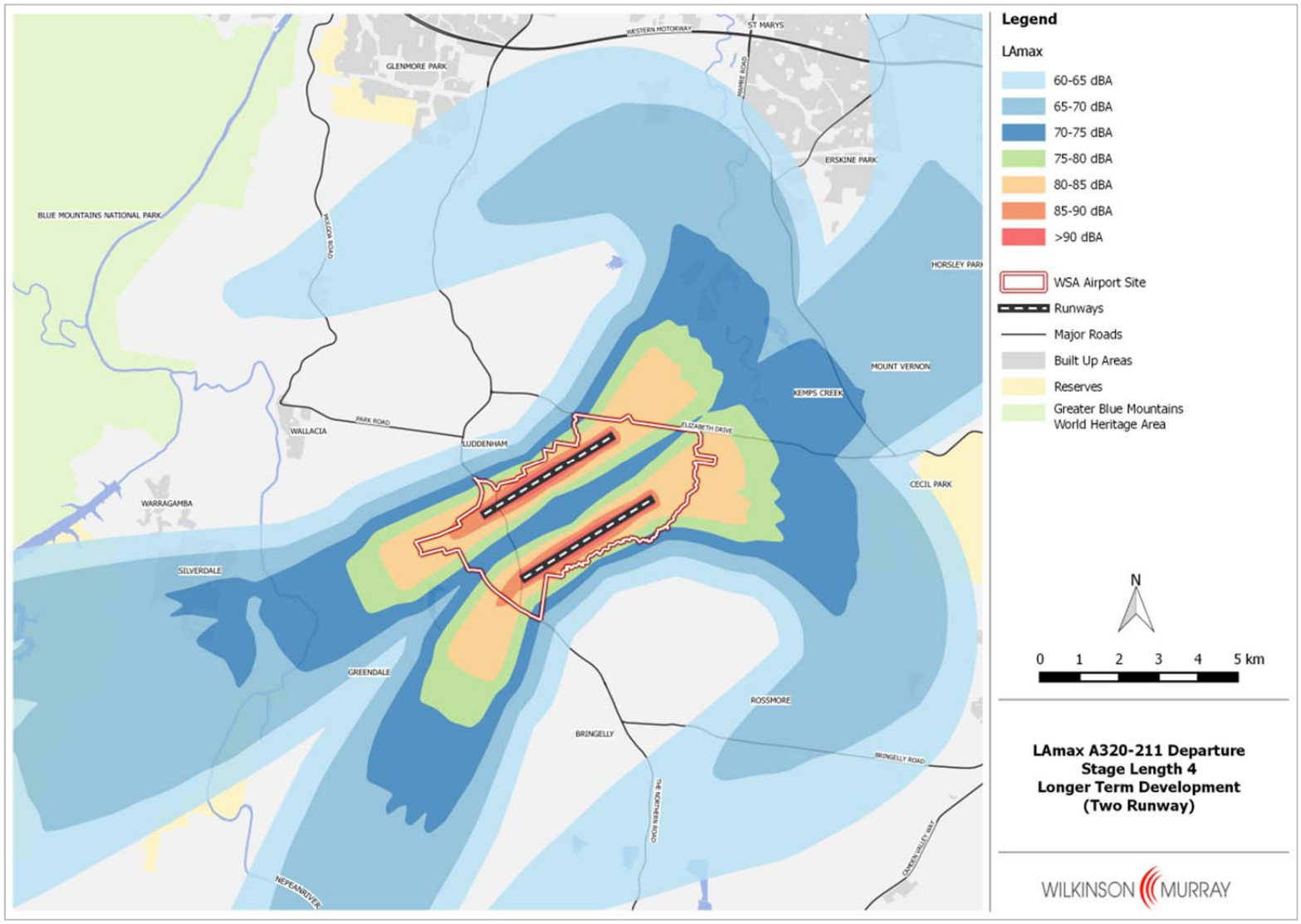


Figure 5-7 Combined Single Event A320 Departure – Stage 1 – Longer Term Assessment Scenario (Macro Scale)

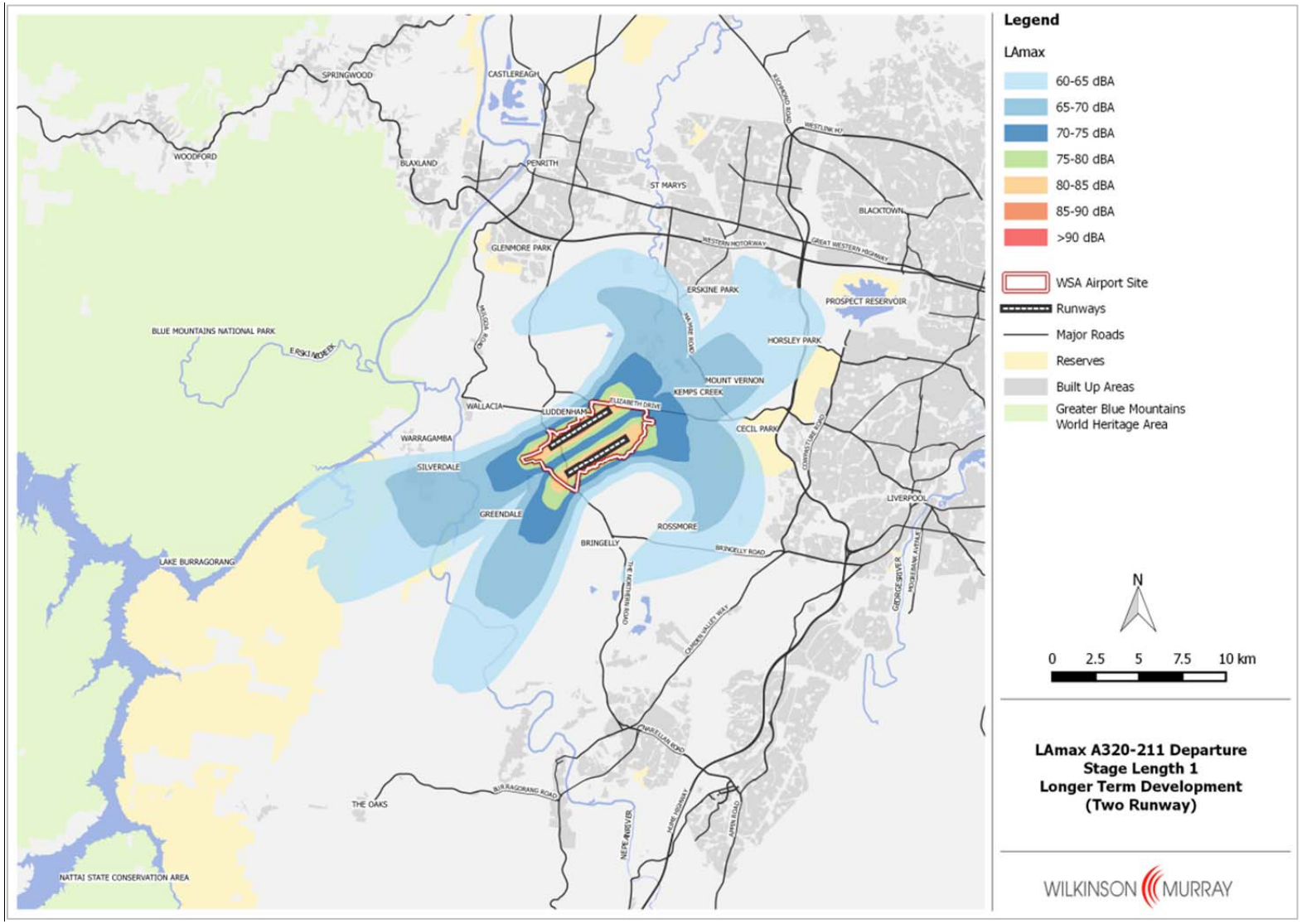


Figure 5-8 Combined Single Event A320 Departure – Stage 1 – Longer Term Assessment Scenario (Meso Scale)

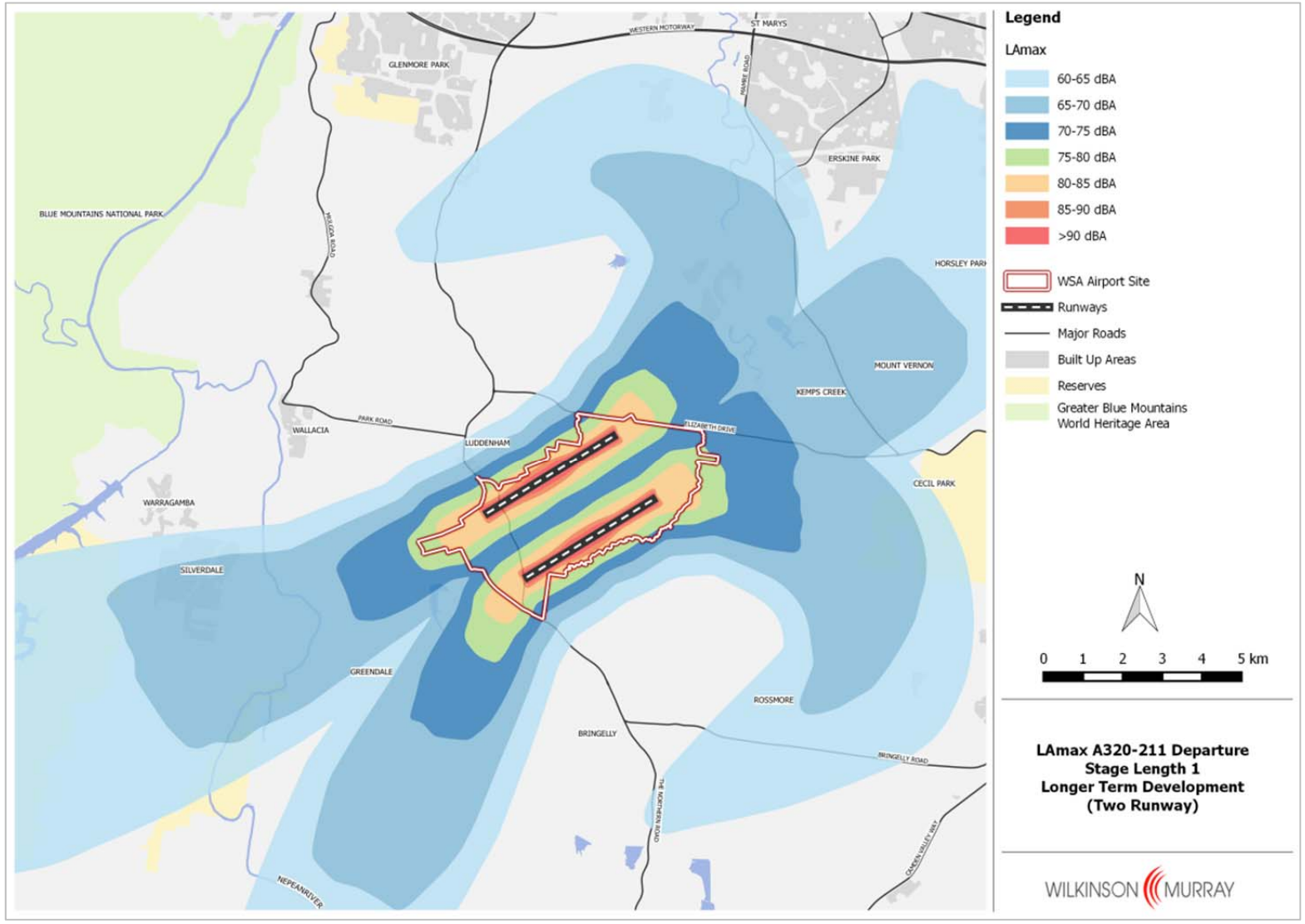


Figure 5-9 Combined Single Event A320 Arrival – Longer Term Assessment Scenario (Macro Scale)

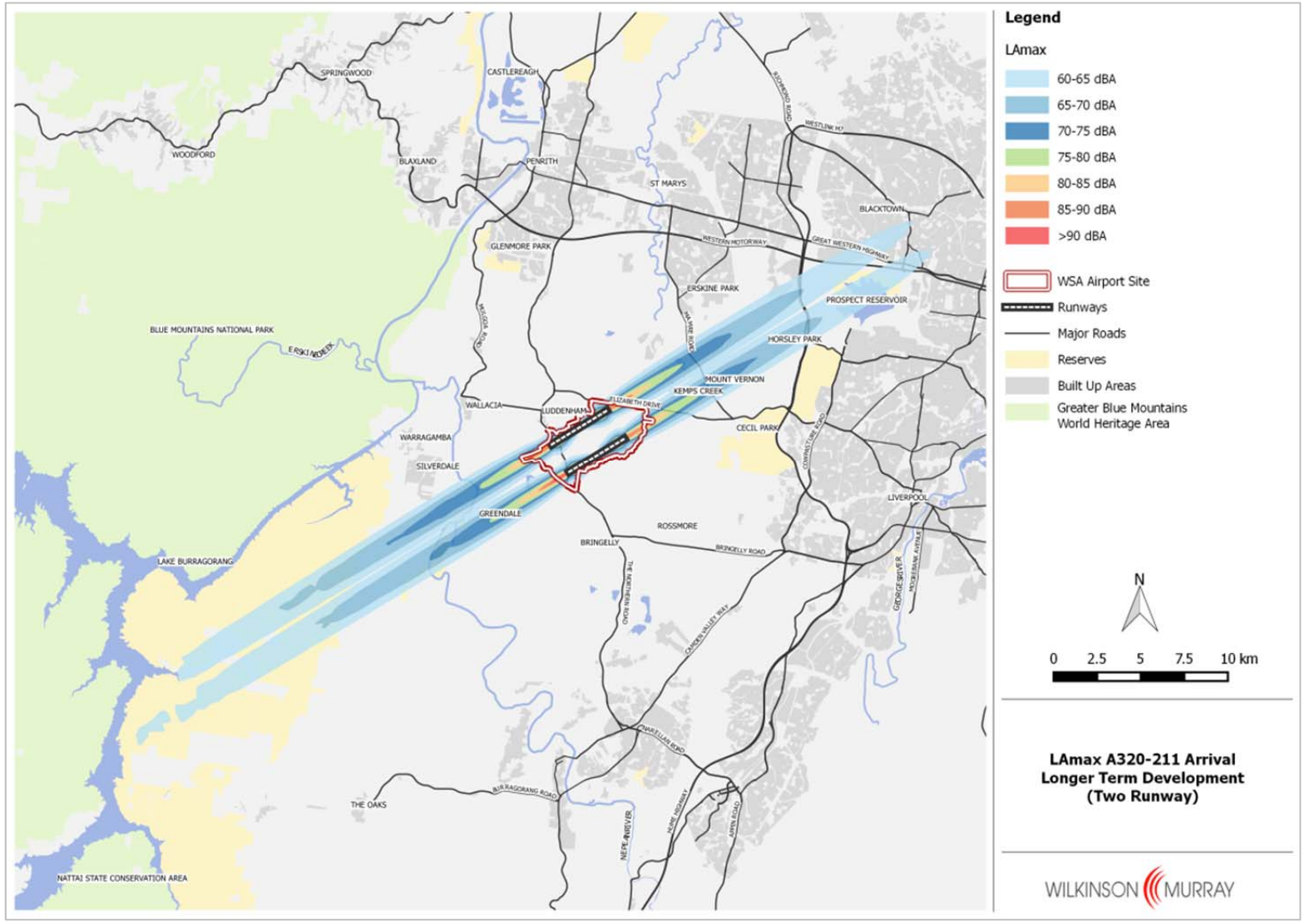
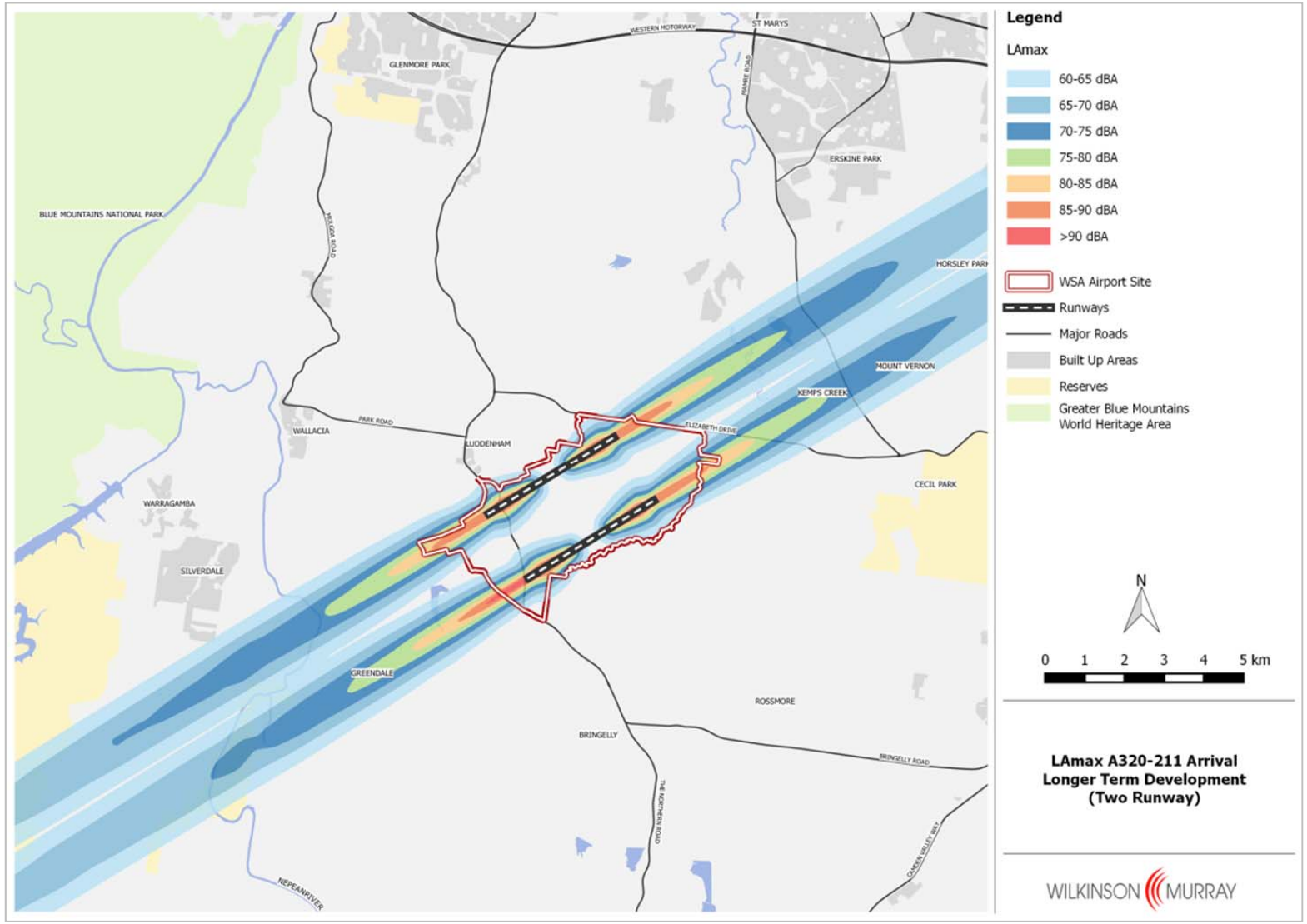


Figure 5-10 Combined Single Event A320 Arrival – Longer Term Assessment Scenario (Meso Scale)



5.2 Noise Levels Over 24 Hours

5.2.1 N70 Results

As in the case of the proposed initial airport development, differences between noise impacts in summer and winter were found to be minor, and hence in this report, noise impacts will be presented on an annual basis.

Figure 5-11 and Figure 5-12 show N70 contours for the two operating strategies considered. The differences between areas of affectation for the two strategies are similar to those found for the initial development.

Comparing Figure 5-11 and Figure 5-12 with Figure 4-3 and Figure 4-4 for the 2050 strategy, there are fewer densely-populated areas within the N70 = 5 contour, despite the number of movements at the airport being approximately doubled between 2050 and 2063. This is particularly true for the Prefer 05 operating strategy. The reason is that movements can be spread between two runways, and also the locations of flight tracks are less constrained in the two runway case.

Figure 5-11 N70 Contours – 2063 – Prefer 05

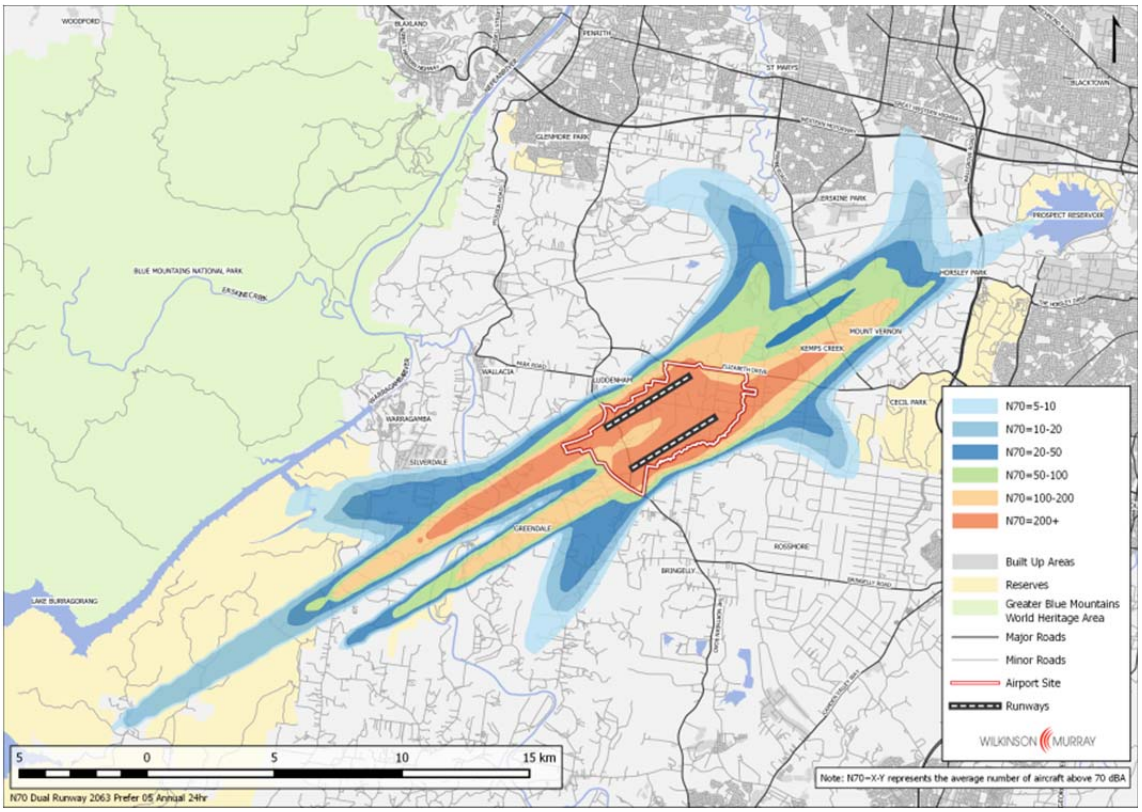
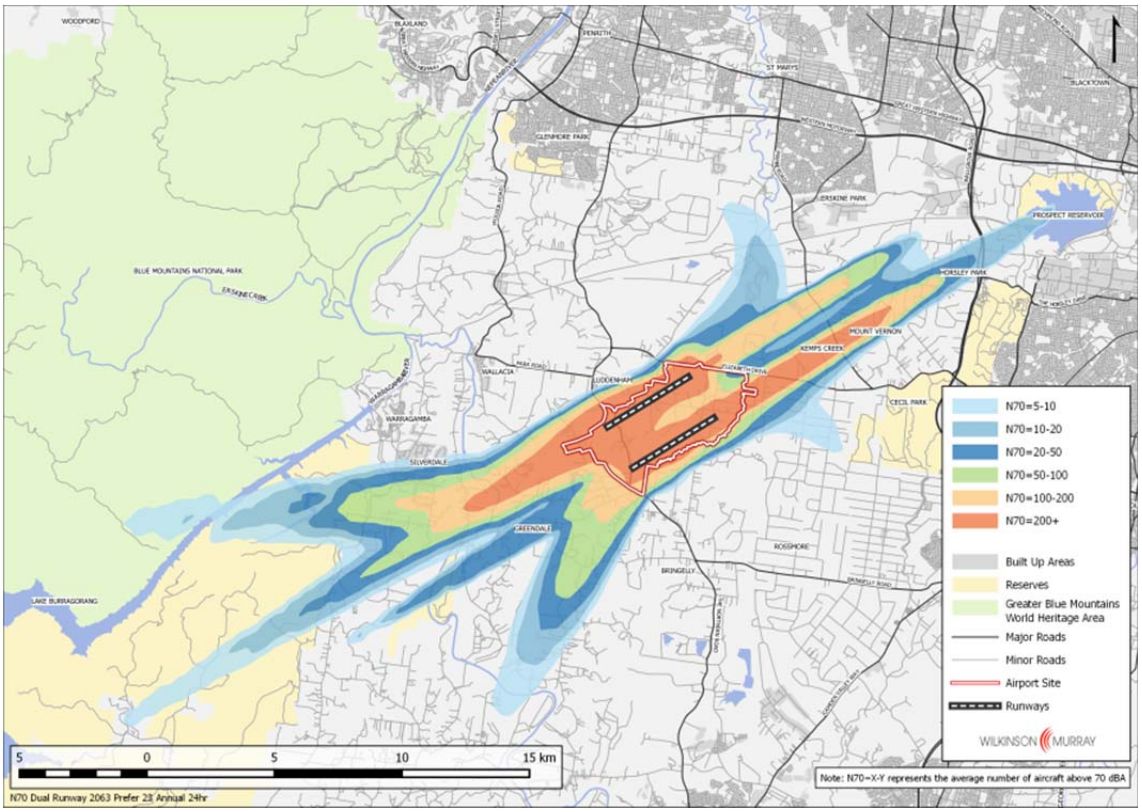


Figure 5-12 N70 Contours – 2063 – Prefer 23



5.2.2 90th Percentile N70 Results

Figure 5-13 and Figure 5-14 show calculated 90th percentile N70 contours for the two relevant strategies.

In this case, comparing “typical worst-case” days, the difference between the two strategies is much less significant than when comparing “average” days, and also less significant than for the 2050 strategy.

Figure 5-13 Mean & 90th Percentile N70 Contours – 2063 – Prefer 05

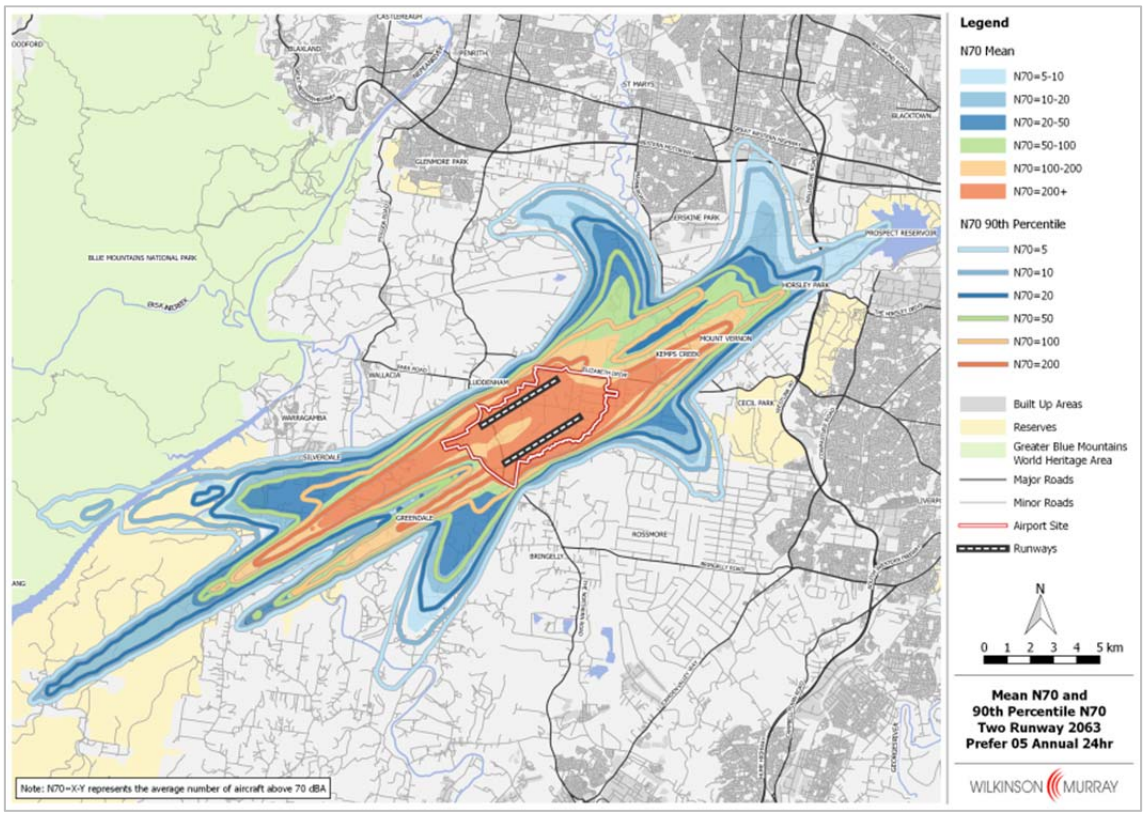
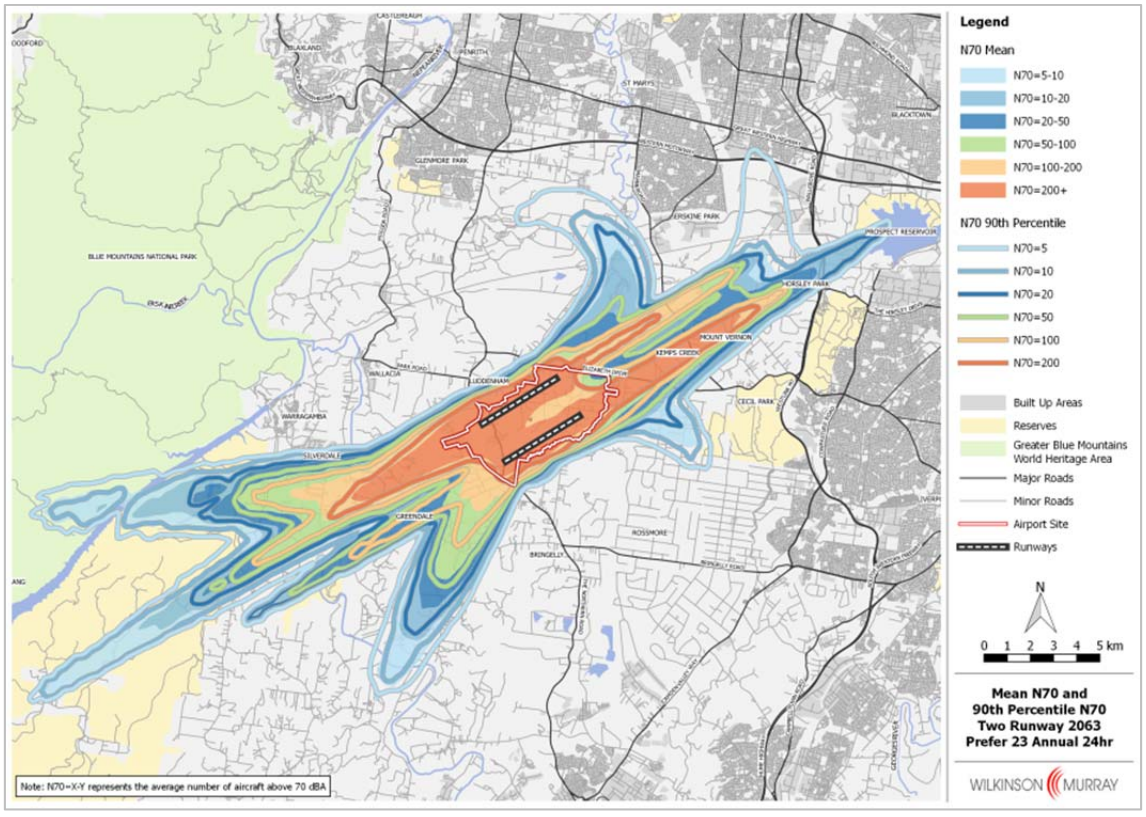


Figure 5-14 Mean & 90th Percentile N70 Contours – 2063 – Prefer 23



5.2.3 Population Exposure Estimates

The future population experiencing various levels of daytime noise impact was estimated using procedures described in Section 2.9. Results are shown in Table 5-1.

As noted above in the two runway case, there is little difference in the predicted number of people experiencing various levels of daytime noise exposure between a Prefer 05 and Prefer 23 strategy. Table 5-2 indicates that the total population affected by greater than 5, or greater than 10, events per day above 70 dBA is predicted to grow with time, with the exception of the Prefer 05 strategy for which the number of affected people decreases in 2063 compared to 2050. Under this strategy, the number of people affected in 2050 is disproportionately large, including large areas of St Marys and adjacent suburbs which are not impacted by noise levels exceeding 5 events above 70 dBA under the indicative 2063 airspace arrangements.

Table 5-1 Estimated Population within N70 Contours – 2063

N70	Operating Strategy	
	Prefer 05	Prefer 23
5-10	3,493	3,738
10-20	3,926	2,988
20-50	4,454	3,807
50-100	2,542	3,106
100-200	1,920	2,511
>200	1,083	1,321
Total	***17,418***	***17,471***

Population figures in this table are estimates only and are valid for comparisons between modes

Table 5-2 Comparison of Population within N70 Contours by Operating Strategy and Assessment Year

Assessment Year	Prefer 05		Prefer 23	
	N70 > 5	N70 > 10	N70 > 5	N70 > 10
2030	1,493	930	1,468	1,068
2050	29,913	9,720	5,289	3,056
2063	17,418	13,925	17,471	13,733

Population figures in this table are estimates only and are valid for comparisons between modes

5.3 Night Time Noise

5.3.1 N60 Results

Calculated average night time N60 contours for the year 2063 are presented in Figure 5-15 and Figure 5-16. It is clear that for either operating strategy, extensive residential areas are predicted to be affected by more than 10 events per night exceeding 60 dBA, but the extent of impact is more severe in the Prefer 05 case. On the other hand, modelling indicates that rural residential areas to the south and west of the airport would be more affected in the Prefer 23 case.

Figure 5-15 N60 Contours – 2063 – Prefer 05

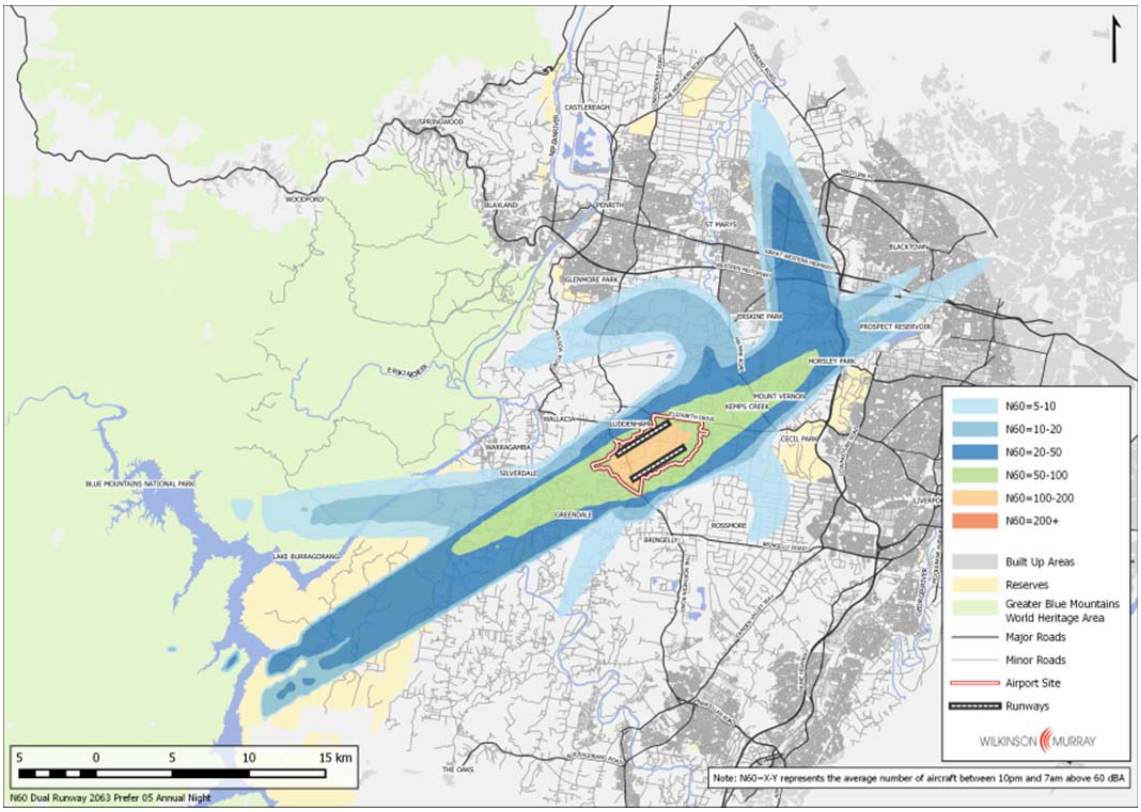
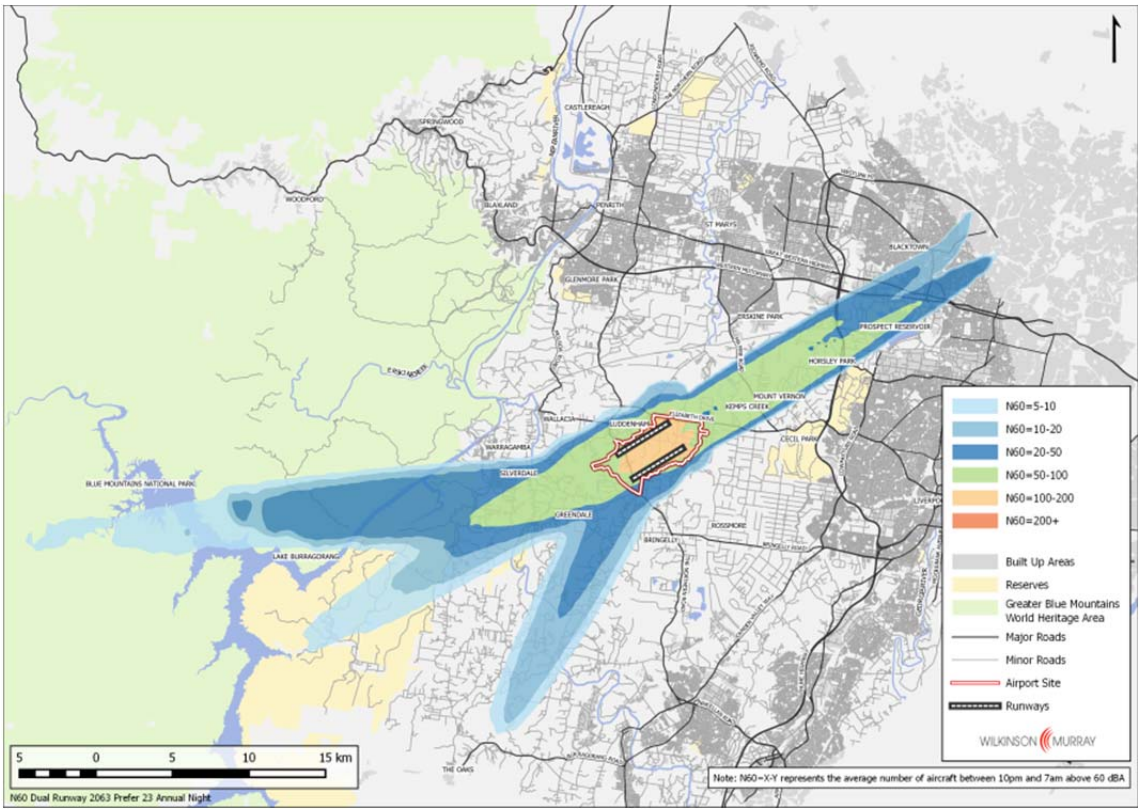


Figure 5-16 N60 Contours – 2063 – Prefer 23



5.3.2 90th Percentile N60 Results

Figure 5-17 and Figure 5-18 show 90th percentile ("typical worst-case") night time N60 contours. The distinction between the two operating strategies is even clearer – in the Prefer 05 case, the "typical worst-case" contours cover significantly more area than the "average" contours, while in the Prefer 23 strategy, the areas are almost the same.

Figure 5-17 Mean & 90th Percentile N60 Contours – 2063 – Prefer 05

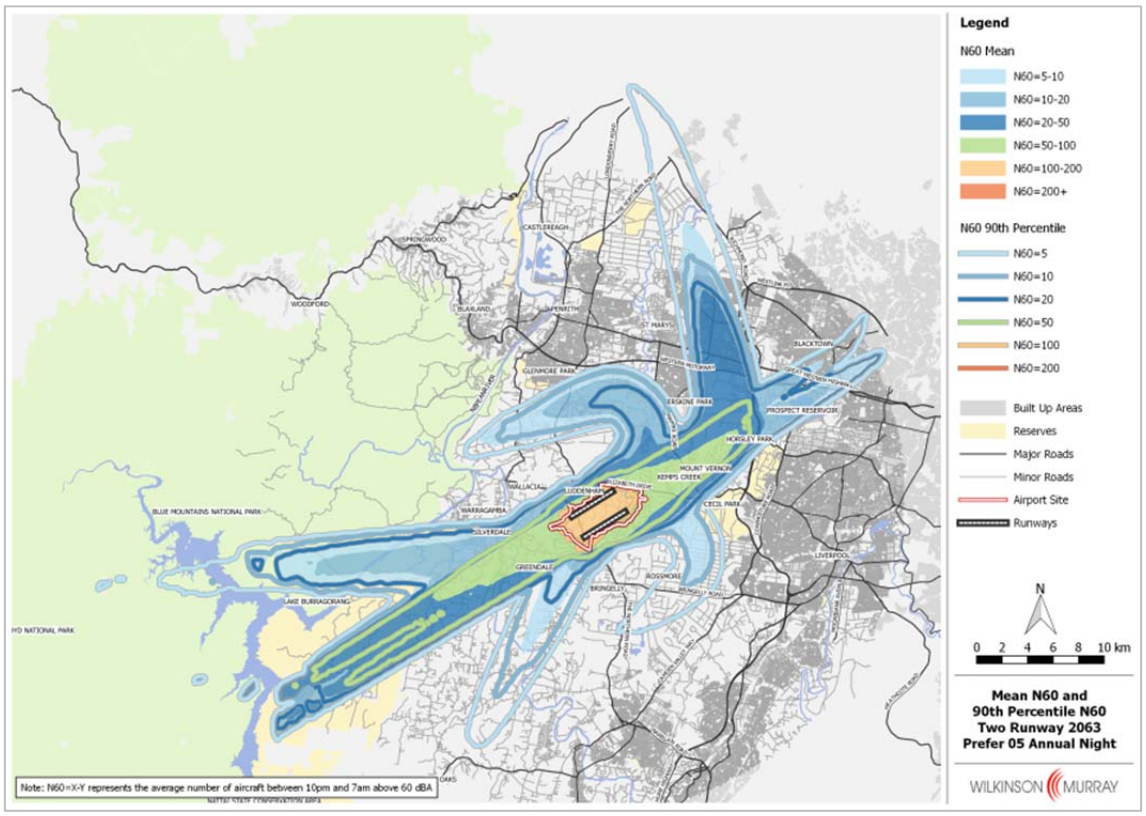
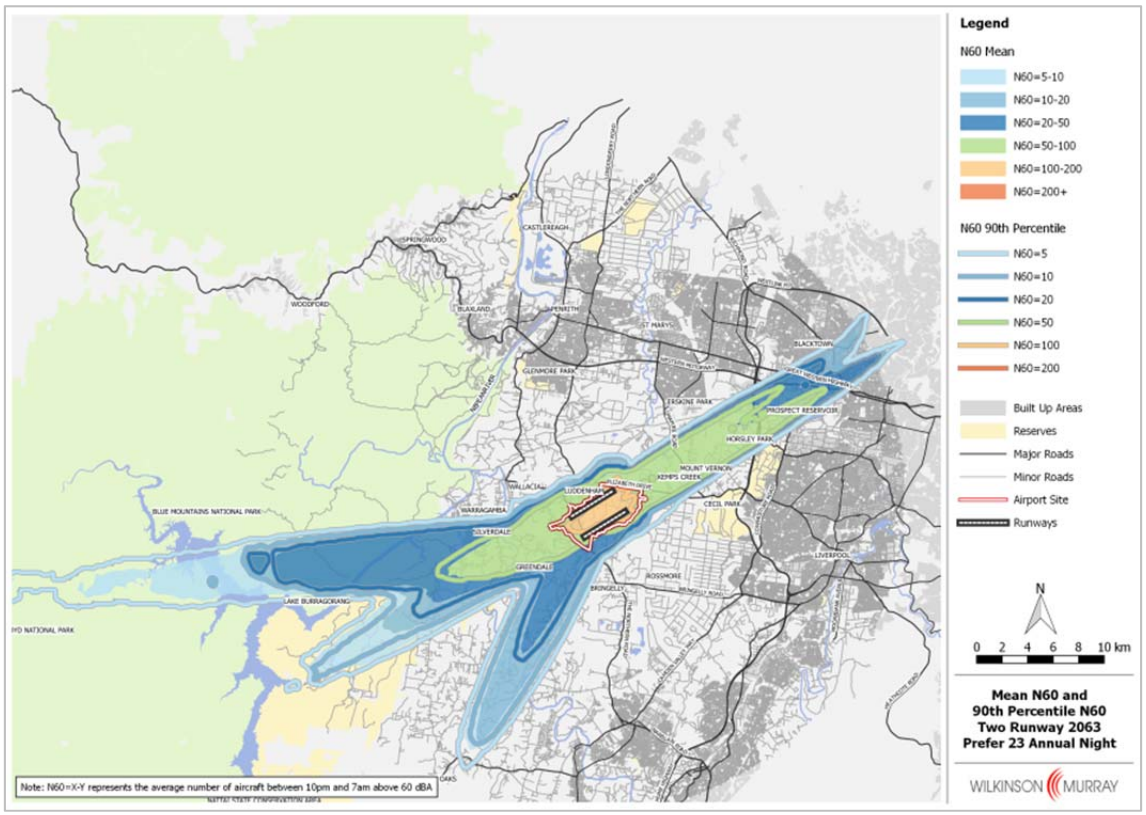


Figure 5-18 Mean & 90th Percentile N60 Contours – 2063 – Prefer 23



5.3.3 Population Exposure Estimates

The future population experiencing various levels of noise impact has been estimated using procedures described in Section 2.9. Results are shown in Table 5-3. This table shows that predicted night time impacts in 2063 are significantly higher with the Prefer 05 operating strategy.
Table 5-4 shows a comparison between night time noise impacts in each nominal year.
However, it should be remembered that analysis for nominal year 2063 does not allow for noise mitigation by the use of alternative night time operating modes. For the Stage 1 and 2050 scenarios, a "Head-to-Head" mode could significantly reduce night time impacts, and it is likely that similar modes could be equally effective in the dual runway case.

Table 5-3 Estimated Population within N60 Contours – 2063

N60	Operating Strategy	
	Prefer 05	Prefer 23
5-10	81,333	10,509
10-20	45,372	43,963
20-50	68,963	42,097
50-100	5,313	8,236
>100	0	0
Total	***200,981***	***104,805***

Population figures in this table are estimates only and are valid for comparisons between modes

Table 5-4 Comparison of Population within N60 Contours by Operating Strategy and Assessment Year

Assessment Year	Prefer 05		Prefer 23	
	N60 > 5	N60 > 10	N60 > 5	N60 > 10
2030	48,405	1,674	6,179	2,743
2050	137,431	108,303	170,391	26,564
2063	200,981	119,648	104,805	94,296

Population figures in this table are estimates only and are valid for comparisons between modes

5.4 Land Use Planning Impacts

5.4.1 ANEC Contours

ANEC contours for the two operating strategies considered are shown in Figure 5-19 and Figure 5-20. As expected, these cover a larger area than for the 2050 assessment scenario and, as shown in Table 5-5, they cover a larger estimated population. However, they remain well separated from existing built-up residential areas.

Figure 5-19 ANEC Contours – 2063 – Prefer 05

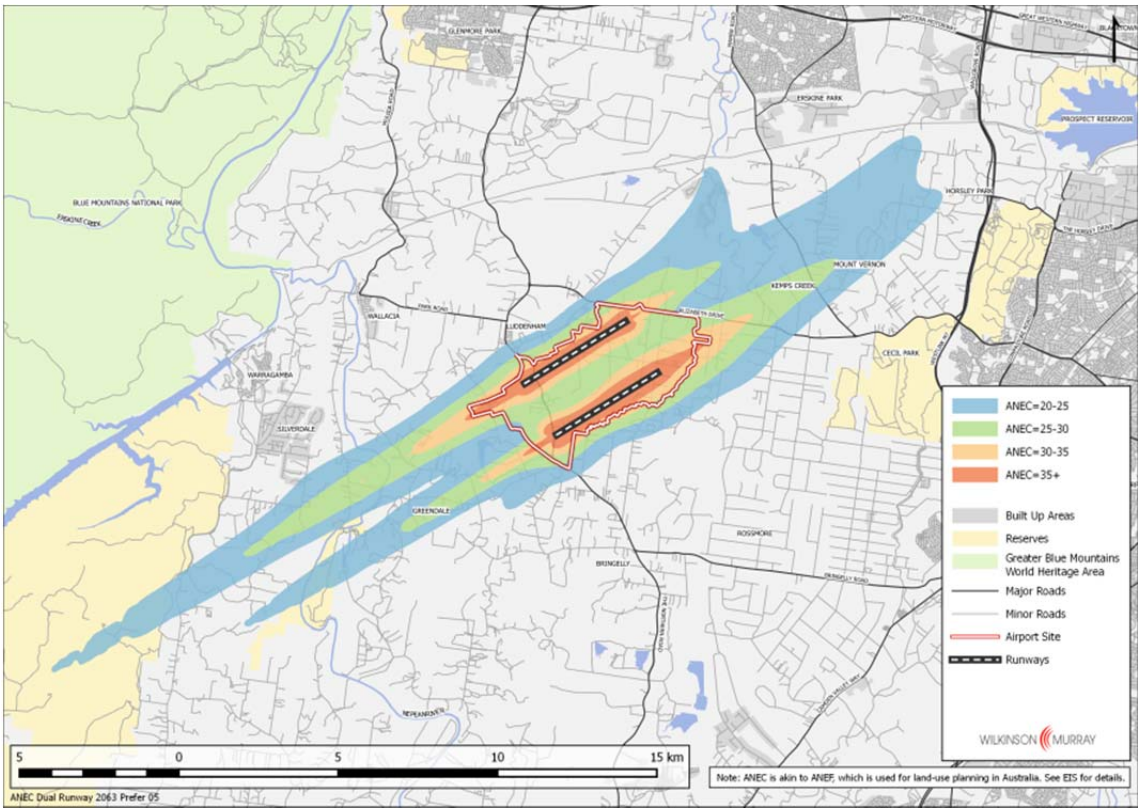


Figure 5-20 ANEC Contours – 2063 – Prefer 23

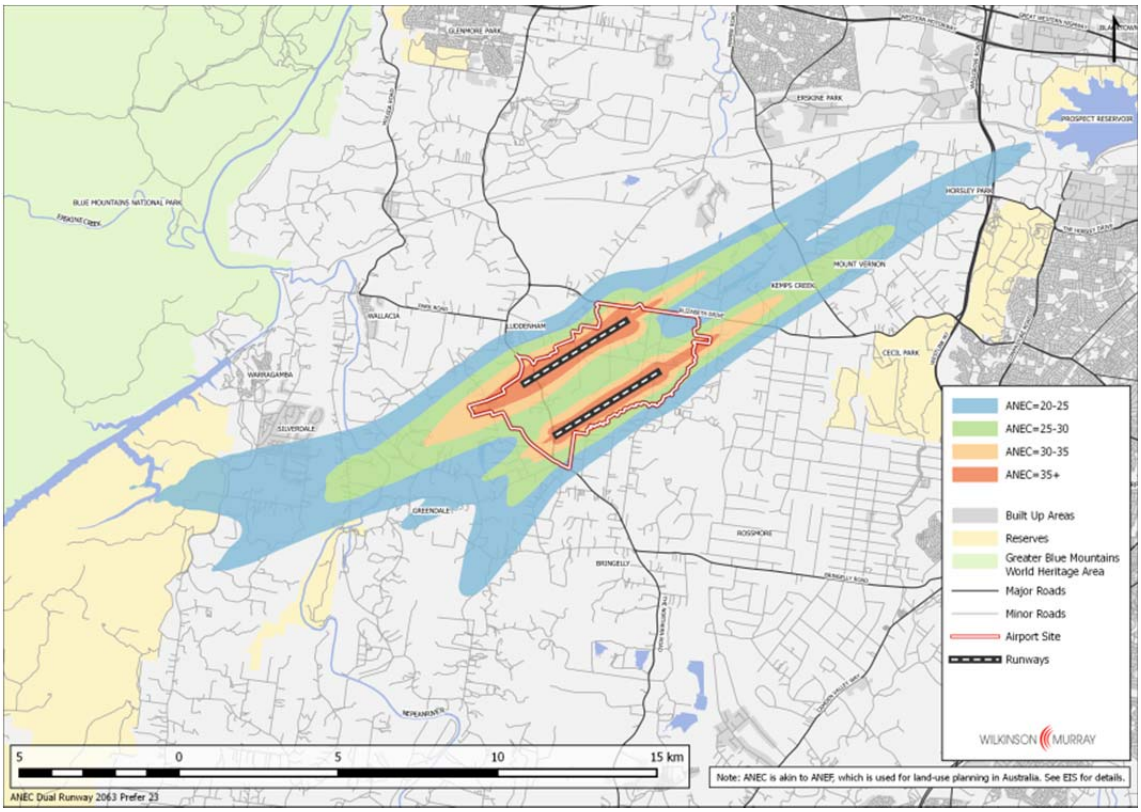


Table 5-5 Estimated Population within ANEC Contours – 2063

ANEC Band	Operating Strategy	
	Prefer 05	Prefer 23
20-25	5803	7832
25-30	1486	1934
30-35	570	527
>35	0	26
Total	***7858***	***10319***

Population figures in this table are estimates only and are valid for comparisons between modes

6 NOISE-INDUCED VIBRATION

At high noise levels, the low frequency components of aircraft noise can result in vibration of loose elements in buildings, notably windows. This effect is distinct from that of wake vortices, which result from aerodynamic turbulence caused by an aircraft as it passes through the air. At some airports, wake vortices have been known to dislodge roof tiles on residences very close to the runway end. Even at the highest expected noise levels the levels of vibration due to low frequency noise are well below those which may cause structural damage to buildings. However, they can result in secondary radiation from loose windows and other building elements.

With typical light building structures, noise induced vibration may begin to occur where the maximum external noise level reaches approximately 90 dBA. The effect is more common on take-offs than for landings, since the noise spectrum for a take-off close to the airport has stronger low frequency components.

Figure 6-1 to Figure 6-3 show 85 dBA and 90 dBA noise level contours for a B747 aircraft departure (stage length 5 for 2030 and stage length 9 for 2050 and 2063). Only areas within the 90 dBA contour could expect to experience any noise-induced vibration of building structures, and then only during a departure of a B747 aircraft with maximum stage length. For 2030, there are estimated to be no existing residences within this contour, while for 2050 there are estimated to be fewer than ten. For the 2063 scenario, there are also estimated to be fewer than 10 existing residences within this contour.

Figure 6-1 85 dBA & 90 dBA L_{Amax} Contours – B747 Departure Stage 5 – Initial Airport Development

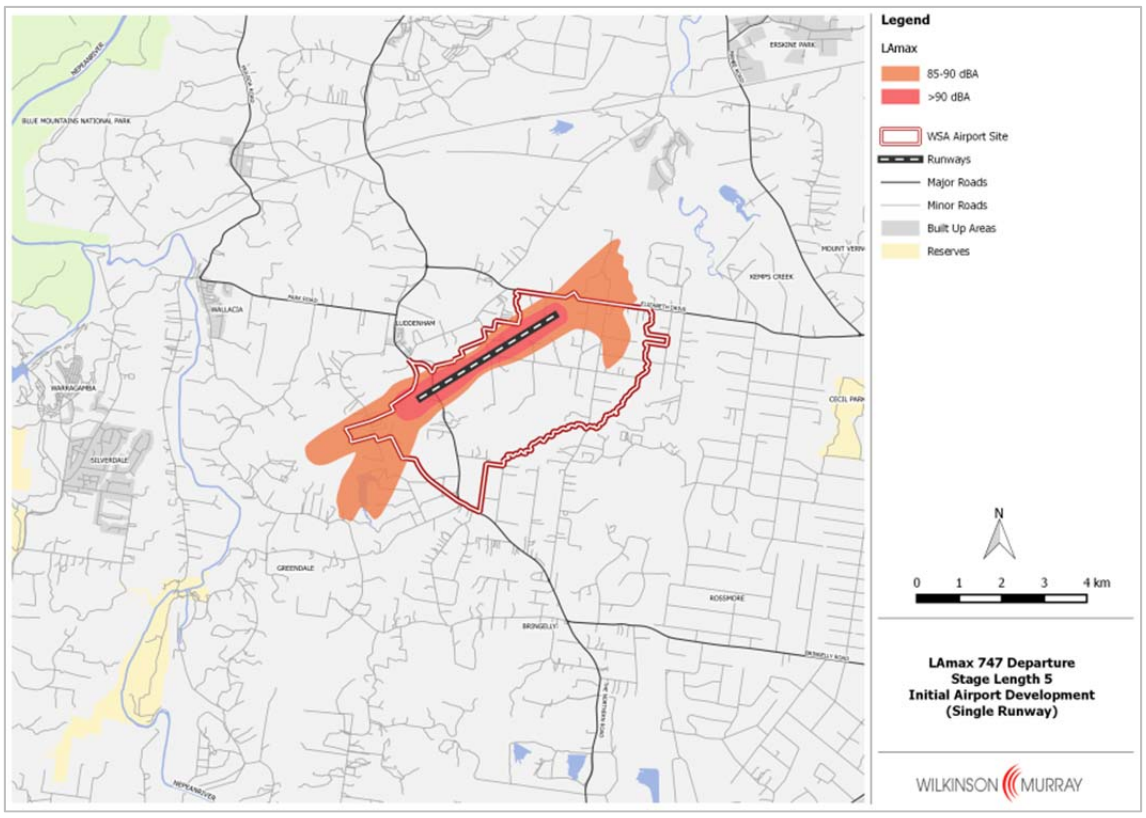


Figure 6-2 85 dBA & 90 dBA L_{Amax} Contours – B747 Departure Stage 9 – Increased Capacity

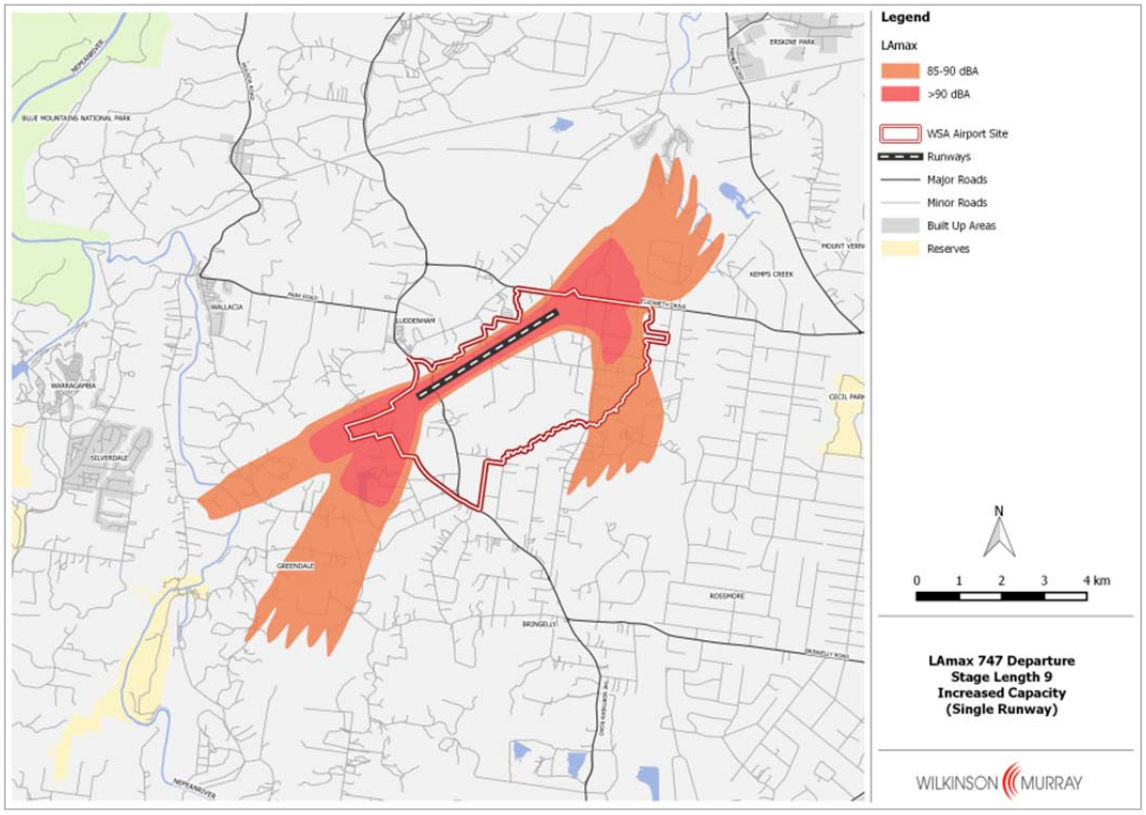
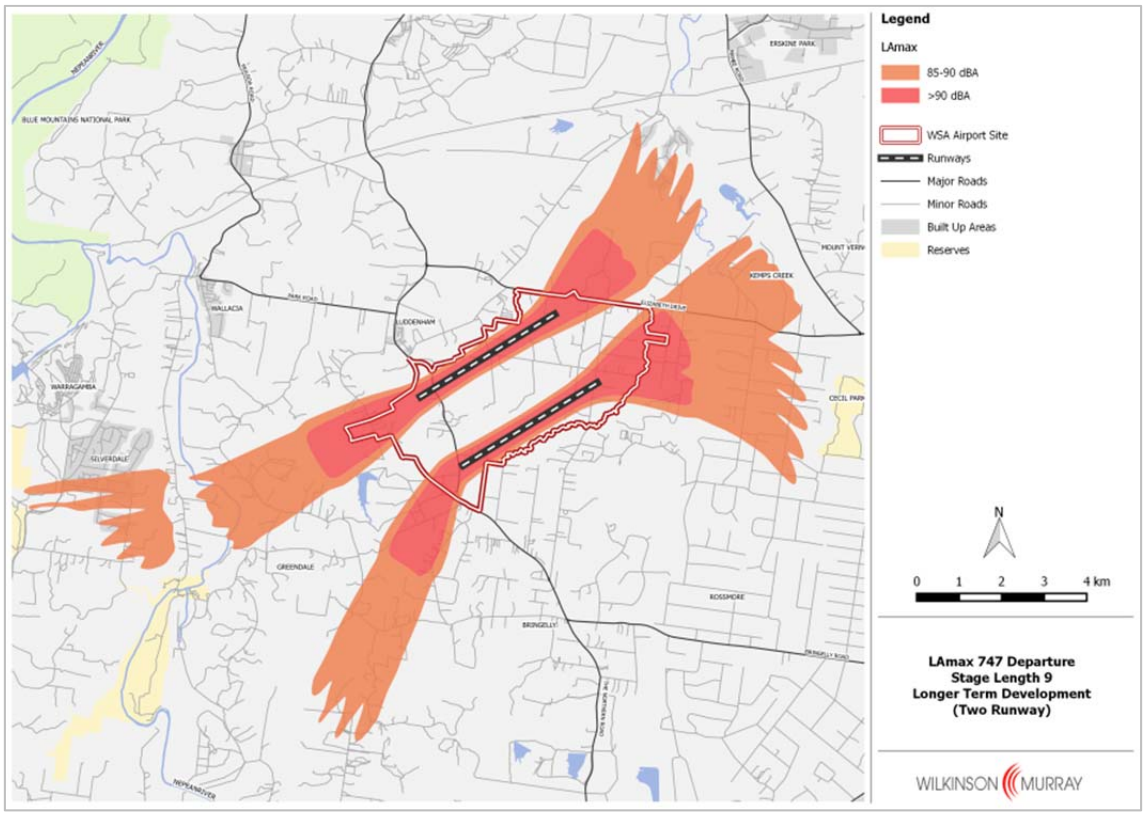


Figure 6-3 85 dBA & 90 dBA L_{Amax} Contours – B747 Departure – Longer Term Airport Development



7 GREATER BLUE MOUNTAINS WORLD HERITAGE AREA

7.1 Track Density Methodology

Over the Greater Blue Mountains World Heritage Area (GBMWHA), noise levels due to aircraft operating at the proposed airport are expected to be lower than the levels described in the previous sections, as the GBMWHA is further from the airport. Although occasional noise events may reach 60 dBA at some points in the area, levels directly beneath a flight track will typically be below 55 dBA, and often much lower. In addition, this area is already subjected to low-level noise from aircraft using Sydney (Kingsford Smith) Airport and other aviation activities, including low-level sightseeing flights.

Nevertheless, given the various amenity issues that complement the biodiversity values and integrity of the GBMWHA, an increase in the number of audible overflights at certain locations within the area may be considered to be intrusive by recreational visitors and other users.

In order to illustrate the potential changes to the number of aircraft movements in the GBMWHA, track density plots have been prepared to provide a graphical representation of the number of existing and projected future operations in the area.

Existing average daily aircraft movements across the GBMWHA were determined from existing flight track data and are based on a sample of one day in every two over the year May 2014 – April 2015. These are plotted as a "heat map" showing the number of tracks per day that pass within 300 m (horizontally) of any point on the ground.

Future predicted operations in 2030 and 2050 were plotted in the same way, after adding these to the "existing" tracks. This is used to illustrate the areas in which additional aircraft would be seen overhead, and the degree of change involved.

Most of the "new" tracks over this area from the proposed airport in 2030 and 2050 are arrivals, and all arriving aircraft are assumed to pass through the designated airspace "merge point".

Results in this section focus on diagrams showing the total number of tracks, independent of aircraft operating height. However, in this area aircraft associated with the proposed airport will generally be lower than existing aircraft. Diagrams in Appendix D show the number of existing and future tracks for regular public transport (RPT) flights at heights of 5000 ft and below.

7.2 Track Density Diagrams – Original Merge Point

Figure 7-1 shows the density of existing RPT aircraft tracks over the GBMWHA. In most areas, this is about 1 per day, rising to 10 per day under certain specific tracks and almost 50 per day under one track to the south-east.

Figure 7-2 to Figure 7-5 show track densities including movements from the proposed airport, for the Prefer 05 and Prefer 23 operating strategies in 2030 and 2050. In many places the predicted difference in density is large, particularly under arrival paths where the number of events can be over 200 per day. Although noticeable, noise levels associated with the overflights are expected to be low and comparable with other sounds heard in the area. The fact that the predicted overflights are concentrated on specific tracks means that other parts of the GBMWHA would be relatively unaffected.

The location of the nominal “merge point” is almost over the township of Blaxland, meaning that residents could expect to experience some 230 overflights per day in 2050 passing directly overhead, albeit at typically more than 5000 ft above ground level and with maximum noise levels below about 55 dBA.

Given this, it was determined to investigate the impact of relocating the “merge point” for assessment purposes.

Figure 7-1 Track Density – Existing 2014 – 15 Aircraft Movements

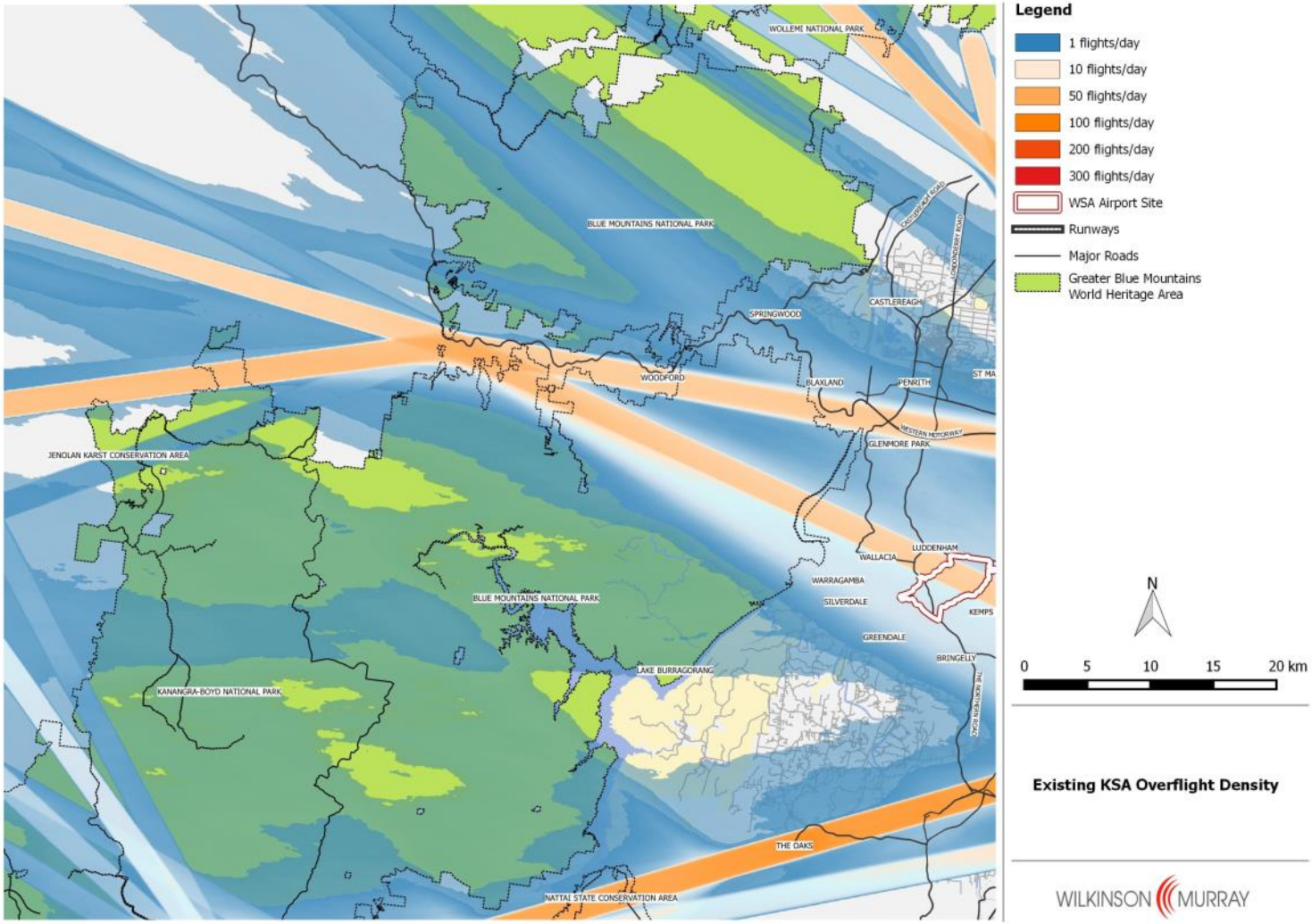


Figure 7-2 Track Density – Existing & WSA 2030 Aircraft Movements – Prefer 05

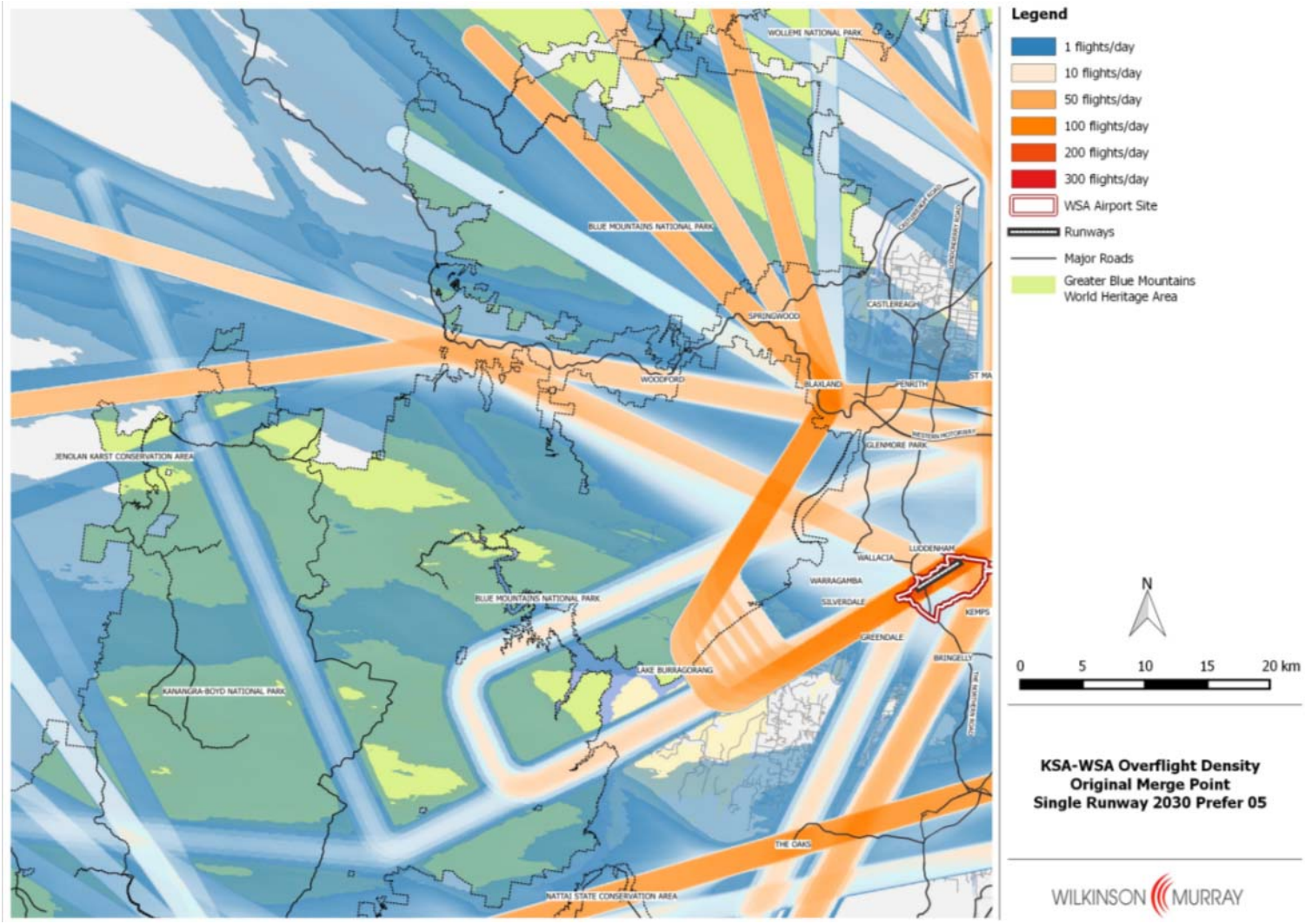


Figure 7-3 Track Density – Existing & WSA 2030 Aircraft Movements – Prefer 23

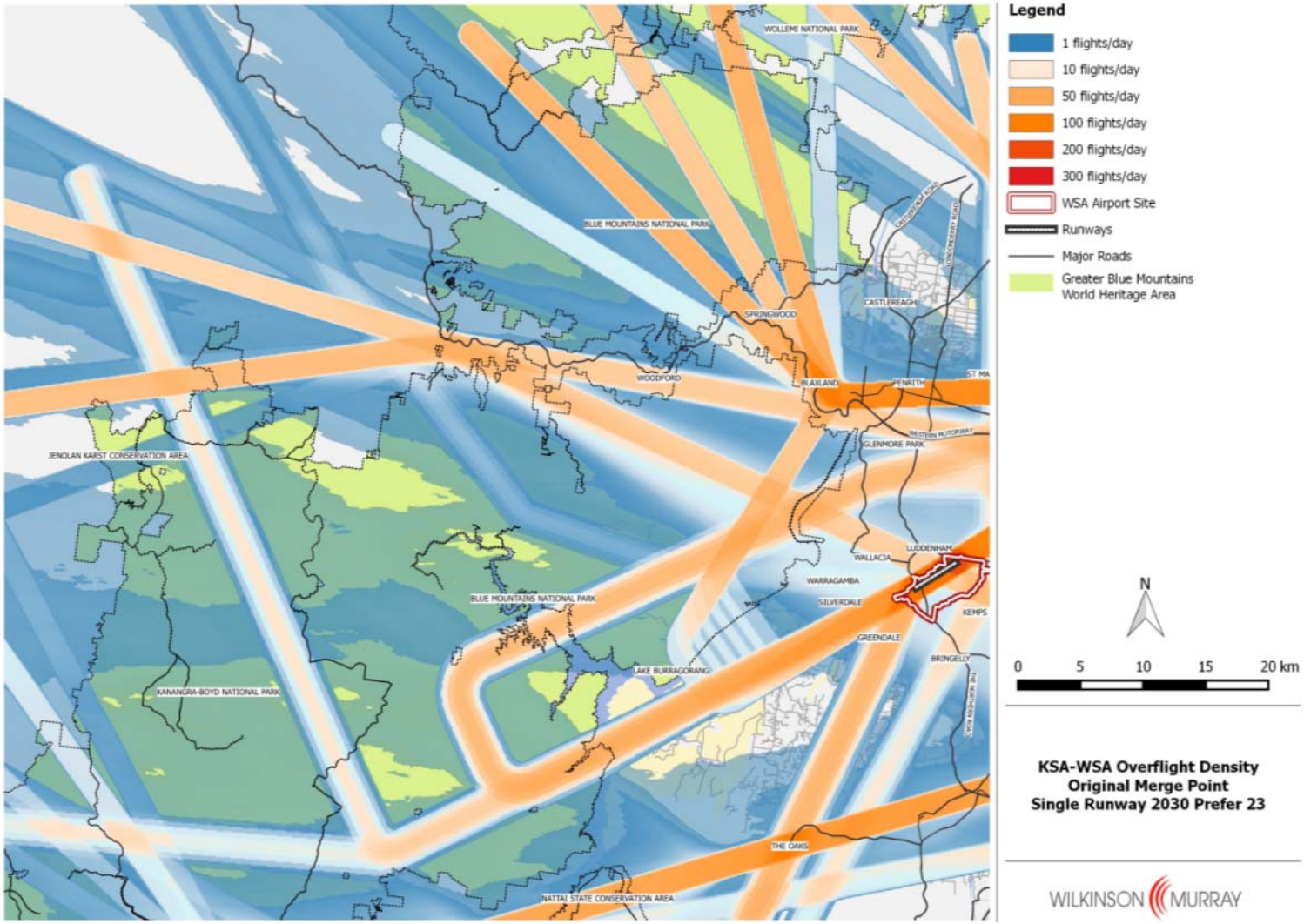


Figure 7-4 Track Density – Existing & WSA 2050 Aircraft Movements – Prefer 05

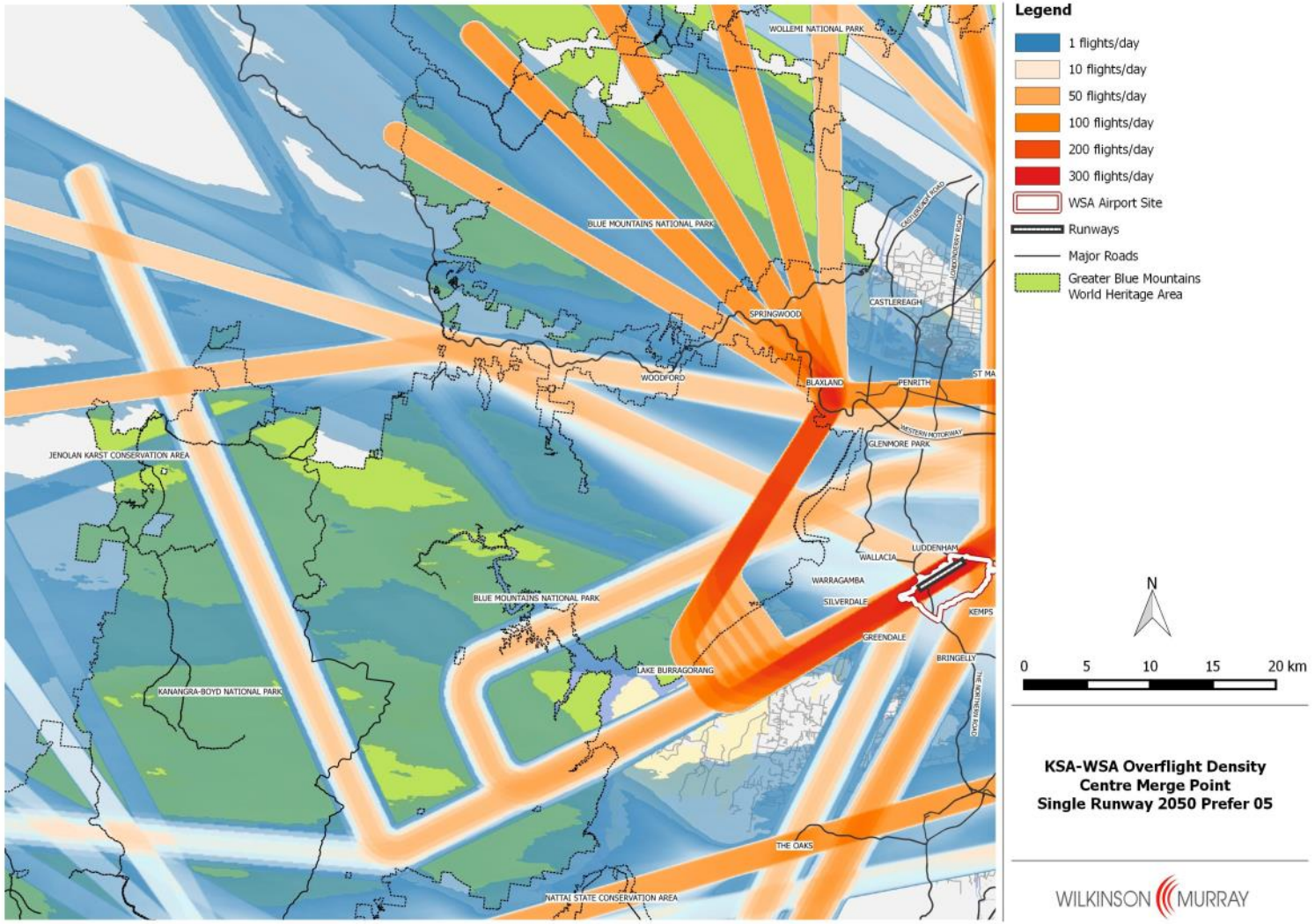
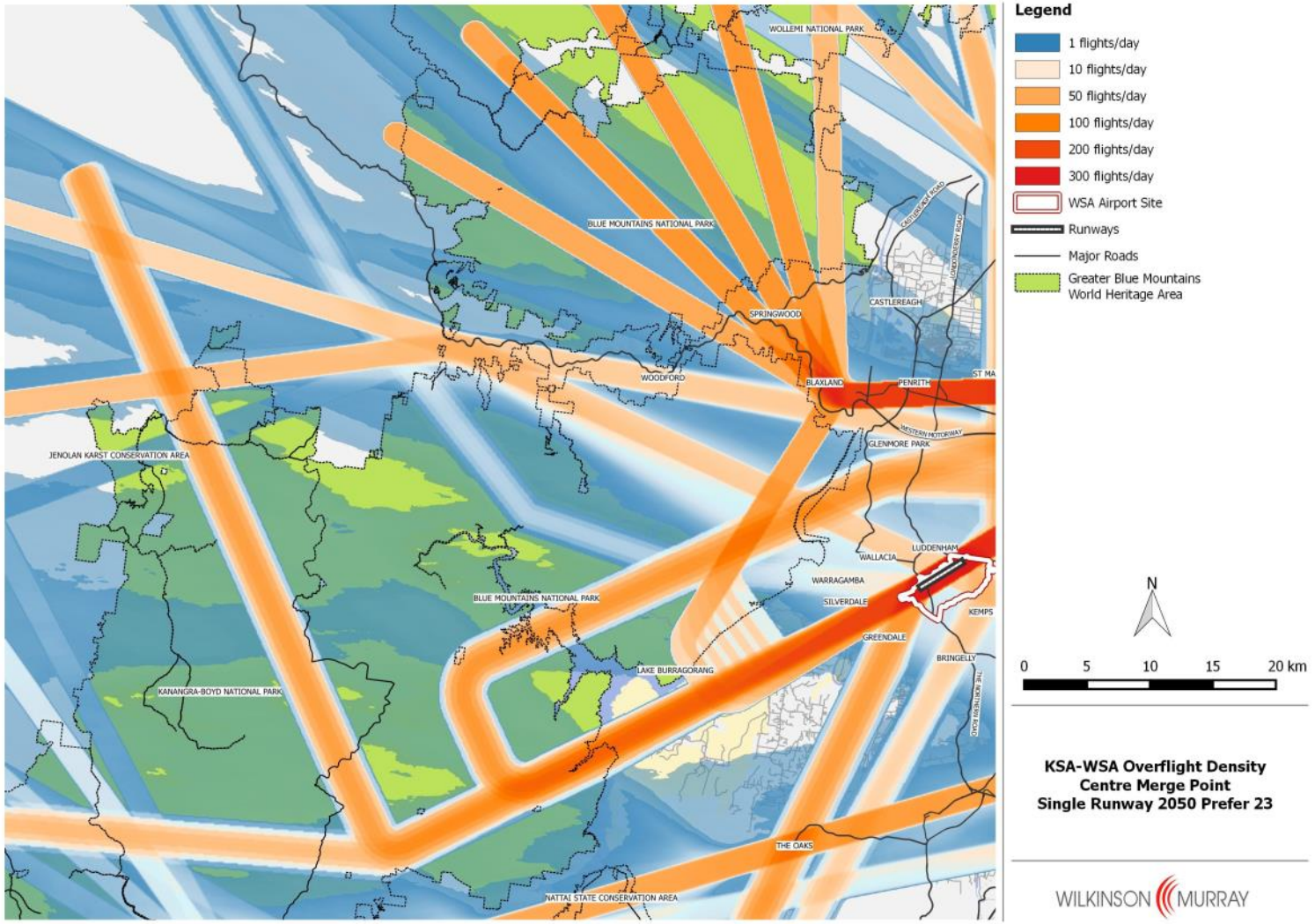


Figure 7-5 Track Density – Existing & WSA 2050 Aircraft Movements– Prefer 23



7.3 Track Density Diagrams – Alternative Merge Points

In consultation with Airservices Australia, two alternative merge points were considered at approximately 3 nautical miles north-east and south-west respectively of the nominal "central" merge point. This was suggested as the likely maximum distance that the point could be moved without disruption to the preliminary airspace design. However, it is emphasised that at the time of writing, no information is available that demonstrates that other possible merge points would not also be feasible. The alternative points considered in this analysis are shown in Figure 7-6.

Figure 7-7 to Figure 7-10 and Figure 7-11 to Figure 7-14 show track density plots for these alternative points, for years 2030 and 2050 respectively. The results are predictable – in both cases track densities over Blaxland are reduced. In the case of the eastern merge point, the point moves closer to rural residential areas outside the GBMWHA, and track densities over Blue Mountains' communities slightly to the east are still predicted to be high, particularly under the Prefer 05 operating strategy. In the case of the western merge point, impacts on some areas within the GBMWHA are increased.

Figure 7-6 Location of Alternative Merge Points for Arrivals



Source: Google Maps

Figure 7-7 Track Density – Existing & WSA 2030 Aircraft Movements – Prefer 05, East Merge Point

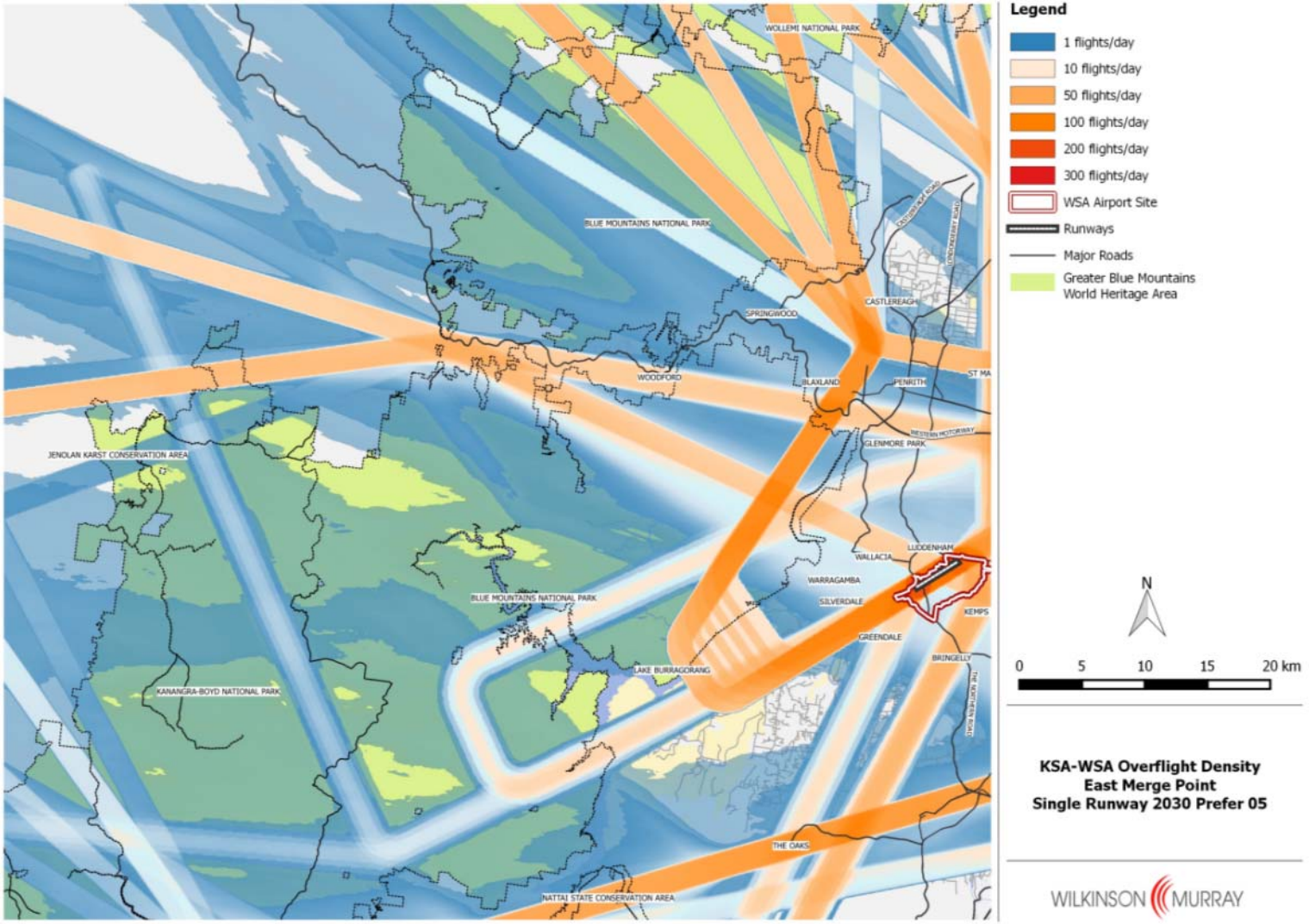


Figure 7-8 Track Density – Existing & WSA 2030 Aircraft Movements Prefer 05, West Merge Point

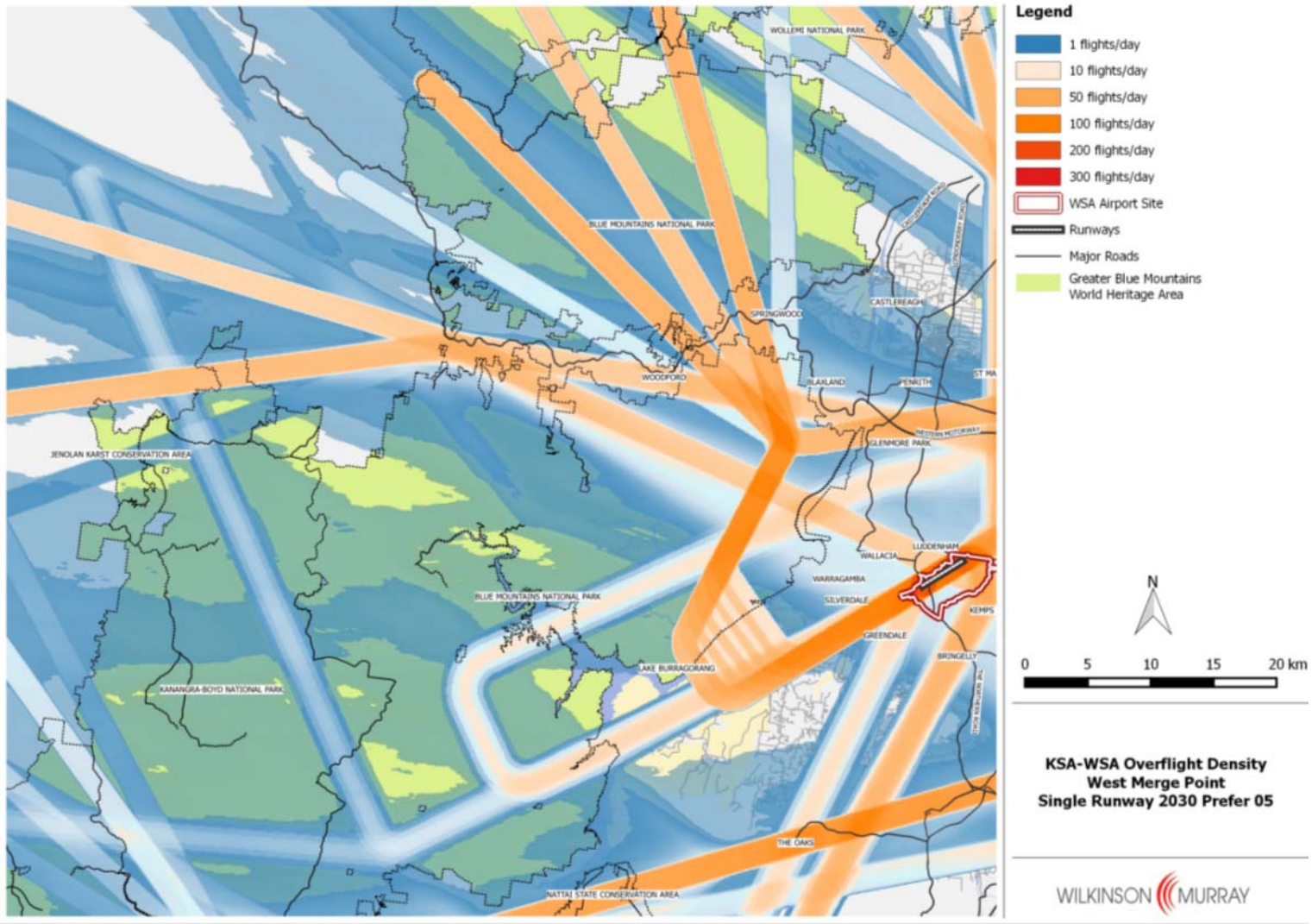


Figure 7-9 Track Density – Existing & WSA 2030 Aircraft Movements Prefer 23, East Merge Point

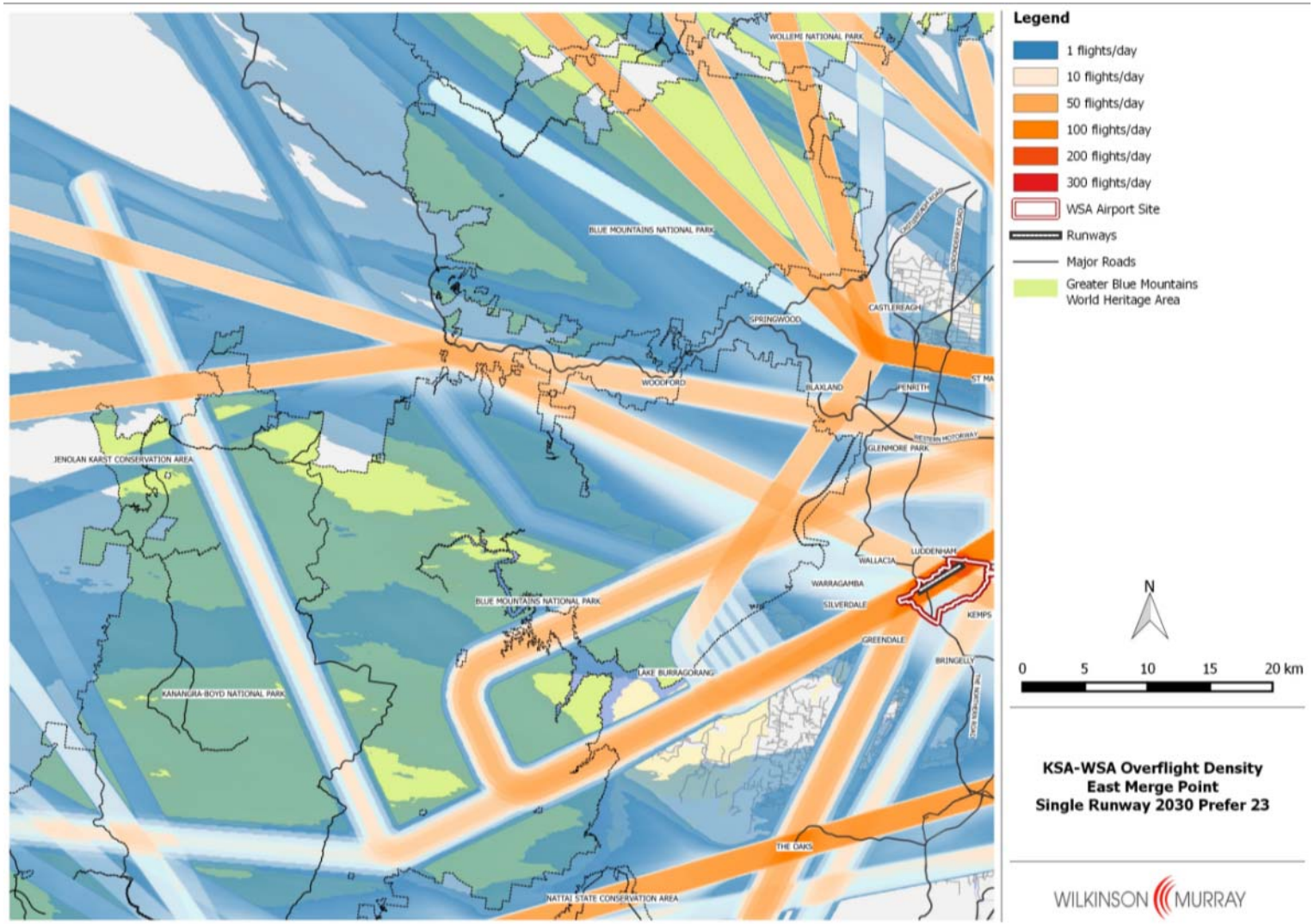


Figure 7-10 Track Density – Existing & WSA 2030 Aircraft Movements Prefer 23, West Merge Point

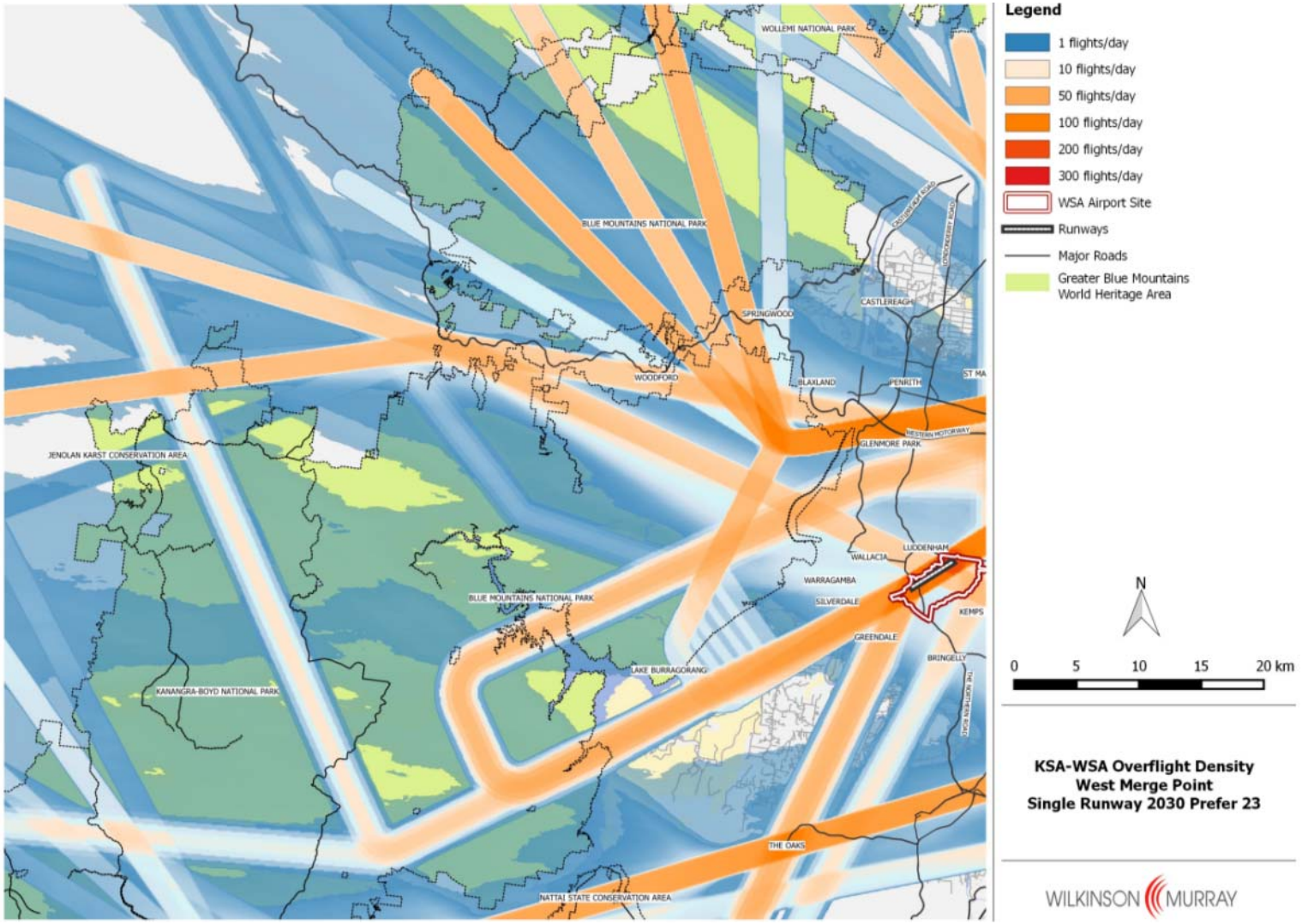


Figure 7-11 Track Density – Existing & WSA 2050 Aircraft Movements – Prefer 05, East Merge Point

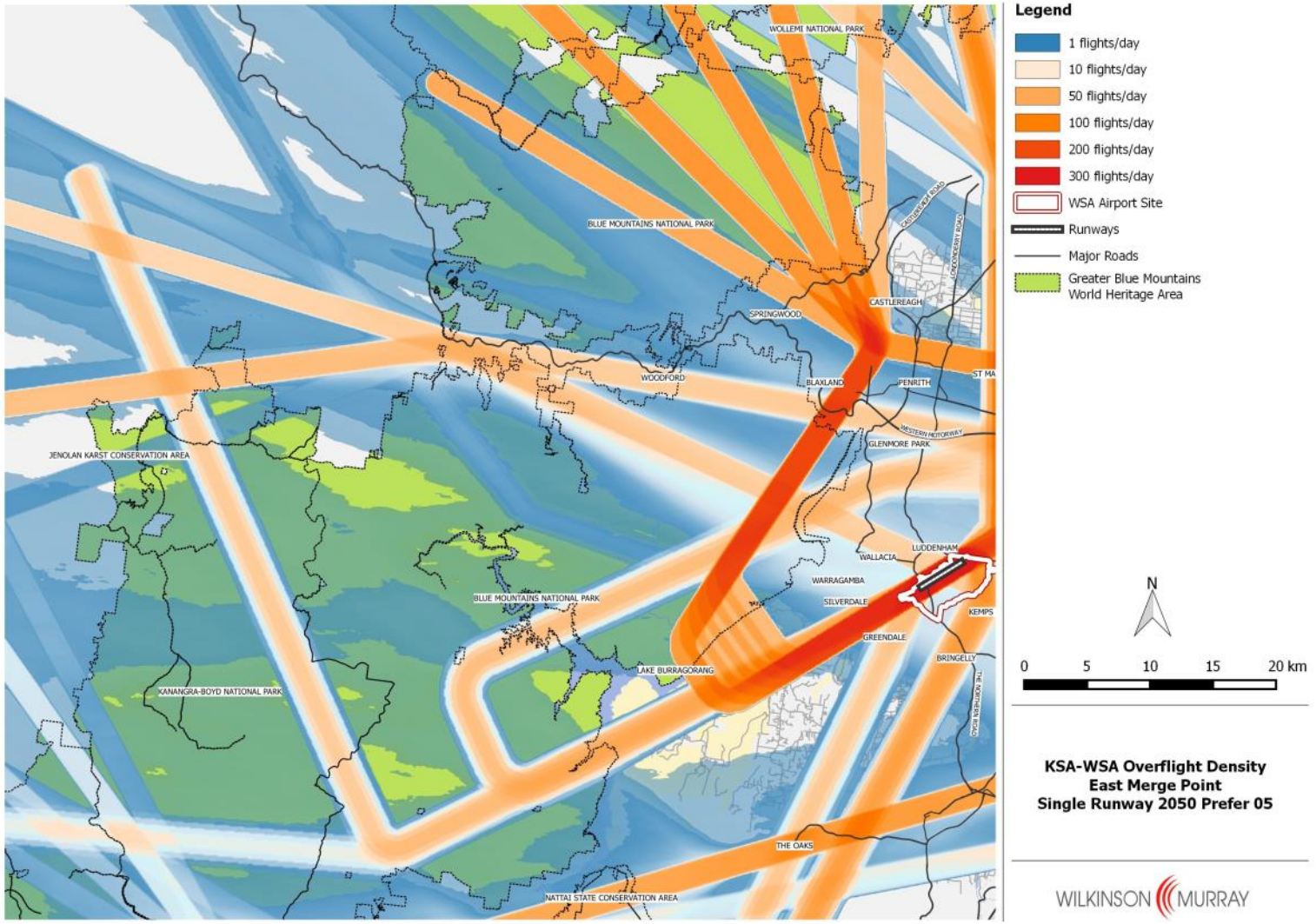


Figure 7-12 Track Density – Existing & WSA 2050 Aircraft Movements – Prefer 05, West Merge Point

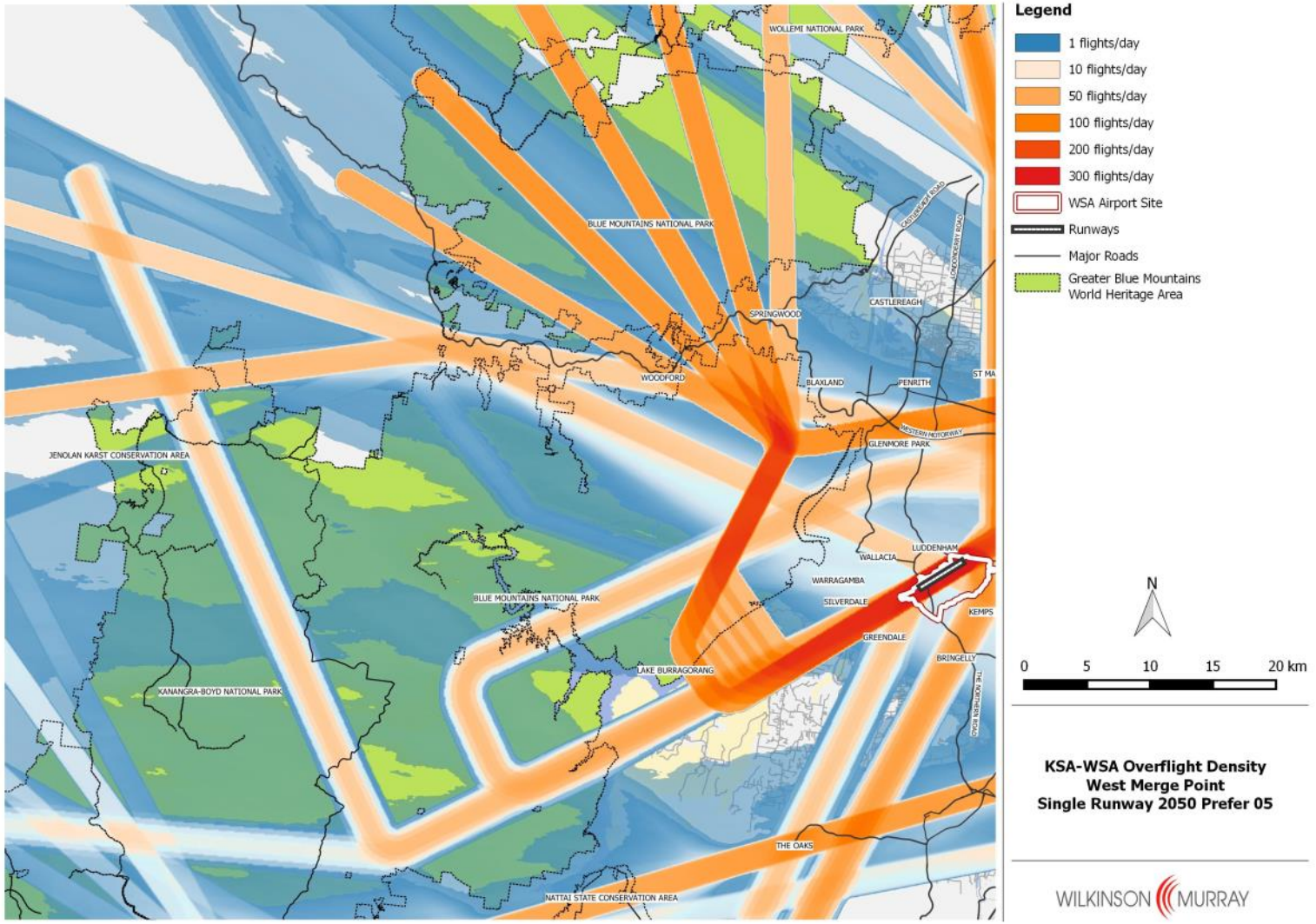


Figure 7-13 Track Density – Existing & WSA 2050 Aircraft Movements – Prefer 23, East Merge Point

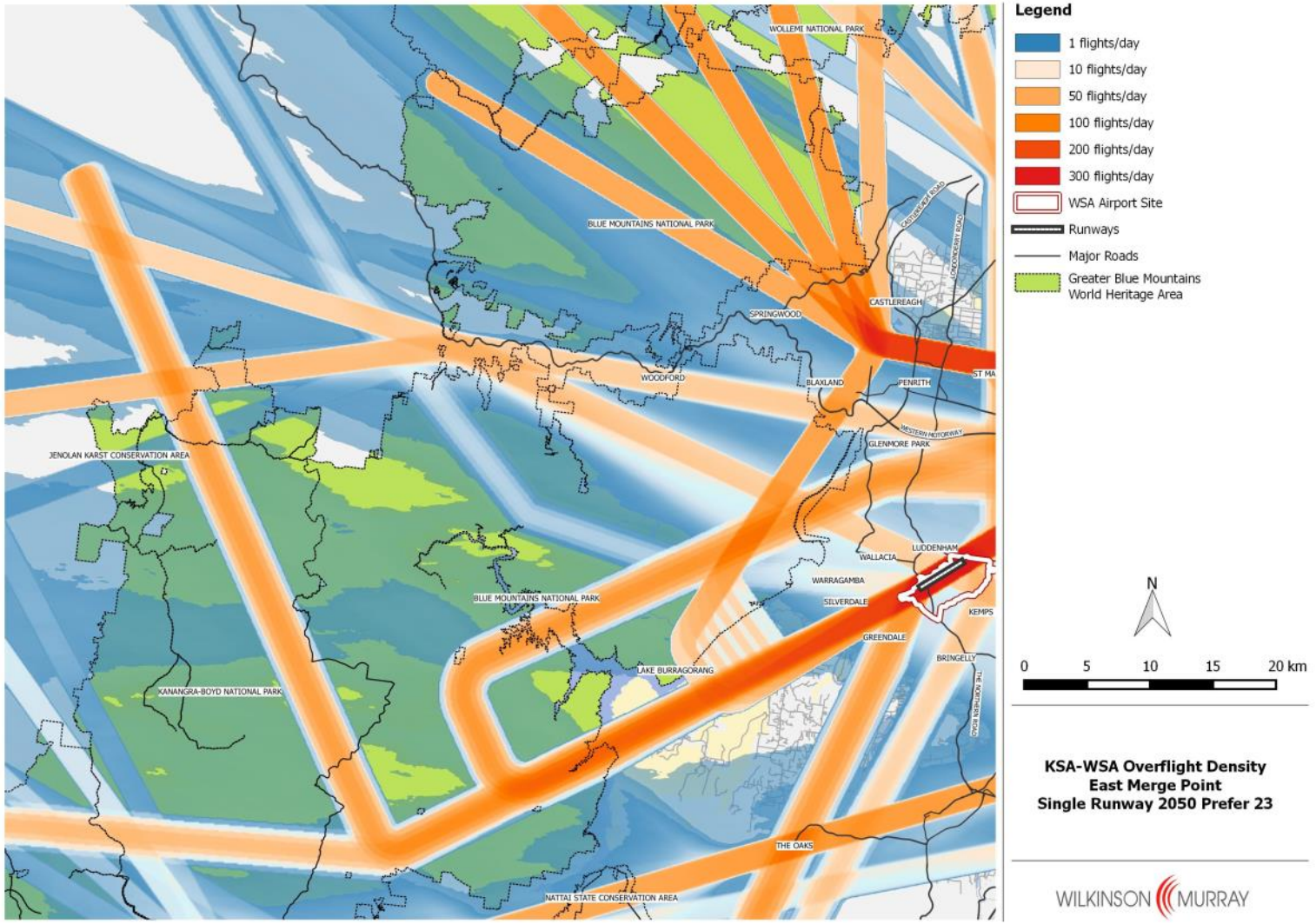
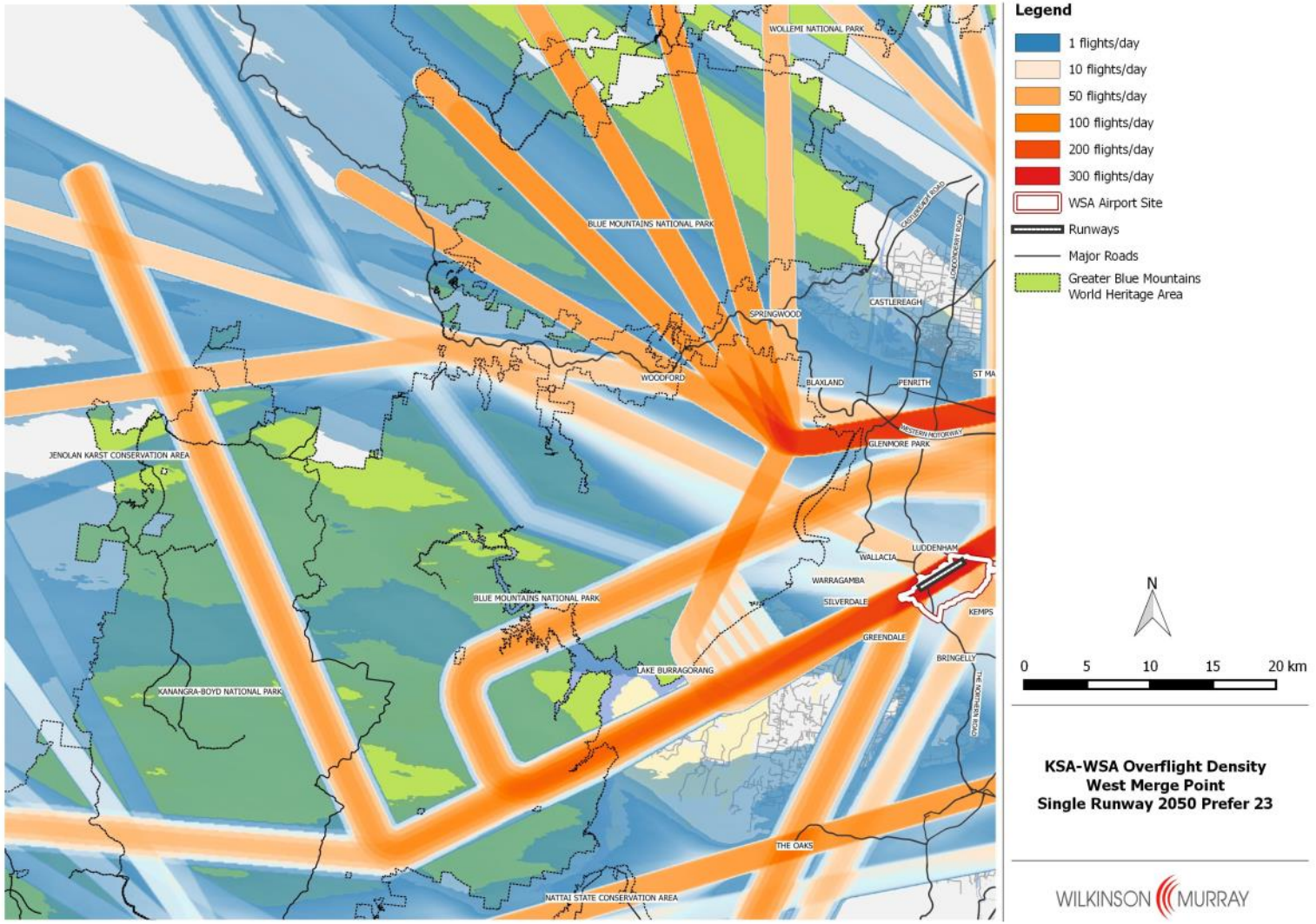


Figure 7-14 Track Density – Existing & WSA 2050 Aircraft Movements – Prefer 23, West Merge Point



8 MITIGATION & MANAGEMENT MEASURES

8.1 Mitigation of Aircraft Noise Impacts

There are three fundamental options for mitigation of aircraft noise:

- reduce noise emissions from the aircraft themselves;
- plan flight paths and airport operating strategies to achieve lower impact over noise-sensitive areas; and
- develop land use planning or other controls to ensure that future noise-sensitive uses are not located in noise-affected areas.

Of these, the possibilities for ensuring reduced aircraft noise emissions are generally limited. However, predictions in this report do incorporate one such measure, namely the use of "continuous descent approach" for all aircraft on all approach paths. The reduction in noise level as a result of this measure depends on the aircraft type and the location of the receiver, but is estimated to be in the order of 0 – 5 dBA.

Aircraft noise emissions have reduced very substantially over the past 30 years. As such, some reduction in aircraft noise emissions over time has been incorporated into the predictions in this report, through altering the mix of aircraft types within "families". However, all aircraft types used in modelling are currently in use, and hence the assumed reduction is considered to be conservative – future noise levels are likely to be, if anything, lower than assumed. There is little opportunity for aircraft designers or regulatory authorities in Australia to directly influence the speed of this reduction.

Much of the analysis in this report is related to the differential impact of alternative airport operating strategies. While various strategies have differing impacts on different populations, it can generally be said that the use of a "Prefer 23" strategy with a "Head-to-Head" mode where possible at night would minimise the number of residents exposed to low-to-medium levels of aircraft noise.

Given the preliminary indicative airspace architecture, areas of the Greater Blue Mountains Area would experience a substantial increase in the number of audible aircraft, at relatively low noise levels. Within the GBMWHA, it is not possible to prevent this impact based on the flight track options modelled, but the locations where it is experienced may be susceptible to alteration. In particular, the location of a "merge point" for arrivals almost directly over the township of Blaxland, while potentially optimal for airspace management, should be reviewed in light of the findings of this report.

Land use planning controls around airports in Australia are based on the recommendations of AS 2021, and it is expected that land use planning around the proposed Western Sydney Airport would be based on a final ANEF chart for the airport. This chart would be prepared on the basis of more detailed planning of the airspace and operating procedures, including consideration of potential environmental impacts and mitigation measures, closer to the time of operations commencing at the proposed airport. This planning process would comply with any requirements for environmental assessment under the EPBC Act.

One important form of mitigation for aircraft noise impacts is the provision of information to both existing and potential residents in areas likely to be affected by noise. This allows potential residents who are particularly sensitive to noise impacts to choose not to move into the area. Information such as that presented in this report can provide a starting point for this process, but other tools, including on-line information systems, can allow greater understanding of the likely impacts at specific locations.

8.2 Monitoring of Aircraft Noise

In Australia noise impacts around major airports are monitored using a Noise and Flight Path Monitoring System (NFPMS) operated by Airservices Australia. As for other airports, a number of permanent monitors should be installed at locations around the proposed airport that are representative of noise impacts at surrounding communities, and monthly results from the monitoring should be available on-line, as are results from other airports.

Airservices' NFPMS collects noise and flight path data at Brisbane, Cairns, Canberra, Gold Coast, Sydney, Melbourne, Essendon, Adelaide and Perth airports. This system operates 24-hours-a-day, 7-days-a-week, collecting data from every aircraft operating to and from the airport. The NFPMS uses monitors located within local communities and is the world's largest, most geographically-spread system of its type.

Noise monitoring is not undertaken to determine compliance with aircraft noise regulations. Rather, it is undertaken to:

- determine the contribution aircraft noise makes to the overall noise to which a community is exposed;
- provide information to the community;
- help local authorities make informed land use planning decisions;
- inform estimates of impact resulting from changes in air traffic control procedures, including changes to reduce aircraft noise impacts;
- validate noise modelling;
- inform the determination of aviation policy by government; and
- assist the government in implementing legislation, such as curfew acts and regulations.

Airservices also produces quarterly reports that include monitoring information from the NFPMS.

8.3 Existing and Future Operational Framework

A number of planning protections are already in place around the Badgerys Creek airport site following the previous EISs. In the lead up to the airport becoming operational, the Australian Government would work closely with the NSW Government and local governments to identify additional long term planning protections that would be required to be put in place around the proposed airport to minimise incompatible development, including in areas expected to experience noise at the more significant ANEF levels.

Each airport is required to put in place an airport Master Plan which is updated every five years, is subject to public consultation and must be approved by the Minister for Infrastructure. The Master Plan is an important document for managing environmental matters including noise. An airport Master Plan is required to include a number of measures relevant to noise including an endorsed ANEF chart, flight paths and plans for managing aircraft noise intrusion in areas forecast to be subject to exposure above the significant ANEF levels.

The Australian Government expects federally leased airports such as the proposed Western Sydney Airport to operate Community Aviation Consultation Groups (CACGs). There are guidelines for CACGs which require that they be independently chaired and should engage broad community representation. While they are not decision making bodies, CACGs provide for effective and open discussion of airport operations and their impacts on nearby communities.

Major capital city airports are also required to establish Planning Coordination Forums. The purpose of Planning Coordination Forums is to support a strategic dialogue between the airport operator and senior local, state and federal government agencies responsible for town planning and infrastructure investment. Effective discussions in Planning Coordination Forums support better integration of planning for the airport and for the surrounding urban and regional community.

Major developments that would significantly increase the capacity of the airport to handle additional aircraft movements beyond those accommodated by the Stage 1 development are likely to require a major development plan to be developed by the airport lessee company. This would be provided for public consultation and proposed for approval by the Infrastructure Minister. The current design for both the proposed airport and airspace is indicative, and the noise modelling presented in this report would be subject to further detailed design and assessment closer to the commencement of operations of the proposed airport. When it does commence, some aspects of airport operations could be introduced to mitigate noise impacts on the community such as flight path planning, preferred runway directions and continuous descent approaches.

It is important to note that the proposed airport has a lengthy construction period and current planning is for the airport to commence operations in about 2025. In this timeframe, technological improvements, including the upgrading of airline fleets, are expected to continue to reduce the industry's noise impacts on communities. These and other potential improvements would be considered in formal airspace design and assessment processes in the future.

Therefore, it is anticipated that the Government would pursue the development of a noise management plan in consultation with appropriate stakeholders. This plan would be developed in parallel with the detailed airport design and future airspace review to provide the local community and other important stakeholders with the chance to be consulted and fully informed of the final expected impacts before the airport commences operations.

9 CONCLUSIONS

Conclusions regarding noise impacts of aircraft overflights associated with the proposed Western Sydney Airport project of the initial development (2030), which is proposed for approval, and the subsequent future development (nominally 2050 and 2063), being subject of future approvals, are as follows.

9.1 Initial Development Stage (2030)

For the initial stage of the proposed airport development – that is, nominal year 2030 – conclusions from the assessment may be summarised as follows.

Maximum noise levels:

- For the loudest aircraft operations (medium-range departures by Boeing 747 aircraft or equivalent), maximum noise levels over 85 dBA would be experienced at a small number of residential locations close to the airport site, in the area of Badgerys Creek. Maximum noise levels of 70 – 75 dBA could be expected within built-up areas in St Marys and Erskine Park due to these worst-case operations, which are predicted to occur on average once per day in 2030.
- Maximum noise levels due to more common aircraft types such as Airbus A320 or equivalent are predicted to be 60 – 70 dBA in built-up areas around St Marys and Erskine Park, and over 70 dBA in some adjacent rural residential areas to the south-west of the airport, notably the area of Greendale on a “Prefer 05” operating strategy.

Noise impact over 24 hours:

- In 2030, the airport operating strategy is predicted to have a minor impact on the total number of residents affected at various noise levels over 24 hours, although the location of the affected residents differs. The “Prefer 23” strategy results in fewer people being affected at lower noise levels (generally to the north of the airport), but this is offset by more people being affected at higher noise levels – generally in rural residential areas to the south and west of the airport.
- Under any of the considered operating strategies, approximately 1,500 people are predicted to be exposed to at least five aircraft operations per day with maximum levels exceeding 70 dBA. None of these are in built-up residential areas.

Night Time Noise Impact:

- The extent of night time noise impact depends strongly on the airport operating strategy, and in particular, the adoption of a “Head-to-Head” operating mode when practicable. This results in approximately 4,300 residents being exposed to more than 5 aircraft noise events per night above 60 dBA, none of whom are in built-up residential areas. An outside noise level of 60 dBA corresponds to an internal level of approximately 50 dBA if windows are open to a normal extent, which is the design criterion for aircraft noise in sleeping areas under Australian Standard 2021. Under the above strategy, the affected residents would be largely in rural residential areas to the south-west of the airport, including Greendale and parts of Silverdale. However, some residents to the north-east of the airport around Horsley Park would also be affected.

- Airport operating strategies that do not include a “Head-to-Head” mode are predicted to result in substantially greater numbers of residents impacted by night time noise, and in particular, a “Prefer 05” strategy would result in large parts of St Marys experiencing more than 5 aircraft noise events per night above 60 dBA in 2030.

Land Use Planning:

- In ANEC contours produced for the 2030 scenario, the area covered by the 20 ANEC contour is centred closely around the airport, with only an estimated 211 – 266 residents living within the contour. However, because land use planning guidelines are intended to address
  long-term planning issues, ANEC contours for longer term scenarios are considered more relevant. An ANEF chart based on further formal flight path design would need to be produced for endorsement by Airservices Australia prior to the commencement of airport operations to inform land use planning.

Greater Blue Mountains Area:

- Based on the indicative airspace design for the proposed airport, large areas of the Greater Blue Mountain World Heritage property would not experience substantial aircraft noise. However, some parts of the property would be subjected to a substantial increase in aircraft overflights. The aircraft would be at heights generally greater than 5,000 feet above ground level. Maximum noise levels may occasionally reach 60 dBA at some points, but levels directly under a flight track would typically be below 55 dBA, and often much lower. The periodic intrusion of aircraft noise may result in occasional disturbance by recreational and other visitors to the property .

- At locations directly under indicative flight tracks, the number of audible aircraft overflights could be over 70 per day in 2030. Worst-case locations would be under one of two approach paths that emanate from a “merge point” in the area of the lower Blue Mountains.

- The nominal location of this merge point based on the indicative flight tracks would be almost directly over the township of Blaxland, meaning that in 2030, residents could expect to experience aircraft overflights at significant altitude (typically over 5000 ft above ground level) almost 100 times per day, with maximum noise levels ranging up to 55 dBA.

Alternative locations for this merge point were considered within about 3 NM from the nominated location. Use of these alternative merge points would substantially reduce the number of overflights passing over populated areas, but would result in other locations within the World Heritage Area experiencing a similar number of overflights to those currently predicted for Blaxland.

9.2 Additional Capacity Scenario (2050)

Maximum noise levels:

- Predicted aircraft operations now include longer-range departures by B747 or equivalent aircraft. For these operations, maximum noise levels over 85 dBA would be experienced at a small number of residential locations close to the airport site, in the area of Badgerys Creek. Maximum noise levels of 75 – 80 dBA can be expected within built-up areas in St Marys and Erskine Park due to these worst-case operations, which are predicted on average to occur once every two days in 2050. These operations may occur during day or night periods.

Maximum noise levels due to more common aircraft types, such as Airbus A320 or equivalent would be the same as those described above for the Initial Development Stage (2030).

- In 2050, there is a very substantial difference between the "Prefer 05" and "Prefer 23" operating strategies in terms of noise impact.
- Most residents affected under the "Prefer 05" strategy are in suburbs to the north, around St Marys and Erskine Park. In terms of total population affected, the "Prefer 05" strategy has a greater impact, with approximately 30,000 residents experiencing more than five events per day over 70 dBA in 2050, compared with approximately 5,000 residents for the "Prefer 23" strategy. These numbers would be reduced slightly if a "Head-to-Head" mode was also adopted.
- Under the "Prefer 23" strategy, the residents predicted to experience the greatest number of overflights over 70 dBA are in rural residential areas to the south-west, including Greendale and parts of Silverdale. These residents would be affected to a greater extent than those to the north – approximately 700 residents would experience more than 100 events per day above 70 dBA, compared with 300 residents under the "Prefer 05" operating strategy.

Night Time Noise Impact:

- The extent of night time noise impact also depends strongly on the airport operating strategy. The most favourable strategy from the point of view of noise impact would be "Prefer 23 with Head-to-Head", which would result in approximately 40,000 residents being exposed to more than 5 aircraft noise events per night above 60 dBA. The affected residents would be largely in s to the north-east of the airport around Horsley Park, Blacktown and St Marys.
- Airport operating strategies that do not include a "Head-to-Head" mode are predicted to result in substantially greater numbers of residents impacted by night time noise, and in particular, a "Prefer 05" operating strategy would result in large parts of St Marys experiencing more than 20 aircraft noise events per night above 60 dBA in 2050.

Land Use Planning:

- Based on airport usage patterns projected for this report, 20 ANEC contours for the 2050 scenario cover areas that are currently largely rural residential in nature, with some industrial use. No areas of built-up residential development are included in the 20 ANEC contour under any operating strategy. The "Prefer 23 with Head-to-Head" strategy results in the smallest area being covered.
- One point of interest is that an area to the west of the airport site, including the townships of Warragamba and Silverdale, although relatively close to the proposed airport, is not included in the 20 ANEC contour under any operating strategy. This is due to the fact that although a departure track is located over this area, the track is designated as being for use by non-jet aircraft only. The ANEC contours presented in this report should not be used for land use planning purposes until the validity of all underlying assumptions has been confirmed. As noted above, an ANEF chart, based on further formal flight path design would need to be produced for endorsement by Airservices Australia prior to the commencement of airport operations to inform land use planning.

Greater Blue Mountains Area:

- Parts of the Greater Blue Mountains World Heritage Area would be subjected to larger numbers of aircraft overflights compared to the 2030 scenario. As in 2030, the aircraft would be at heights generally greater than 5,000 feet. Maximum noise levels may occasionally reach 60 dBA at some points, but levels directly under a flight track would typically be below 55 dBA, and often much lower. The intrusion of aircraft noise may result in some disturbance to recreational and tourist visitors to the property in areas – under a flight track.

- At locations directly under indicative flight tracks, the number of audible aircraft overflights could be over 200 per day in 2050. Worst-case locations would be under one of two approach paths that emanate from a "merge point" in the area of the lower Blue Mountains.

- As for the 2030 scenario, the nominal location of this merge point based on the indicative flight tracks would be almost directly over the township of Blaxland, and in 2050 residents could expect to experience aircraft overflights at significant altitude (typically over 5000 ft) some 230 times per day, with maximum noise levels ranging up to 55 dBA.

- As for the 2030 scenario, the use of alternative merge points would substantially reduce the number of overflights passing over populated areas, but would result in other locations within the World Heritage Area experiencing a similar number of overflights to those currently predicted for Blaxland.

9.3 Longer Term Airport Development (2063)

- In considering future projected impacts from an airport comprising two runways, nominally in 2063, the proposed airport's operating strategy would again have a significant bearing on the noise outcomes. A number of alternative airport operating modes may be available under conditions of low traffic volume, and these may result in reduced noise impacts, particularly at night. However, at the time of production of this report, it was not possible to identify which modes could be available and under what conditions. Hence in this report, only the two basic operating strategies – "Prefer 05" and "Prefer 23" are considered.

- Predicted noise impacts for the longer term development are similar to those described above for the modelled single runway scenarios and occur in similar areas. However, the total number of residents affected is generally higher, largely as a result of population growth and ongoing housing development. For example, under a "Prefer 23" operating strategy, the number of residents experiencing more than 5 events per day above 70 dBA is estimated at approximately 17,000 (compared with 5,000 nominally in 2050).

- ANEC contours for this case are similar to those for the 2050 scenario, although somewhat larger. Once again, the 20 ANEF contour does not enclose any existing built-up residential areas, and does not include the townships of Warragamba and Silverdale.

9.4 Options for Noise Mitigation

There are three fundamental options for mitigation of aircraft noise:

- reduce noise emissions from the aircraft themselves;

- plan flight paths and airport operating modes to achieve lower impacts over noise-sensitive areas; and

- develop land use planning or other controls to ensure that future noise-sensitive uses are not located in noise-affected areas.

With respect to the first point, the use of continuous descent approaches has already been adopted in noise assessments for this report, and at this time there appear to be no other feasible options by which noise emissions from an aircraft in flight could be reduced through alternative operating procedures.

It is difficult to foresee the magnitude of future reductions in aircraft noise emission levels, as this is primarily the role of aircraft designers and manufacturers, and while reduced noise levels are highly desirable, they are one of many outcomes that aircraft designers strive to achieve in newer aircraft.

In fact, aircraft noise emissions have reduced very substantially over the past 30 years. Although it is very likely that noise emission from future aircraft will also be lower than for current aircraft, due to the absence of specific information this report has adopted a conservative approach by modelling future aircraft types on the basis of existing noise emission levels. This is reflected in the inclusion of B747 or equivalent aircraft in the assumed fleet mix in all scenarios. By 2030 the number of operations by this aircraft type at the proposed airport is expected to be very low.

The mitigation measures most relevant to the EIS process, and for which detailed preliminary noise impact information has been provided in this report, are related to airspace design and airport operating modes. While both these issues are subject to their own specific objectives and legislation, consideration of environmental impact is one important consideration in the future design process. This report canvasses a number of options and considers the range of possible outcomes for each.

The indicative airspace design, and particularly the location of the “merge point” for arriving aircraft, provides some flexibility for reducing the noise exposure of residents in the lower Blue Mountains.

However, in considering both airspace design and the selection of operating modes, it should be noted that competing interests will include the safety of all aircraft, consideration of other airspace users, and aircraft fuel consumption. Some of these may compete with the aim of lowering environmental noise impact.

With respect to planning issues, since the 1980s the NSW Government and local governments have been actively planning for an airport at Badgerys Creek and have undertaken a number of steps aimed at limiting future noise exposure of the residential population. These have included zoning land near the airport as appropriate for less sensitive uses, as well as ensuring that local government has planning procedures in place to limit sensitive uses in areas potentially affected by aircraft overflight noise. This has limited the potential noise impact from an urban greenfield airport to a level that is lower than would otherwise be expected for a development of this type and scale.

One important form of mitigation for aircraft noise impacts is the provision of information to both existing and potential residents in areas likely to be affected by noise. This allows potential residents who are particularly sensitive to noise impacts to choose not to move into the area. Information presented in this report provides a starting point for this process, but other tools, including the website information tool, can help to facilitate a greater understanding of the likely impacts at specific locations.

It is understood that should the Australian Government decide to proceed with development of the proposed airport, more detailed planning of the airspace design and operating procedures, including consideration of potential environmental impacts and mitigation measures, would be undertaken in consultation with industry and stakeholders.

The current design for both the proposed airport and airspace is indicative, and the noise modelling presented in this report would be subject to further detailed design and assessment closer to the commencement of operations. When it does commence, some aspects of airport operations could be introduced to mitigate noise impacts on the community such as flight path planning, preferred runway directions and continuous descent approaches.

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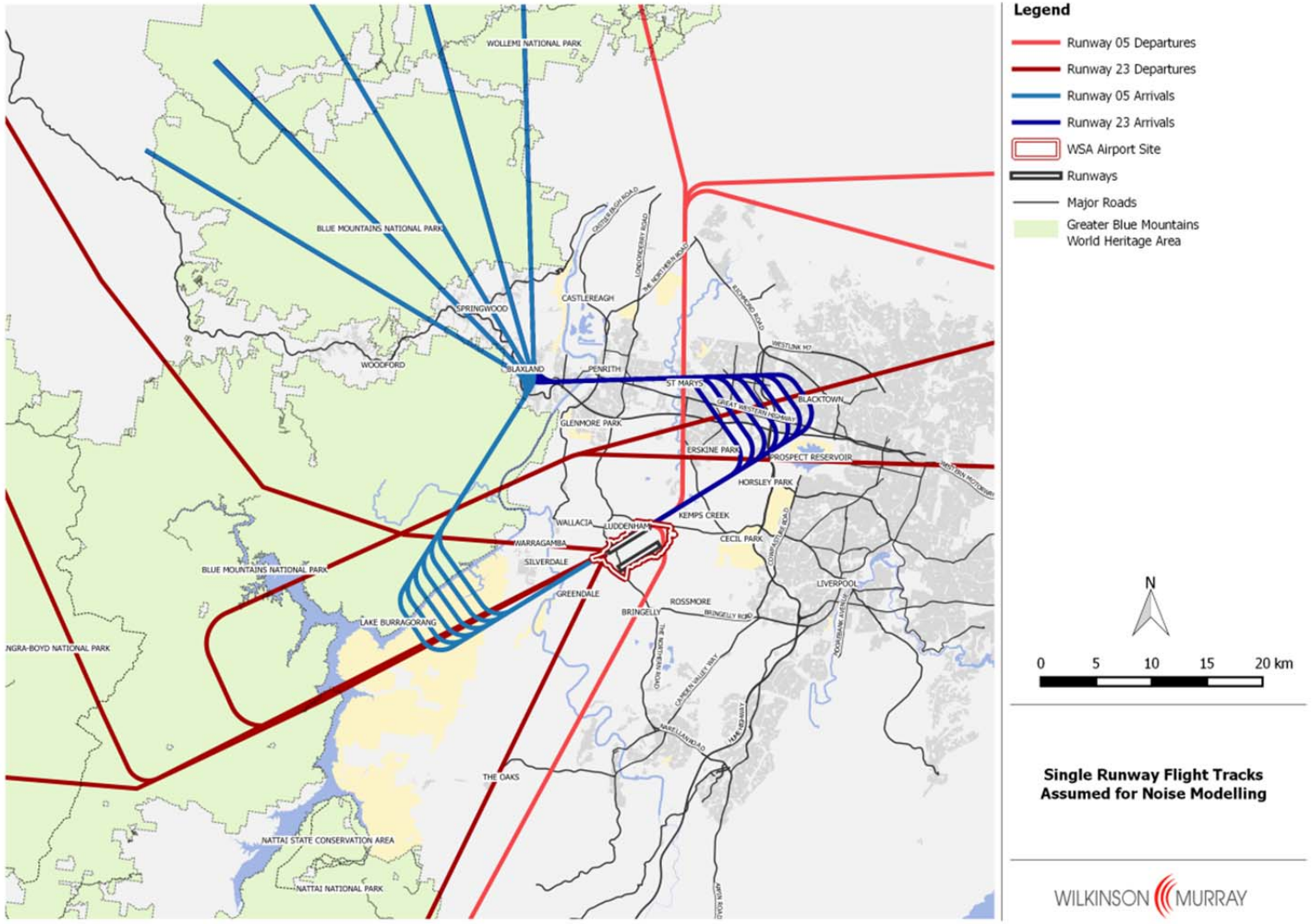
APPENDIX A

PRELIMINARY INDICATIVE FLIGHT TRACKS – INITIAL DEVELOPMENT

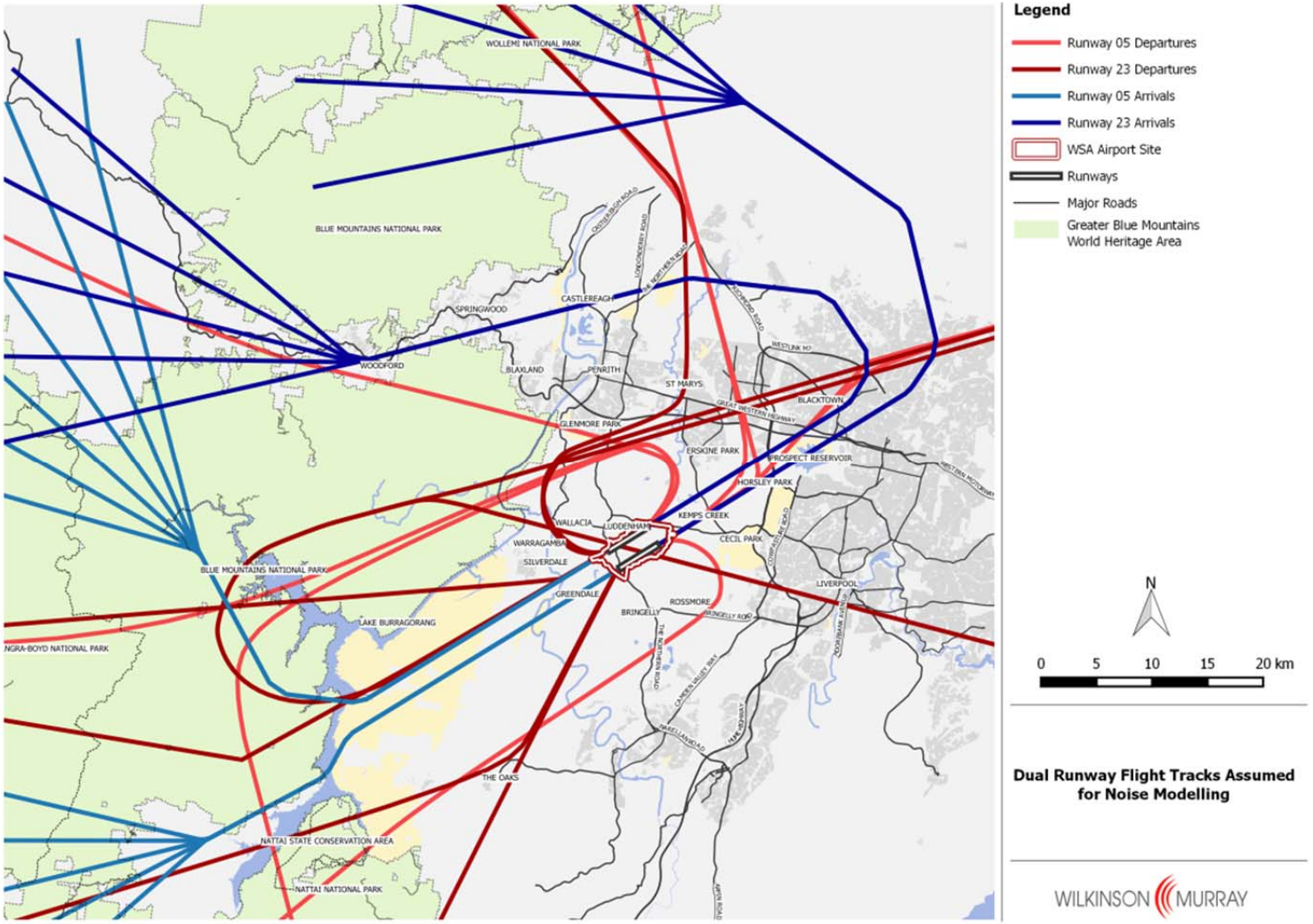
Figure-A1 Flight Tracks Modelled for Initial Development (Single Runway – All Operating Modes Combined)



APPENDIX B

PRELIMINARY INDICATIVE FLIGHT TRACKS – LONGER TERM DEVELOPMENT

Figure-B1 Flight Tracks Modelled for Longer Term Development (Dual Runway – All Operating Modes Combined)



APPENDIX C

COMPARISON OF SUMMER, WINTER & ANNUAL CONTOURS

Figure C-1 N70 Contours – 2030 – Prefer 05 – Summer

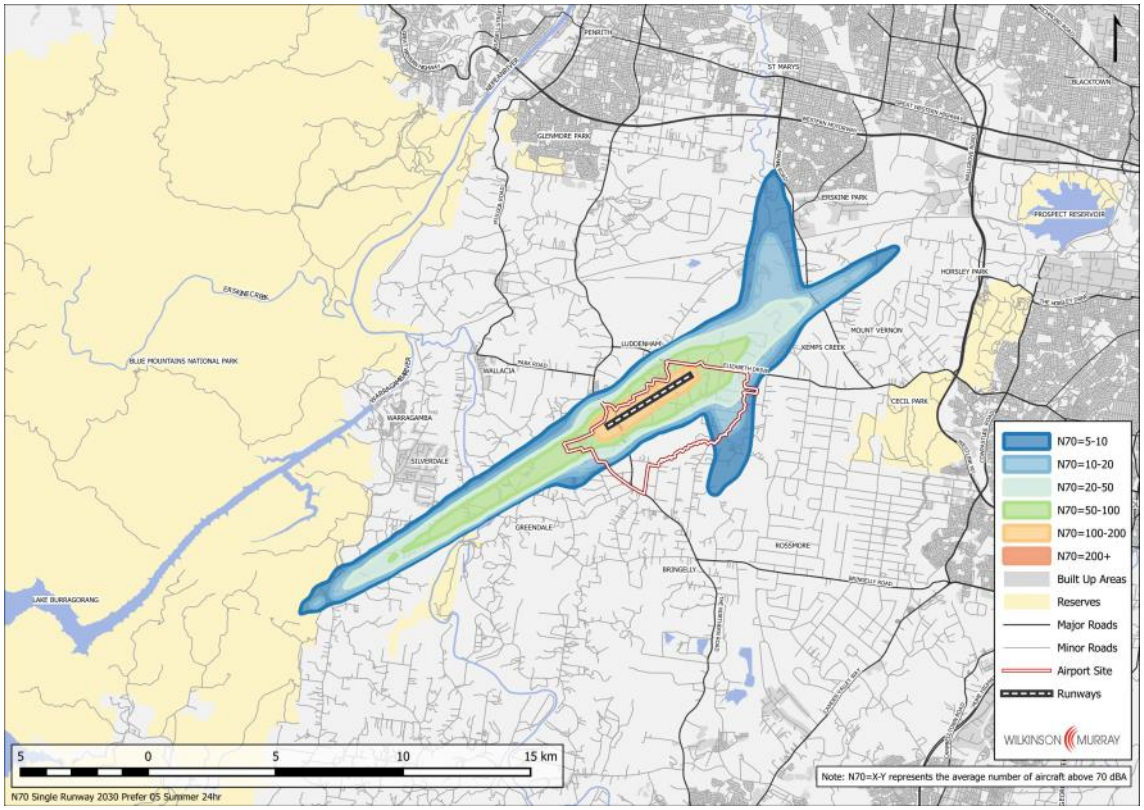
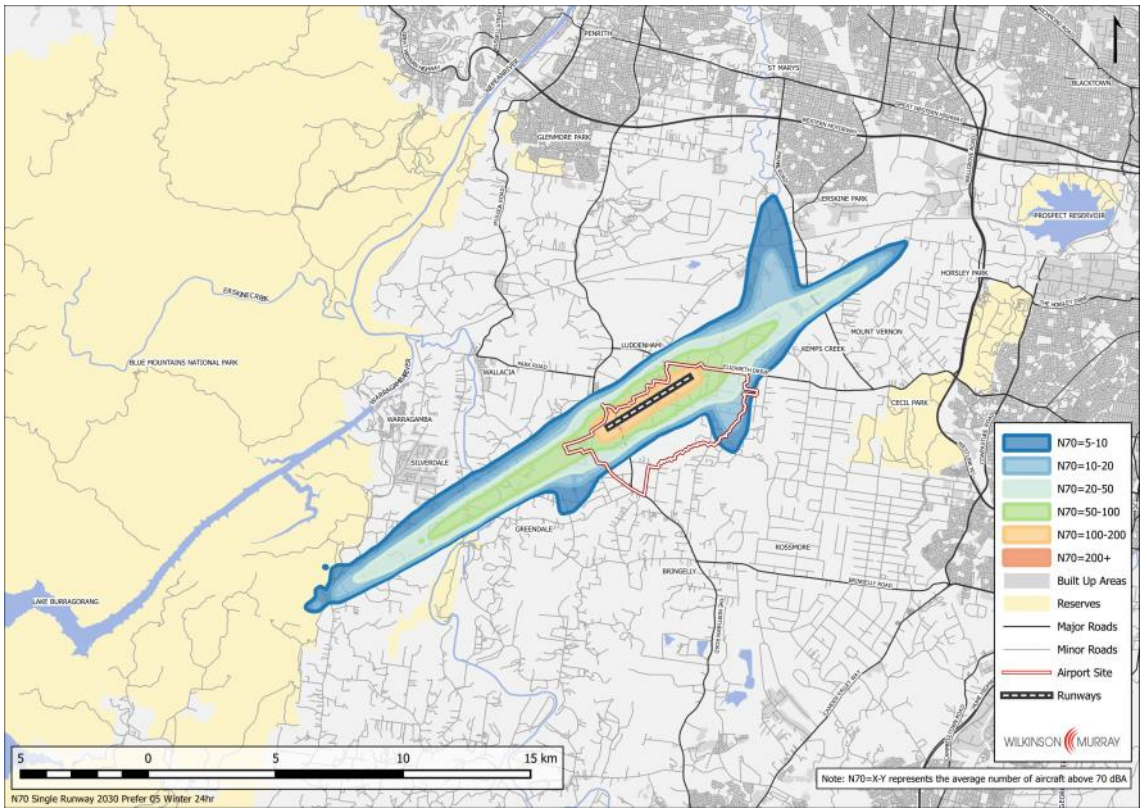


Figure C-2 N70 Contours – 2030 – Prefer 05 – Winter



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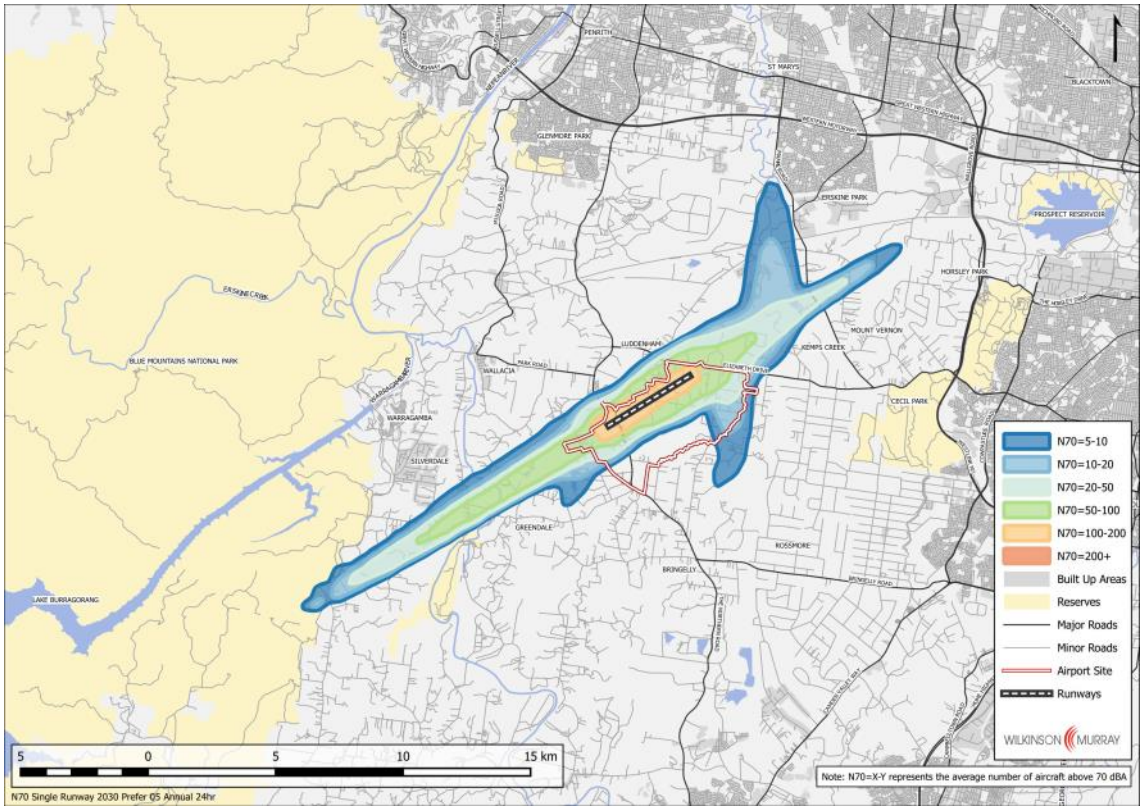


Figure C-4 N60 Contours – 2030 – Prefer 05 – Summer

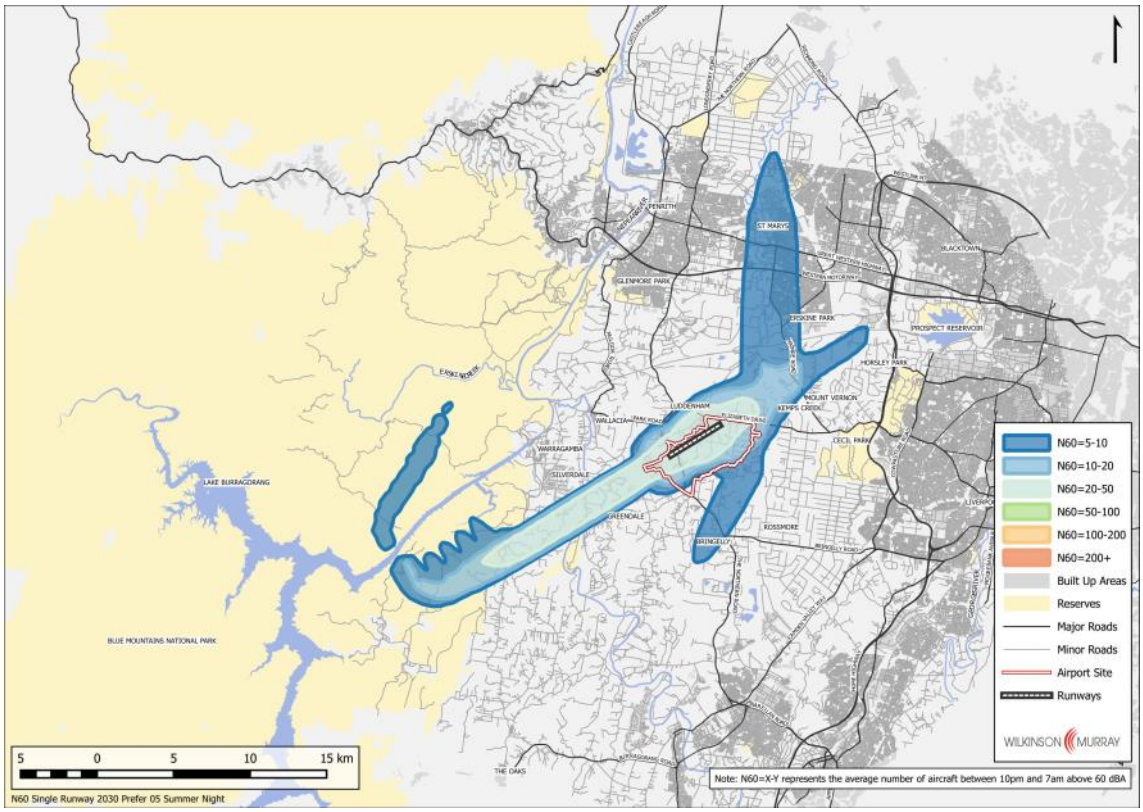


Figure C-5 N60 Contours – 2030 – Prefer 05 – Winter

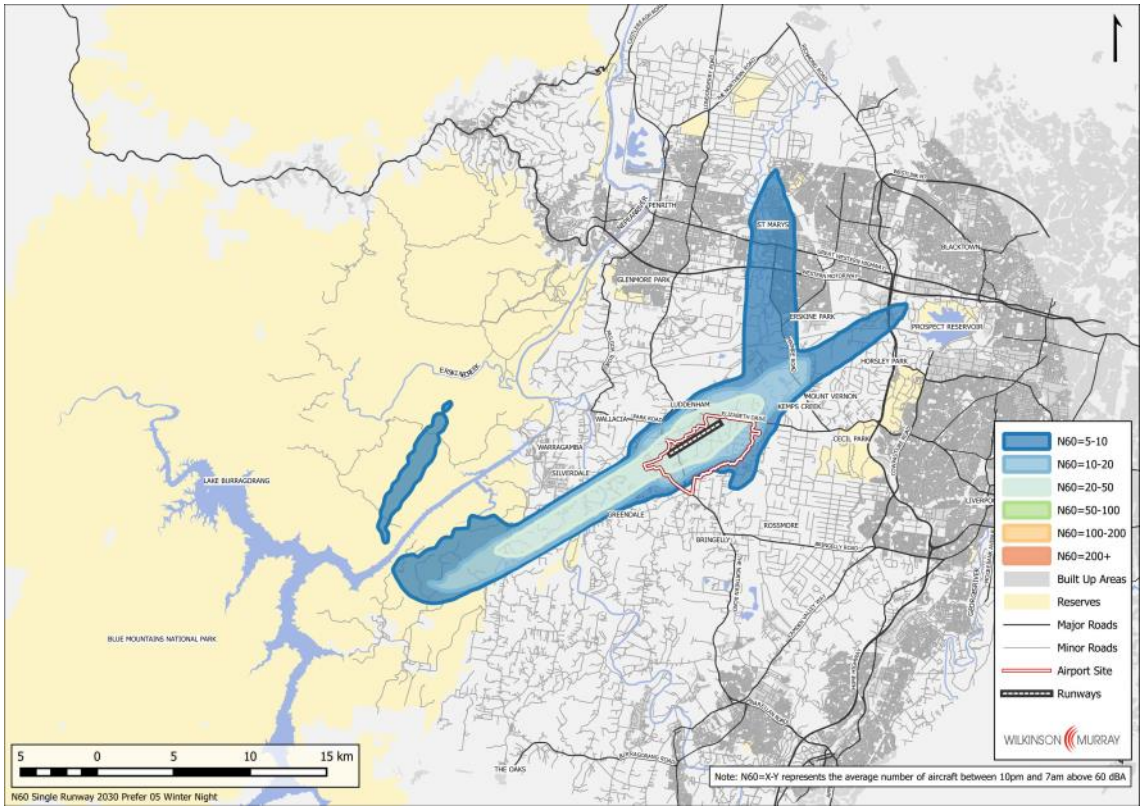


Figure C-6 N60 Contours – 2030 – Prefer 05 – Annual

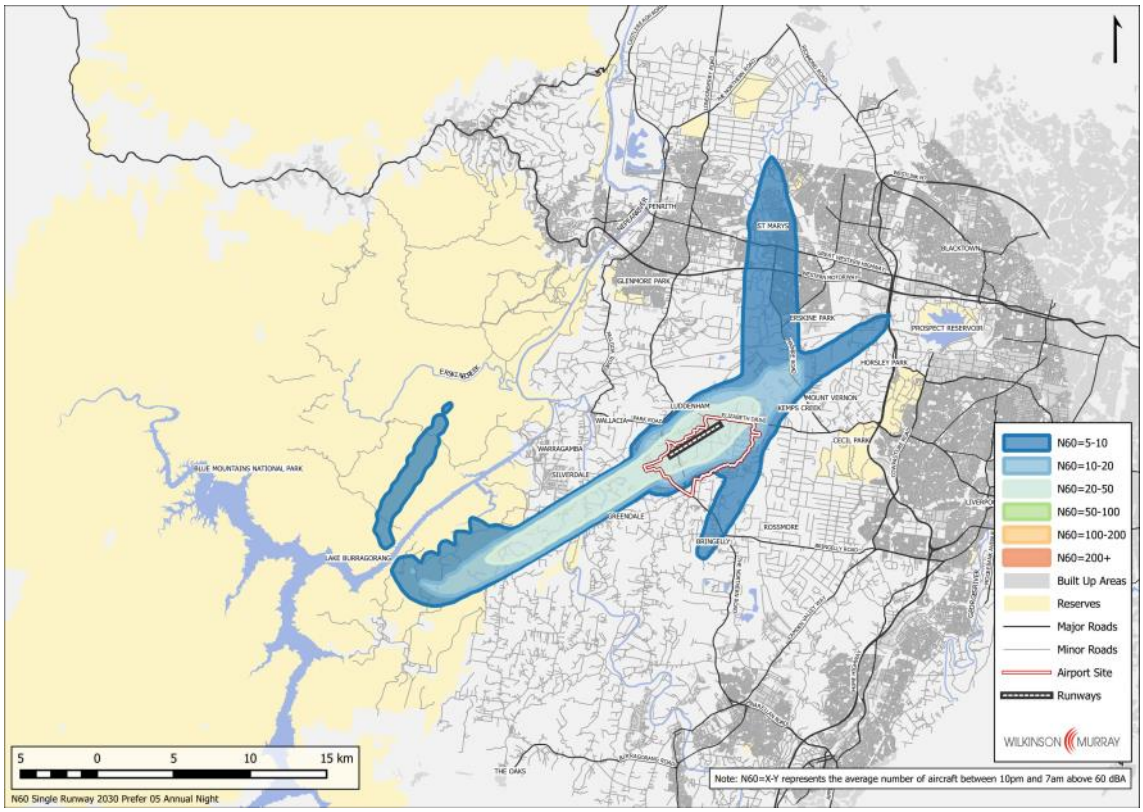
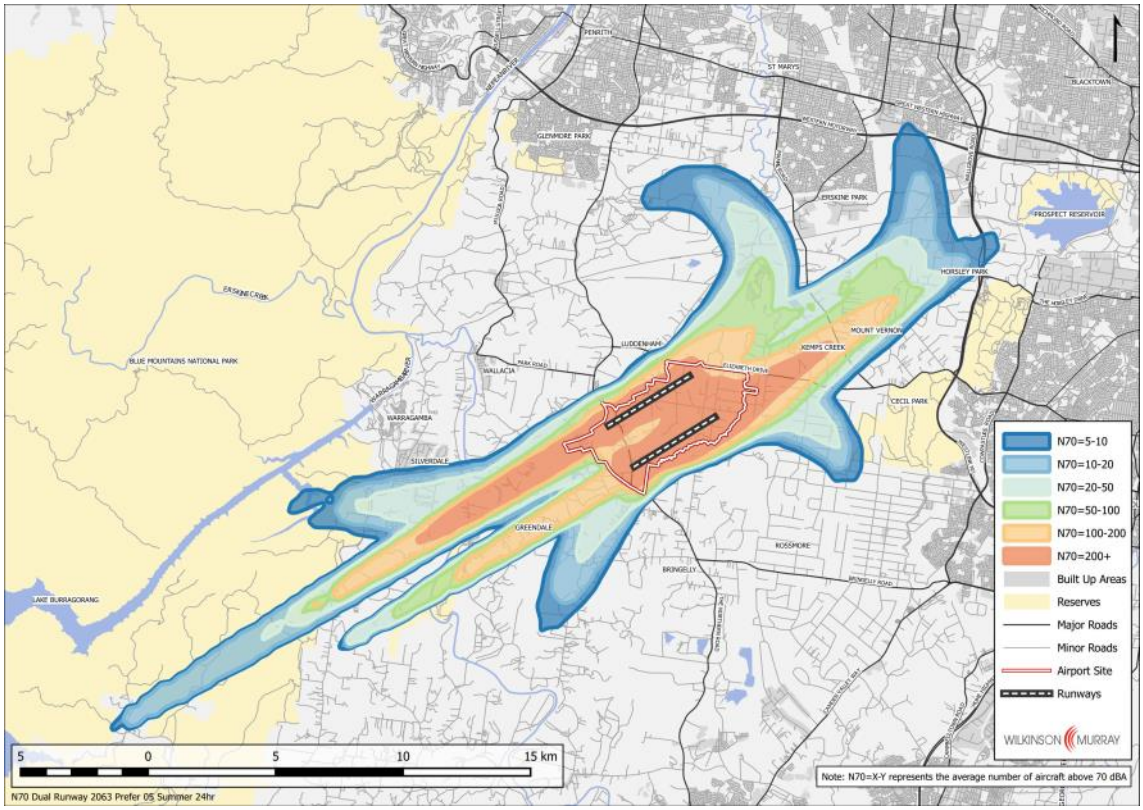


Figure C-7 N70 Contours – 2063 – Prefer 05 – Summer



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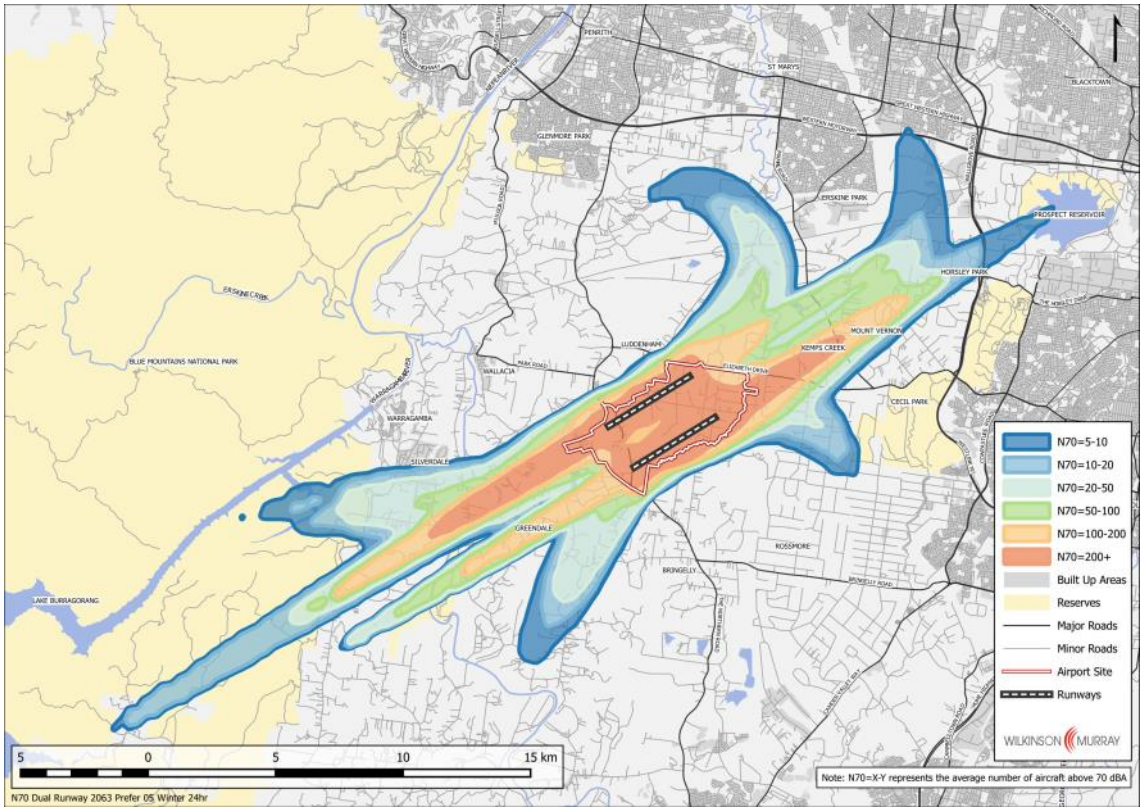
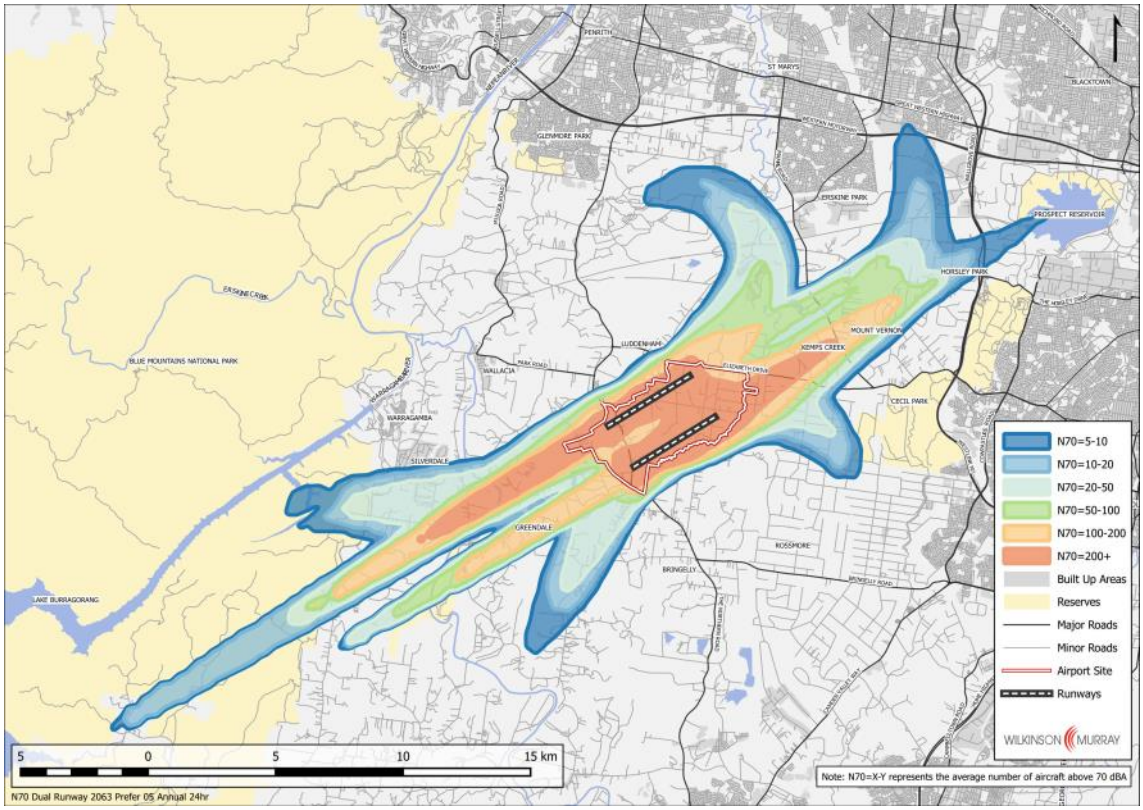


Figure C-9 N70 Contours – 2063 – Prefer 05 – Annual



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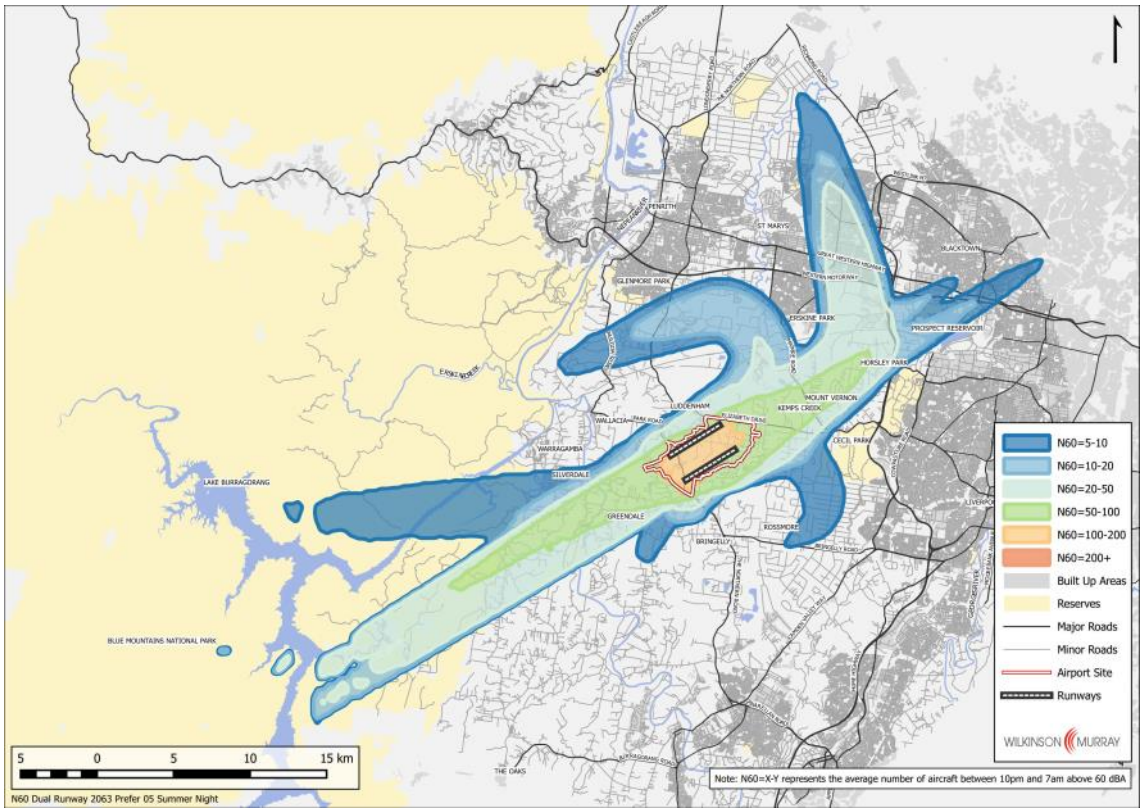

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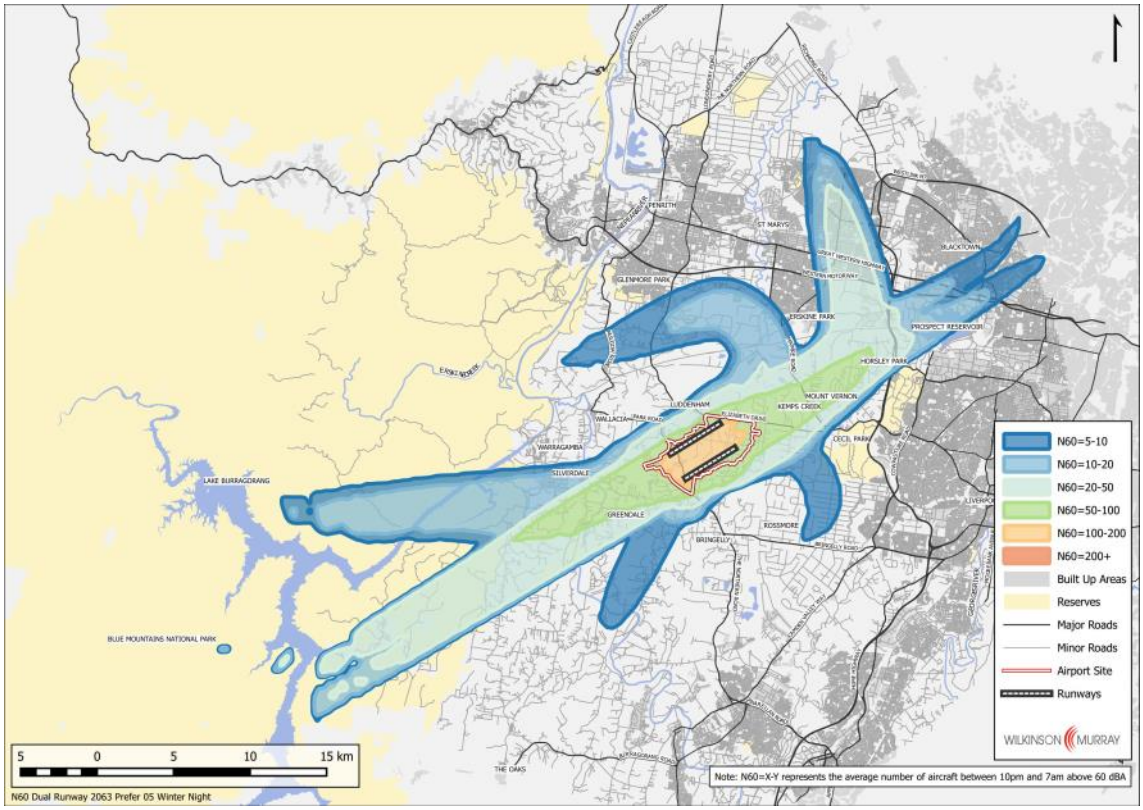
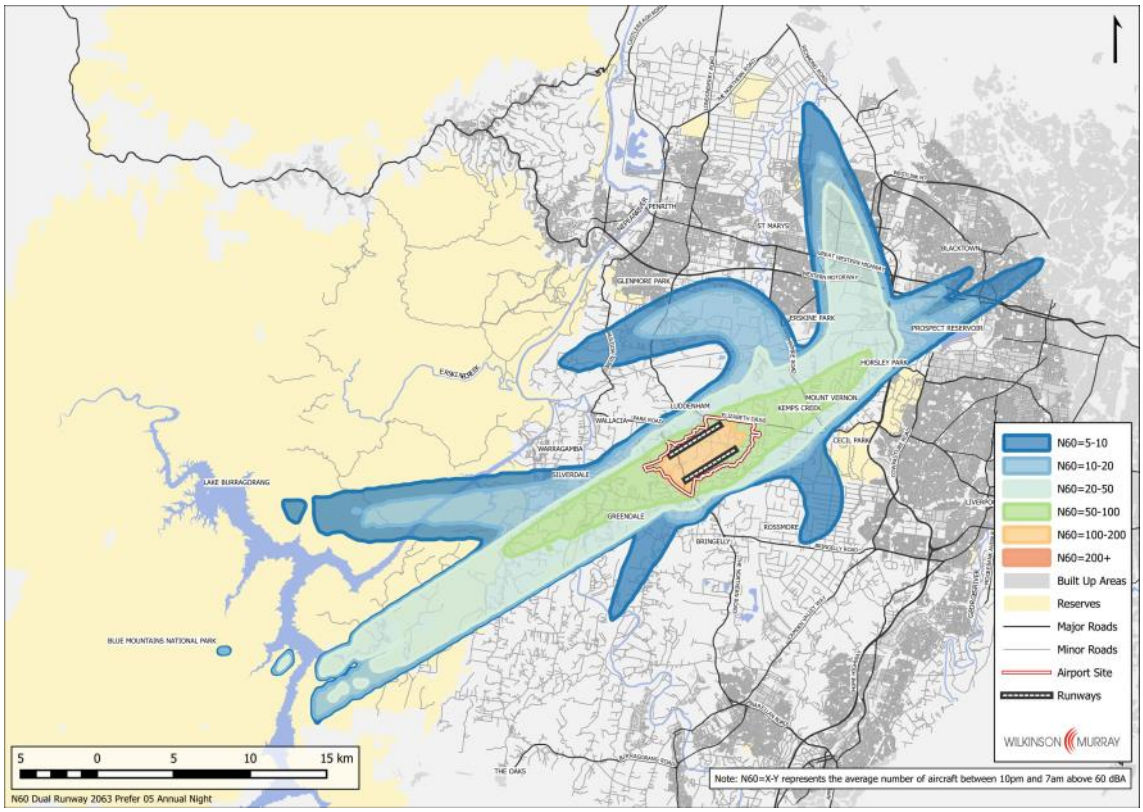


Figure C-12 N60 Contours – 2063 – Prefer 05 – Annual



APPENDIX D

GBMWHA FLIGHT DENSITY PLOTS FOR AIRCRAFT BELOW 5000 FT

Figure D-1 Track Density of Existing 2015 Aircraft Movements below 5000 ft

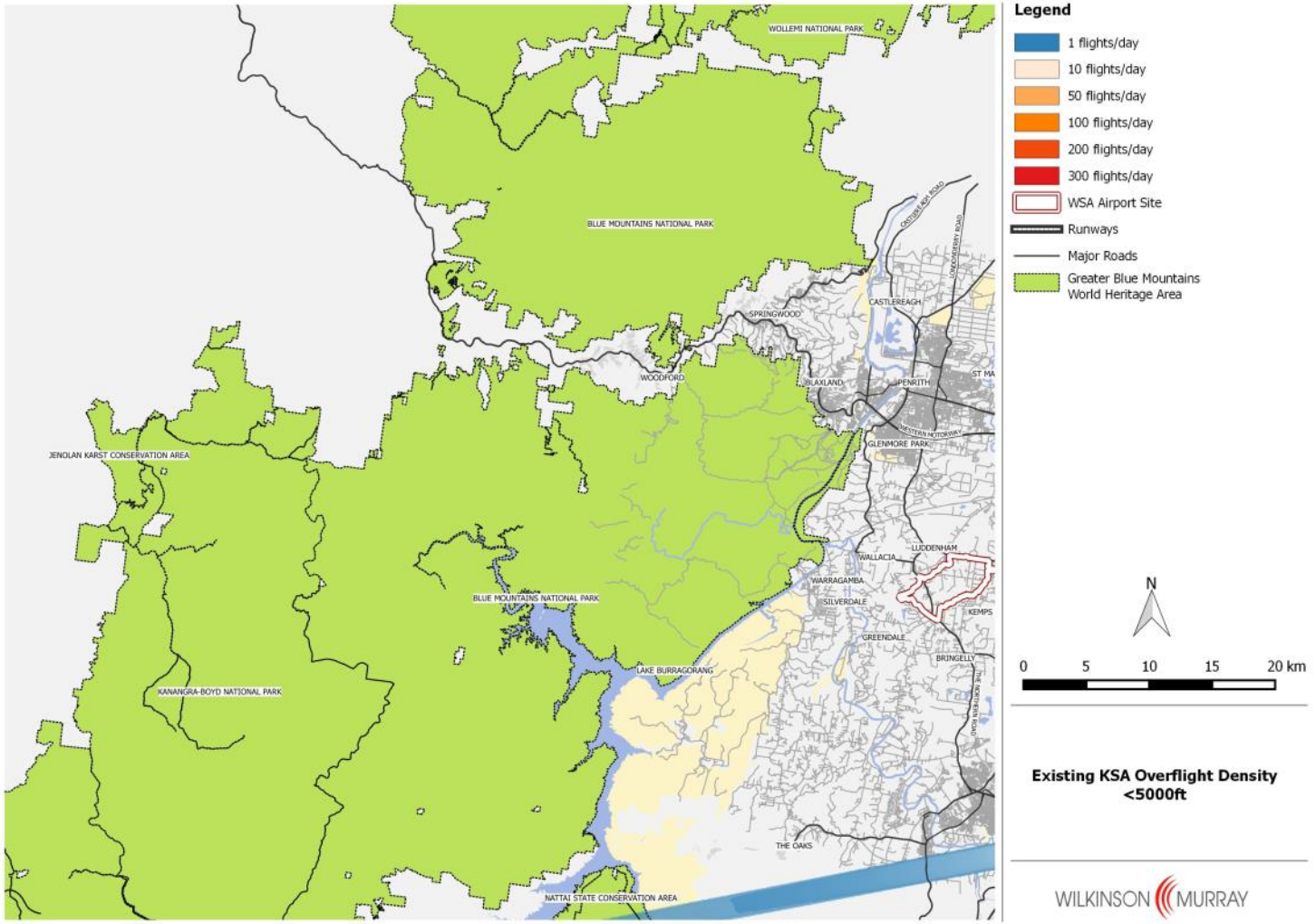


Figure D-2 Track Density – Existing & WSA 2030 Aircraft Movements – Prefer 05

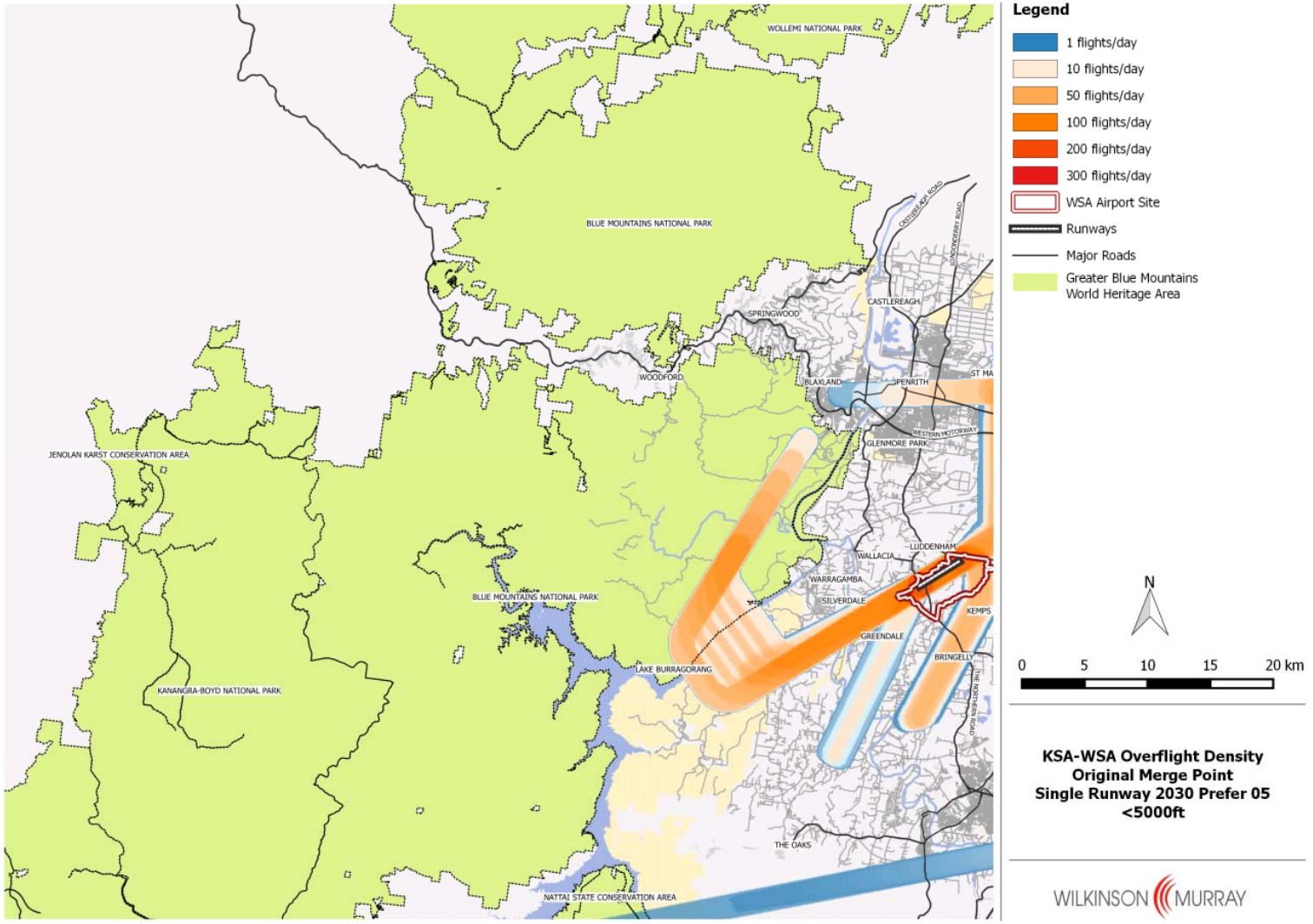


Figure D-3 Track Density – Existing & WSA 2030 Aircraft Movements – Prefer 23

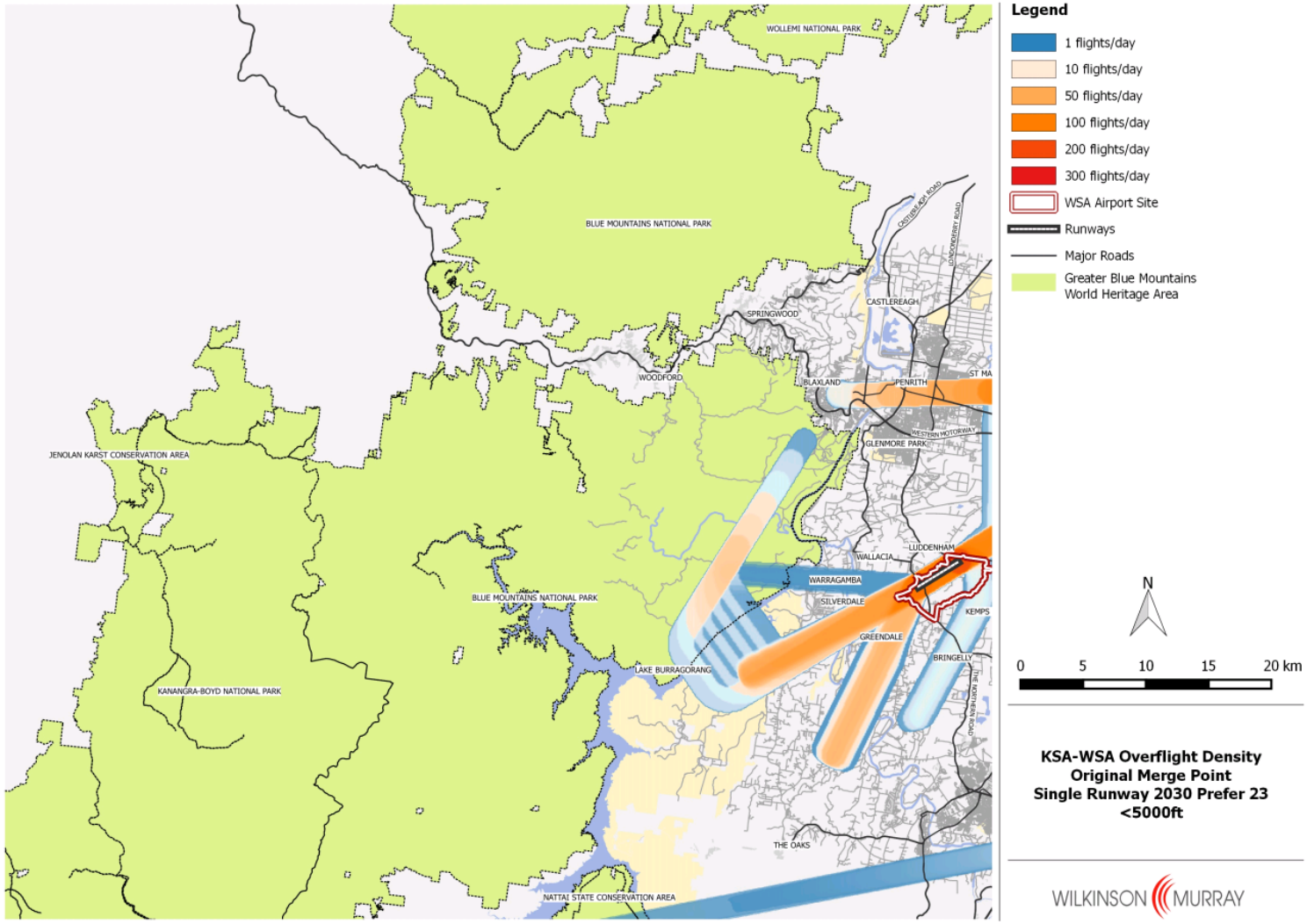


Figure D-4 Track Density – Existing & WSA 2050 Aircraft Movements – Prefer 05

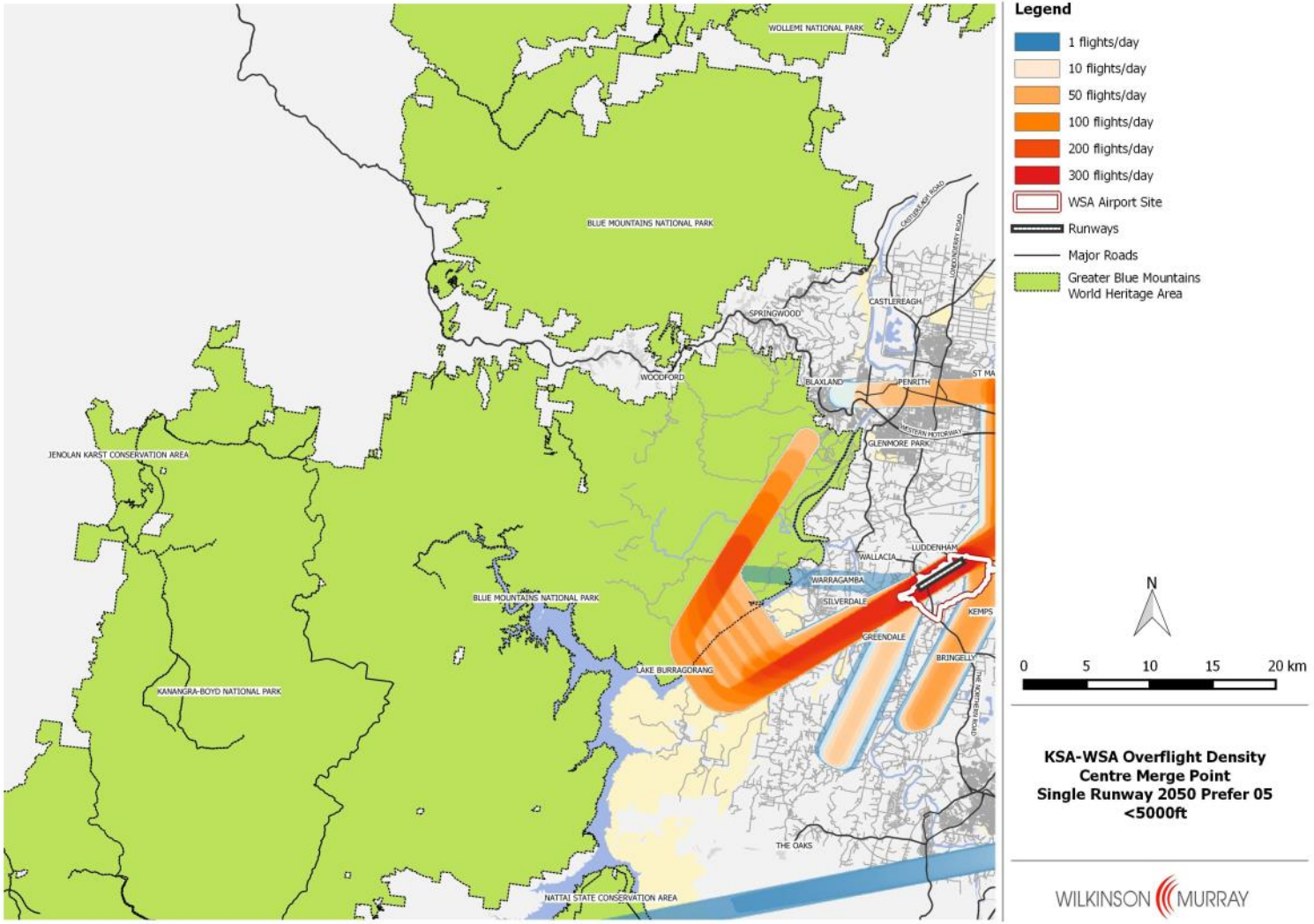
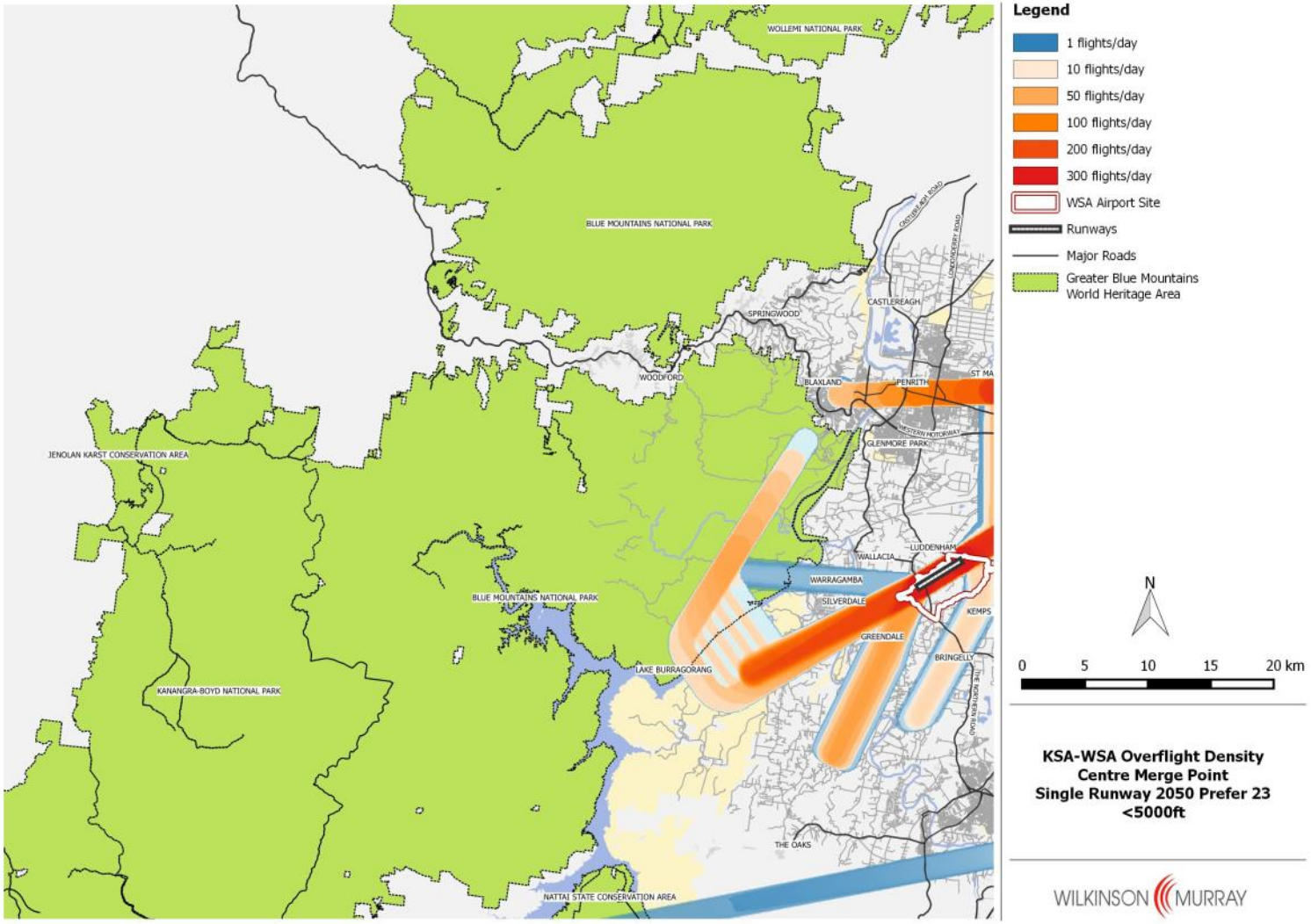


Figure D-5 Track Density – Existing & WSA 2050 Aircraft Movements – Prefer 23



APPENDIX E

GLOSSARY

ACOUSTIC TERMINOLOGY

A-Weighted Noise Level (dBA) – This is a value representing the loudness of a sound at a specific time, allowing for the differential response of the human ear to different sound frequencies.

Maximum Noise Level (L_{Amax}) – L_{Amax} over a sample period is the maximum A-weighted noise level measured during the period. In the context of aircraft overflight noise, L_{Amax} generally means the maximum A-weighted noise level recorded during a specific overflight, measured using "Slow" speed, and can therefore also be written L_{ASmax}. In this report, L_{Amax} denotes the maximum level attained during a single overflight.

L_{A90} – The L_{A90} level is the A-weighted noise level which is exceeded for 90% of the sample period. During the sample period, the noise level is below the L_{A90} level for 10% of the time. This measure is commonly referred to as the background noise level.

L_{Aeq} – The equivalent continuous sound level (L_{Aeq}) is the energy average of the A-weighted noise level over a sample period, and is equivalent to the level of a constant noise which contains the same energy as the varying noise environment. This measure is sometimes used to describe aircraft noise, in which case it refers to the noise level that is due to aircraft only, excluding other noise. Variants of this measure have been defined that cover specific time periods, such as $L_{Aeq,9am-3pm}$ which is used to describe noise affecting school classrooms.

ANEF & ANEC – For land use planning around airports, Australia has adopted the Australian Noise Exposure Forecast (ANEF) system, which describes cumulative aircraft noise for an annual period. The unit of noise measurement is similar to L_{Aeq}, but uses a more complex measure of noise from an individual overflight.

ANEC – An ANEC chart represents a forecast produced for a hypothetical future usage pattern, and is useful for considering the land use planning consequences of alternative strategies. ANEC forecasts are based on indicative data on aircraft types, flight paths, operating modes etc., and are generally used in environmental assessments to depict potential noise exposure for the hypothetical scenarios being considered;

ANEF - An ANEF chart shows contours representing a forecast of future noise exposure around an airport that has been endorsed by Airservices Australia on the basis of approved operational arrangements and official air traffic forecasts. In some cases an ANEF chart may be based on the outer envelope of contours from a number of ANEC charts.

N70 – N70 is a measure of noise exposure that indicates the average number of aircraft overflights per day (or other specified time period) exceeding 70 dBA. The numbers of overflights are graded in contour lines on a map. N70 contours can be calculated for different time periods, indicating the average number of over flights experienced per day in that period.

N60 – N60 is a measure of noise exposure defined exactly as for N70, but representing the average number of aircraft overflights per day exceeding 60 dBA. N60 is generally used to describe night time noise exposure. In this report, unless otherwise noted, N60 values represent the average number of aircraft overflights per day exceeding 60 dBA during the period 10pm to 7am.

90th Percentile N70 – This unit has been introduced in the present report to overcome one drawback of N70 values, namely that they represent an average number of events over a large number of days, which can mask variation between days. The 90th Percentile N70 represents the N70 value that is exceeded on only 10% of days, and hence represents the upper range of aircraft numbers likely to be experienced per day at any point.

90th Percentile N60 – This is defined exactly as for 90th Percentile N70, and represents the N60 value that is exceeded on 10% of nights.

Point Merge – Point Merge is an airspace management concept referenced by ICAO as a technique to support continuous descent approaches. It involves designing all approach tracks to pass over a specific "merge point" before beginning the final approach. A point merge manages traffic flow in order to space aircraft more efficiently and eliminate the need for vectoring or stacking. If there is runway congestion, this system 'holds' the aircraft at much higher altitudes which consequently decreases fuel burn and reduces the effect on the environment. It was first implemented at Oslo airport in 2011 and since then in a number of other European and Asian airports including Dublin (2012), Seoul (2012), Paris ACC (2013), Kuala Lumpur (2014), Lagos (2014), Canary Islands (2014) and Hannover (2014).

Airport Operating Mode – A way of allocating aircraft operations to runways and runway directions at an airport. For example, one operating mode may require all aircraft to approach and depart using one runway direction, while another mode may require them to approach and depart in the opposite direction. Modes may or may not be available for use at any given time, depending on meteorology, number of aircraft operations per hour, and sometimes other factors. The proposed runway orientation at WSA is 05/23 (that is, 50/230 degrees compass bearing or approximately north-east/south-west). 05 operations involve landing from the south-west and take-off to the north-east whilst 23 operations involve landing from the north-east and take-off to the south-west.

Airport Operating Strategy – A way of determining which airport operating mode will be in use at any time. For example, a strategy may indicate that where several modes are available, one particular mode should be preferred, whereas in an alternative strategy, another mode is preferred.

OTHER TERMINOLOGY

EIS – environmental impact statement.

Western Sydney Airport (WSA) – The proposed airport at Badgerys Creek as assessed in the Western Sydney Airport Environmental Impact Statement.

Airport Site – The airport site is the total of all properties that may become part of the proposed Western Sydney Airport.

DIRD – the Australian Government Department of Infrastructure and Regional Development tasked with the detailed planning and investigation of the proposed Western Sydney Airport.

Initial Development – The first stage in the development of the proposed Western Sydney Airport, including a single runway and associated infrastructure to handle up to approximately 10 million annual passenger movements, presently anticipated to occur in 2030. Also referred to as the Stage 1 development.

Longer Term Development – A longer term development at Western Sydney Airport could include dual runways and associated infrastructure to handle approximately 82 million annual passenger movements. The Western Sydney Airport EIS considers this patronage level could be reached around 2063.

GBMWHA – Greater Blue Mountains World Heritage Area.

Aircraft Operation – In the context of this report, this refers to an aircraft arrival or departure.

Flight Track – A flight track is a line in three-dimensional space representing the path travelled by an aircraft, generally as it descends for landing at an airport and ascends after take-off.

Flight Path – A flight path is the two-dimensional projection of a flight track onto the ground – that is, it represents the points on the ground that lie directly beneath an aircraft's flight track.

Instrument Meteorological Conditions (IMC) – An aviation flight category that describes weather conditions requiring pilots to fly primarily by reference to instruments, and therefore under instrument flight rules (IFR), rather than by outside visual references under visual flight rules (VFR). Typically, this means flying in cloud or bad weather.

Visual Meteorological Conditions (VMC) – An aviation flight category in which visual flight rules (VFR) flight is permitted — that is, conditions in which pilots have sufficient visibility to fly the aircraft maintaining visual separation from terrain and other aircraft.

Instrument Landing System (ILS) – An instrument landing system is a ground-based navigational aid that provides precision horizontal and vertical guidance to an aircraft approaching and landing on a runway, using a combination of radio signals and, in many cases, high-intensity lighting to enable a safe landing during IMC, or other adverse meteorological conditions.

Continuous Descent Approach – An approach in which the aircraft's height is reduced continuously from a point at a large distance from the airport until it touches the runway. This results in lower noise emission than alternatives in which the aircraft's height may be held constant for sections of the track.

VOLUME 4

Appendix E2
Airport ground-based noise and vibration

ACOUSTICS AND AIR

WESTERN SYDNEY AIRPORT EIS

ASSESSMENT OF GROUND-BASED OPERATIONAL NOISE

REPORT NO. 14168-1
VERSION F

SEPTEMBER 2015

PREPARED FOR

GHD PTY LTD
LEVEL 15
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SYDNEY NSW 2000

WILKINSON MURRAY

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E	Draft	11 September 2015	Barry Murray	-
F	Final	6 October 2015	Barry Murray	-

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TABLE OF CONTENTS

Page

EXECUTIVE SUMMARY **1**

1 INTRODUCTION **3**

1.1 Background **3**

1.2 Terms of Reference **4**

1.3 Scope of this Report **4**

1.4 Report Structure **5**

2 EXISTING NOISE ENVIRONMENT **6**

3 ASSESSMENT OF AIRPORT GROUND-BASED OPERATIONAL NOISE **9**

3.1 NSW *Industrial Noise Policy (INP)* **9**
3.1.1 Adapted *INP* Criteria for Residential Locations 9
3.1.2 *INP* Noise Criteria for Other Receiver Types 10
3.1.3 Relevance of *INP* to Ground-Based Operational Noise 11

3.2 Noise Criteria for Engine Ground Running **11**

3.3 Noise Criteria for Taxiing **11**

3.4 Summary of Airport-Specific Operational Noise Criteria **12**

3.5 Prediction Method **12**
3.5.1 Aircraft Engine Ground Running Noise for Initial Airport Development 13
3.5.2 Taxiing Noise for Initial Airport Development 13

3.6 Assessment of Initial (Stage 1) Airport Development **15**

3.7 Assessment of Longer Term Airport Development **17**

3.8 Mitigation of Ground-Based Operational Noise Impact **19**

4 ASSESSMENT OF AIRPORT CONSTRUCTION NOISE & VIBRATION **21**

4.1 Relevant Criteria **21**
4.1.1 NSW *Interim Construction Noise Guideline (ICNG)*[R8] and Construction Noise Criteria 21
4.1.2 Vibration Criteria 22

4.2 Construction Noise Sources **22**

4.3 Construction Noise Scenarios and Predicted Levels **23**

4.4 Construction Noise Mitigation Measures **29**

4.5 Construction Vibration Assessment **30**

4.6 Construction Traffic Noise Assessment **31**

5 ROAD TRAFFIC NOISE 32

5.1 Relevant Criteria 32

5.2 Noise Impact of Traffic on Specific Roads 32

6 CONCLUSIONS 34

7 REFERENCES 36

GLOSSARY 37

APPENDIX A – Ambient Noise Measurements

EXECUTIVE SUMMARY

This report assesses noise impacts on surrounding communities from ground-based operational activity at the proposed Western Sydney Airport. The assessment has been undertaken as part of the EIS for the proposal. Aircraft overflight noise, which includes aircraft take-off and reverse thrust noise, is addressed in a separate EIS technical report.

Existing Noise Environment

The existing noise environment of the study area was surveyed to determine background noise levels and establish noise criteria for the construction and operational phases of the proposal. The results obtained are shown in Table 2-1 of the report.

Assessment of Airport Ground-based Operational Noise

Criteria for operational noise have been set for night time (the most sensitive period) using the measured background noise levels. The following residential noise criteria have been adopted taking into account any intermittency of the noise in question.

- Engine ground running noise ($L_{Aeq,15min}$) 45 dBA
- Taxiing noise ($L_{Aeq,15min}$) 40 dBA

The assessment of the initial (Stage 1) airport development shows that a significant population could be expected to be affected by noise levels above these criteria during night time hours (10pm-7am) and under worst-case assumptions of a temperature inversion. This impact is summarised in Table 3-1 of the report.

Noise criteria were also established for other uses. The assessment shows that up to five educational institutions, three places of worship, two passive recreation areas and three active recreation areas would be affected by operational noise levels above the noise criteria.

There are limits to the extent that mitigation measures can be applied to reduce the impacts of ground-based operational noise. One noise generating operation is engine ground running which is a mandatory procedure for all aircraft returning into service after maintenance. Although a contributor to overall noise levels, engine running at high power would not occur often. The most effective form of mitigation is to ensure that engine runs on high power do not occur at night time, except for abnormal situations where run-up is required to allow early departure of an aircraft.

Run-up noise level reductions of up to 10 dBA (an effective halving of the perceived noise level) may be achieved by locating or constructing buildings, barriers or mounds around the run-up area.

The noise impact from taxiing is much lower as aircraft engines are at idle power settings and specific noise mitigation is less likely to be required.

Apart from these operational noises, other noise would be generated within the proposed airport by vehicle movements and mechanical plant. However, this type of noise will be much lower in level than the operational noise assessed.

Assessment of Construction Noise and Vibration

Noise levels have been calculated for the bulk earthworks stage of the proposed construction works, which is expected to be the noisiest stage. Noise levels have been calculated for the four proposed earthworks areas and the results are shown in contour form in Figure 4-1 to Figure 4-4 of this report for the worst meteorological conditions of a temperature inversion. Construction noise levels would be confined mostly to the airport site, but some impact to the west of the airport site near Luddenham and to the north-east around Badgerys Creek is expected. However, no residence will be affected by construction noise levels in excess of the acceptable standard in the Airports (Environment Protection) Regulations.

During construction, heavy and light vehicles are expected to use Elizabeth Drive for access to the construction site. However, the increase in road traffic noise levels on Elizabeth Drive during construction would not be significant. Vibration from construction is not likely to damage buildings.

Assessment of Operational Road Traffic Noise

During operation of the proposed airport, there would be an increase in road traffic in the area surrounding the airport site. Apart from the M12 motorway, the road traffic increases attributable to the operation of the proposed airport are not expected to result in significant noise level increases. Impacts associated with the development of the M12 and other local road upgrades and realignments are to be separately assessed by the NSW Government as part of the planning for these projects.

1 INTRODUCTION

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies – including two previous environmental impact statements for a site at Badgerys Creek – having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016 with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services with development staged in response to demand. The initial development of the proposed airport would include a single 3,700 metre runway coupled with landside and airside facilities, such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24-hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, a delegate of the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Terms of Reference

The Department of the Environment issued EIS guidelines in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* for the Western Sydney Airport proposal. Requirements of the EIS guidelines relevant to aircraft noise are as follows:

> *Impacts to the environment (as defined in section 528) should include but not be limited to the following:*
>
> *Aircraft noise and vibration impacts on everyday activities and on sensitive environmental receptors (all sensitive receptors within the community and natural environment). Discussion and quantification/modelling of aircraft noise impacts should include consideration of all potential flight paths, height of flights, noise exposure patterns, noise contours, the range of frequencies of the noise, cumulative exposure, peak noise, frequency of overflights and temporal variability of this (including long term trends), varying aircraft types, varying aircraft operating procedures, and variations in noise patterns due to seasonal and meteorological factors*

This report has been prepared in accordance with the EIS guidelines.

1.3 Scope of this Report

This report addresses the operational noise impacts associated with the following components of the proposed airport:

- ground running of aircraft engines;
- taxiing of aircraft; and
- road traffic changes in the surrounding area.

Apart from these operational noises, other noise would be generated within the proposed airport by vehicle movements and mechanical plant. However, this type of noise will be much lower in level than the operational noise assessed.

The use of auxiliary power units (APUs) on aircraft has not been assessed because it is assumed that power and pre-conditioned air would generally be supplied to aircraft at the terminal gates.

The report also addresses construction noise, including construction generated traffic and vibration.

Collectively, the activities assessed in this report are referred to as airport ground-based operational noise sources. Noise from aircraft departing and arriving, including whilst on the runway, is assessed in the Aircraft Overflight and Operational Noise Report.

Ground-based operational noise at airports is regulated by the Airports (Environment Protection) Regulations 1996. These regulations include specific limits for certain activities at certain times of the day and provide other more general principles to be applied by the airport environment officer at other times. All airports have specific procedures around ground noise and it is likely that these types of procedures would be applied to the proposed airport.

The following NSW noise policies have been referred to in assessing the impacts associated with ground-based noise sources, because these policies best address community reaction:

- NSW *Industrial Noise Policy (INP)*[R3];
- NSW *Road Noise Policy (RNP)*[R4].

In addition to the NSW *Road Noise Policy* which is applicable to construction as well as operational traffic, the construction noise assessment has also been undertaken with regard to the *Interim Construction Noise Guideline (ICNG)*[R8] (NSW Department of Environment and Climate Change, now NSW Environment Protection Authority, July 2009).

1.4 Report Structure

The remainder of this report is structured as follows:

Chapter 2 – presents a summary of the existing noise environment, including results of ambient noise monitoring.

Chapter 3 – presents the assessment of airport operational noise sources including ground running of aircraft engines and taxiing of aircraft

Chapter 4 – presents the assessment of construction noise and vibration sources, including construction traffic noise.

Chapter 5 – presents the assessment of airport-related road traffic.

Section 6 – presents the conclusions of the report.

2 EXISTING NOISE ENVIRONMENT

The various NSW noise policy documents considered in this report require knowledge of the existing noise environment, in particular, the background noise levels in the area surrounding the proposed airport. This sets the benchmark against which the potential impacts of constructing and operating the proposed Western Sydney Airport can be assessed. Accordingly, ambient, or background, noise levels have been measured at a number of locations. These measurements were carried out in accordance with AS1055: 1997(R12).

Noise measurements were carried out at 10 locations generally over the period Monday, 23 March to Thursday, 2 April 2015, although at some locations a shorter period [the minimum duration required by the *INP* (7 days)] was completed. The measurement locations are described in Table 2-1 and shown in Figure 2-1. The area is rural and rural-residential and the measurement locations reflect this environment. The locations were also chosen to represent potentially-affected development in the surrounding area.

The noise monitoring equipment used for these measurements consisted of environmental noise loggers set to A-weighted, fast response, and continuous monitoring over 15-minute sampling periods. This equipment is capable of remotely monitoring and storing noise level descriptors for later detailed analysis. The equipment was calibrated before and after the survey to ensure the accuracy of observations. No significant drift in level was noted.

The logger determines L_{A1}, L_{A10}, L_{A90} and L_{Aeq} levels of the ambient noise. L_{A1}, L_{A10} and L_{A90} are the levels exceeded for 1%, 10% and 90% of the sample time respectively. The L_{A1} is indicative of maximum noise levels due to individual noise events such as the occasional pass-by of a heavy vehicle. This is used for the assessment of sleep disturbance. The L_{A90} level is normally taken as the background noise level during the relevant period.

The results of measurements are shown in graphical form in Appendix A. From the measurement data, the Rating Background Level (RBL) as defined in the *INP* has been determined and shown in Table 2-1.

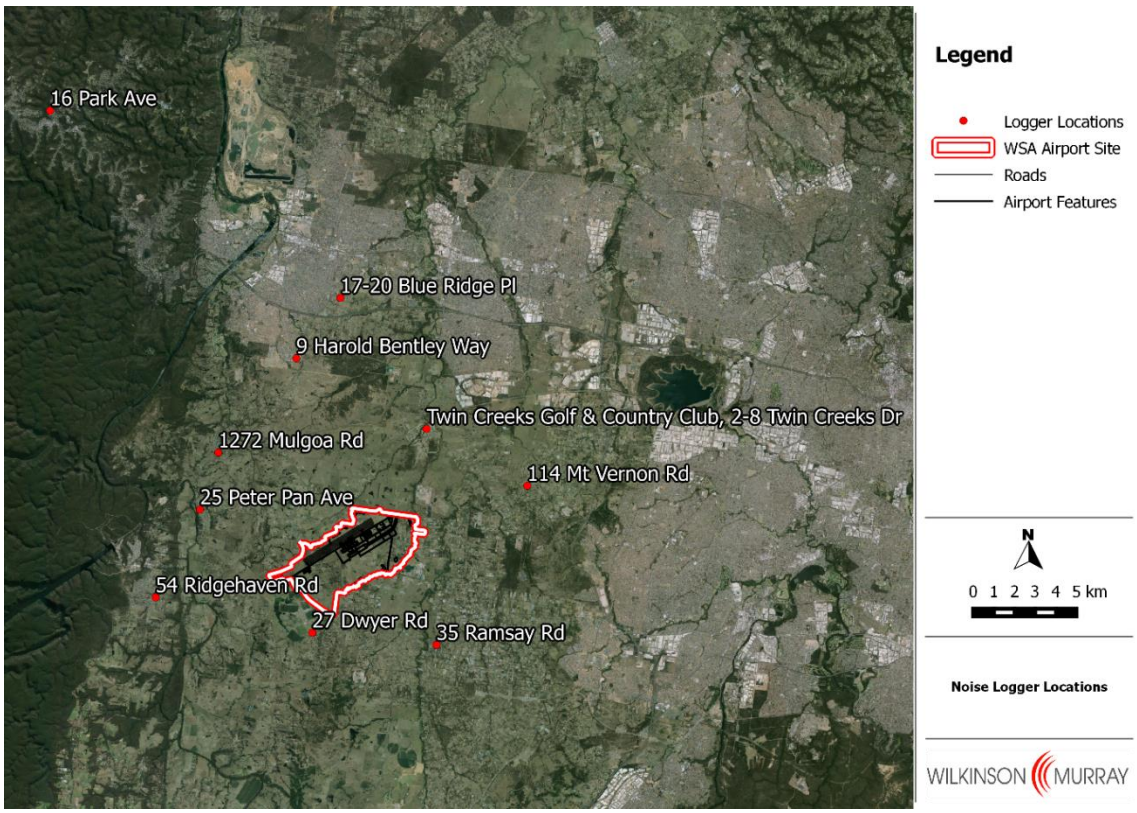
Table 2-1 Measured Background Noise Levels around the proposed Western Sydney Airport

Location	Measurement Duration	Rating Background Level (dBA)		
		Day (7am-6pm)	Evening (6pm-10pm)	Night (10pm-7am)
9 Harold Bentley Way, Glenmore Park	Monday 23/3/15 – Thursday 2/4/15	39	42	38
16 Park Avenue, Springwood	Wednesday 25/3/15 – Thursday 2/4/15	29	32	24
17 Blue Ridge Place, Orchard Hills	Monday 23/3/15 – Tuesday 31/3/15	34	38	36
25 Peter Pan Avenue, Wallacia	Monday 23/3/15 – Thursday 2/4/15	37	34	28
27 Dwyer Road, Bringelly	Monday 23/3/15 – Thursday 2/4/15	33	38	35
35 Ramsay Road, Rossmore	Friday 27/3/15 – Thursday 2/4/15	35	37	35
54 Ridgehaven Road, Silverdale	Thursday 26/3/15 – Thursday 2/4/15	36	36	31
114 Mount Vernon Road, Mount Vernon	Monday 23/3/15 – Thursday 2/4/15	34	35	33
120 Vincent Avenue, Mulgoa	Monday 23/3/15 – Tuesday 31/3/15	38	42	35
Twin Creeks Golf & Country Club (2 Twin Creeks Drive, Luddenham)	Thursday 26/3/15 – Thursday 2/4/15	34	38	33

The measurement periods are in accordance with the *INP*.

According to the *INP*, where the RBL has been measured as less than 30 dBA, it should be assumed to be 30 dBA for the purpose of setting noise criteria. This applies at the Springwood and Wallacia locations. The relevant RBL values across all locations therefore fall in the range 30-38 dBA for the night period.

Figure 2-1 Background Noise Measurement Locations



3 ASSESSMENT OF AIRPORT GROUND-BASED OPERATIONAL NOISE

This section addresses the potential impacts of ground-based noise from operations within the boundary of the proposed airport. It discusses general noise criteria which are applied to industrial noise in NSW as the basis for setting criteria for the relatively constant ground-based noise. It then sets specific noise criteria for the particular types of noise to be expected, based on industrial noise assessment procedures. It is important to recognise in setting these criteria that the character of noise from ground-based activities at an airport is different from the character of noise from many other developments, such as industrial developments.

The Airports (Environment Protection) Regulations provide a regulatory approach for ground-based operational noise. However, these regulations are not intended to provide a basis for the assessment of the impact caused by such noise and they do not set criteria for aircraft engine noise. As a result, it is necessary to identify other noise guidelines which could be used as a benchmark to reflect the potential response of members of the community to any ground-based operational noise. This analysis uses the *Industrial Noise Policy (INP)* [R3], which is published by the NSW Government. While the *INP* has no application to the regulation of Commonwealth leased airports, it provides a useful basis for assessing potential noise impacts in specific circumstances.

3.1 NSW *Industrial Noise Policy (INP)*

The *INP* [R3] provides guidance on the assessment of industrial noise and other noise of a similar character. It sets out noise criteria that are useful as a planning tool but recognises that the assessment of noise impact is complex and subjective, and should include consideration of other social and economic aspects of the development or activity.

The *INP* recommends that the $L_{Aeq,15min}$ noise level from an industrial development not exceed two noise criteria at residential locations, as measured outside:

- Intrusiveness criterion – this criterion is calculated as RBL +5 dB; and
- Amenity criterion – this criterion applies to the daytime period, evening period and night time period and is specified as an absolute level (i.e. it is not related to existing noise conditions).

In the area surrounding the airport, the intrusiveness criterion is the more stringent at all locations.

For ground-based operational noise the *INP* intrusiveness criterion would be the RBL (as shown in Table 2-1) + 5 dB. However, further consideration is necessary before finalising the airport-specific criteria for the different noise types.

3.1.1 Adapted *INP* Criteria for Residential Locations

The *INP* based intrusiveness noise criteria for residential land uses have been determined by adding 5 dB to the measured RBL levels.

The *INP* criteria are shown in Table 3-1 for generally continuous noise. However, adjustments need to be made where the noise is not continuous.

Table 3-1 *INP* Intrusiveness Noise Criteria for Residential Locations

Location	Measurement Duration	$L_{Aeq,15min}$ Noise Criteria (dBA)		
		Day (7am-6pm)	Evening (6pm-10pm)	Night (10pm-7am)
9 Harold Bentley Way, Glenmore Park	Monday 23/3/15 – Thursday 2/4/15	44	47	43
16 Park Avenue, Springwood	Wednesday 25/3/15 – Thursday 2/4/15	35	37	35
17 Blue Ridge Place, Orchard Hills	Monday 23/3/15 – Tuesday 31/3/15	39	43	41
25 Peter Pan Avenue, Wallacia	Monday 23/3/15 – Thursday 2/4/15	42	39	35
27 Dwyer Road, Bringelly	Monday 23/3/15 – Thursday 2/4/15	38	43	40
35 Ramsay Road, Rossmore	Friday 27/3/15 – Thursday 2/4/15	40	42	40
54 Ridgehaven Road, Silverdale	Thursday 26/3/15 – Thursday 2/4/15	41	41	36
114 Mount Vernon Road, Mount Vernon	Monday 23/3/15 – Thursday 2/4/15	39	40	38
120 Vincent Avenue, Mulgoa	Monday 23/3/15 – Tuesday31/3/15	43	47	40
Twin Creeks Golf & Country Club (2 Twin Creeks Drive, Luddenham)	Thursday 26/3/15 – Thursday 2/4/15	39	43	38

The night time noise criteria are the most important criteria for airport ground-based operational noise because ambient noise levels will generally be lower than those during the day and evening and the applicable noise criteria for a given noise-generating event will also be lower. These criteria vary according to the location and are in the range 35-43 dBA.

So that the noise contours included below in this report can be readily interpreted, it is preferable to adopt one criterion for all residences. By the time the proposed airport becomes operational, background noise levels in the general area are expected to have increased as a result of increased road traffic and associated development in the surrounding area. This would particularly be so for the lower background noise levels and would in turn raise the value of the appropriate noise criteria for the assessment of airport operational noise. For this reason, an overall noise criterion of 40 dBA can be taken as generally appropriate for residential locations at night. Whilst this general criterion will be conservative for some locations, it takes into account the uncertainty of future noise levels.

3.1.2 *INP* Noise Criteria for Other Receiver Types

The *INP* also recommends noise criteria for other receiver types potentially affected by ground-based noise from the proposed airport. Some of these criteria are for indoor noise levels and these have been converted to outdoor noise levels by adding 10 dB. This is equivalent to the attenuation that would be perceived indoors from an external noise source with windows partly open.

The external criteria for these other receiver types are shown in Table 3-2, and these apply during normal use, i.e. generally daytime only, but also at night in the case of hospital wards.

Table 3-2 Noise Criteria for Other Receiver Types

Type of Receiver	Recommended Maximum L_{Aeq} Noise Criterion (dBA)
School Classroom	50
Hospital Ward	55
Place of Worship	55
Passive Recreation Area	55
Active Recreation Area	60

3.1.3 Relevance of *INP* to Ground-Based Operational Noise

The *INP* criteria discussed above apply to relatively continuous noise such as that produced by taxiing. The following sections address the specific noise types in detail and set the appropriate noise criteria.

3.2 Noise Criteria for Engine Ground Running

Engine ground running noise would be intermittent and would most likely be subject to limitations during the night time period. In practice, ground running would not often occur during night time and high power running would not occur every night. When when it does occur, it would occur for only a short period.

For modelling purposes it has been assumed that high power run up would occur for less than 5 minutes in any night. Therefore, the night time residential criterion for this activity has been set using the industrial noise criterion as 5 dB over the general *INP* night time criterion for residential receivers; that is 45 dBA, in accordance with the *INP* duration adjustment. The criteria for other land uses have been set 5 dB over the levels referred to in Table 3-2.

Like other major airports in Australia, the proposed airport is expected to have restrictions in place on engine ground runs, including limitations on night time run up activity.

3.3 Noise Criteria for Taxiing

Taxiing would occur relatively continuously at the proposed airport during daytime, but it would be expected to be intermittent at night time as a result of the limited number of aircraft movements proposed. However, during the busiest 15-minute period at night time, taxiing would be expected to be relatively continuous.

Since the resulting noise from taxiing aircraft would be relatively continuous, but fluctuating during the worst-case 15-minute period, it may be assessed according to the general *INP* criteria. 40 dBA has been set as a relevant criterion for residential receivers subject to taxiing noise and the criteria in Table 3-2 have been adopted for other land uses (see Section 3.1.1). These criteria apply at night.

3.4 Summary of Airport-Specific Operational Noise Criteria

Table 3-3 summarises the operational noise criteria adopted.

Table 3-3 Summary of Airport-Specific Operational Noise Criteria

Operation	Receiver Type	Measure	Noise Criterion (dBA)
Engine ground running	Residential	$L_{Aeq,15min}$	45
	School	$L_{Aeq,15min}$	55
	Hospital	$L_{Aeq,15min}$	60
	Place of worship	$L_{Aeq,15min}$	60
	Passive recreation	$L_{Aeq,15min}$	60
	Active recreation	$L_{Aeq,15min}$	65
Taxiing	Residential	$L_{Aeq,15min}$	40
	School	$L_{Aeq,15min}$	50
	Hospital	$L_{Aeq,15min}$	55
	Place of worship	$L_{Aeq,15min}$	55
	Passive recreation	$L_{Aeq,15min}$	55
	Active recreation	$L_{Aeq,15min}$	60

The noise criteria in Table 3-3 apply during the night time for residential and hospital developments. For the other uses, they apply during the daytime. However, the levels expected from all operations based on the measure indicated in the table would be the same during night time as during the day time or evening, despite the fact that the intensity of operation would be greater during the day time and evening. This means that the levels calculated and reported below for night time operations can be considered appropriate for assessment for all receiver types.

3.5 Prediction Method

Ground-based operational noise levels have been predicted for the initial airport development and for the longer term development. The initial development is presently expected to occur around 2030 and is the focus of this assessment.

Noise levels were calculated using the CadnaA noise model which is considered to be equivalent to a temperature inversion. CadnaA is a widely used and highly accepted environmental noise model which allows calculation of noise levels from a series of noise sources into the surrounding area. It takes into account the noise level of the noise sources, distance attenuation, air absorption, ground effects, shielding by intervening buildings and topography, and the effects of specific weather conditions. In this case, the model prepared for prediction incorporated the topography surrounding the airport, the final landform of the airport and the buildings proposed to be constructed during the initial airport development and the longer term airport development. Concawe is a document that describes environmental noise calculation procedures, including methods of assessing the effects of different weather conditions. Its algorithms were incorporated within CadnaA.

The philosophy applied to the assessment of ground-based operational noise involves, as is normal practice, the assessment under typical worst-case conditions. This includes assessment of the worst 15-minute period in those cases where the noise level varies with time, and assessment under worst-case meteorological conditions. The worst-case meteorological conditions were taken to be the worst conditions from Concawe[R1], which is equivalent to a temperature inversion. It should also be noted that no allowance has been made for any potential reduction in aircraft noise levels over time and the predictions discussed are based on known aircraft noise levels.

3.5.1 Aircraft Engine Ground Running Noise for Initial Airport Development

It has been assumed that aircraft ground runs would occur at the location shown in Figure 3-1. The orientation of an aircraft during run-up would depend on the prevailing wind conditions, as described in section 3.3. Taking a conservative approach to allow for a range of orientations, it has been assumed for modelling purposes that the noise source would be omni-directional and a level of 151 dBA has been assumed, based on measurements of aircraft taking off.

For the worst-case meteorological condition assumption, that being a temperature inversion, the calculated noise contours are shown in Figure 3-2 for the initial development. These contours reflect an assumption that there would be shielding from a maintenance building near the ground running area. They are $L_{Aeq,15min}$ contours and are based on the assumption that, at the very most, no more than one run up on full power would occur during any night and only for a maximum of five minutes.

3.5.2 Taxiing Noise for Initial Airport Development

Taxiing noise has been predicted by modelling the worst-case 15-minute period likely to occur during the night time period, using CadnaA. Aircraft taxiing on the taxiways shown in Figure 3-1 have been assumed for the proposed initial airport development by applying a line source along each taxiway.

A sound power level (noise level at source) for each aircraft of 138 dBA has been assumed. This is the highest level measured for aircraft taxiing, based on measurements of a B777, B747, B737, B717 and A330 aircraft.

The $L_{Aeq,15min}$ noise levels were predicted for worst-case meteorological conditions and are shown in Figure 3-3.

Figure 3-1 Ground-Based Operational Noise Source Locations – 2030

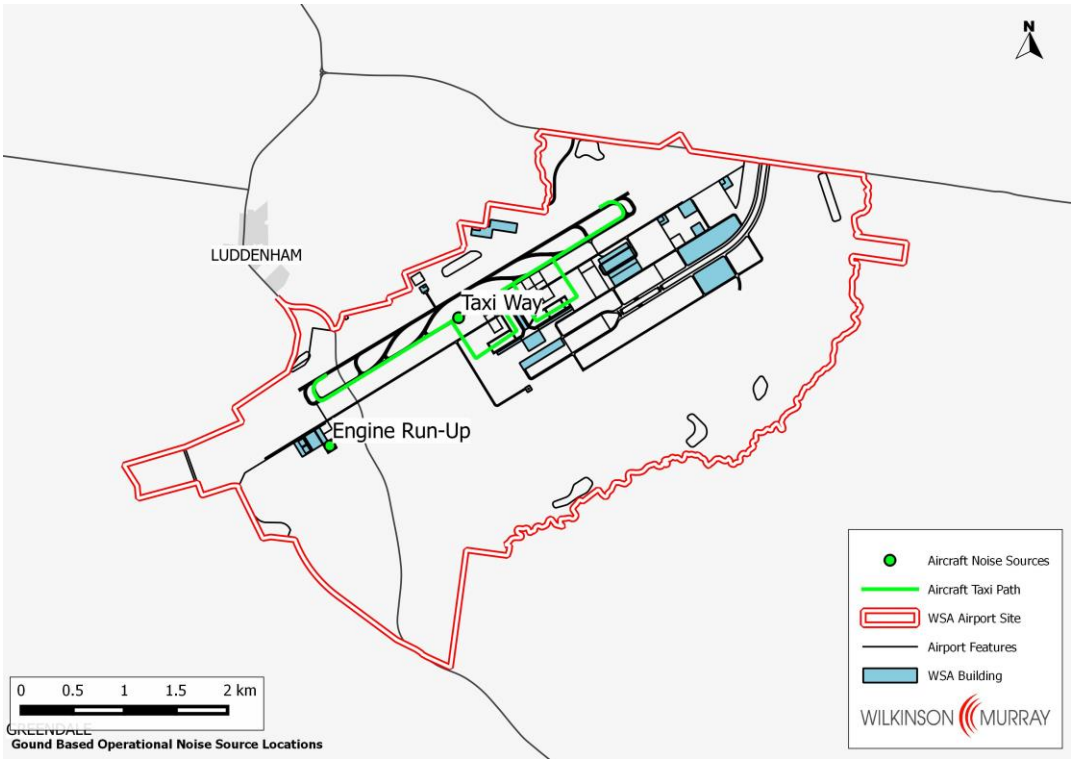


Figure 3-2 Worst-Case $L_{Aeq,15min}$ Engine Ground Running Noise Contours – 2030

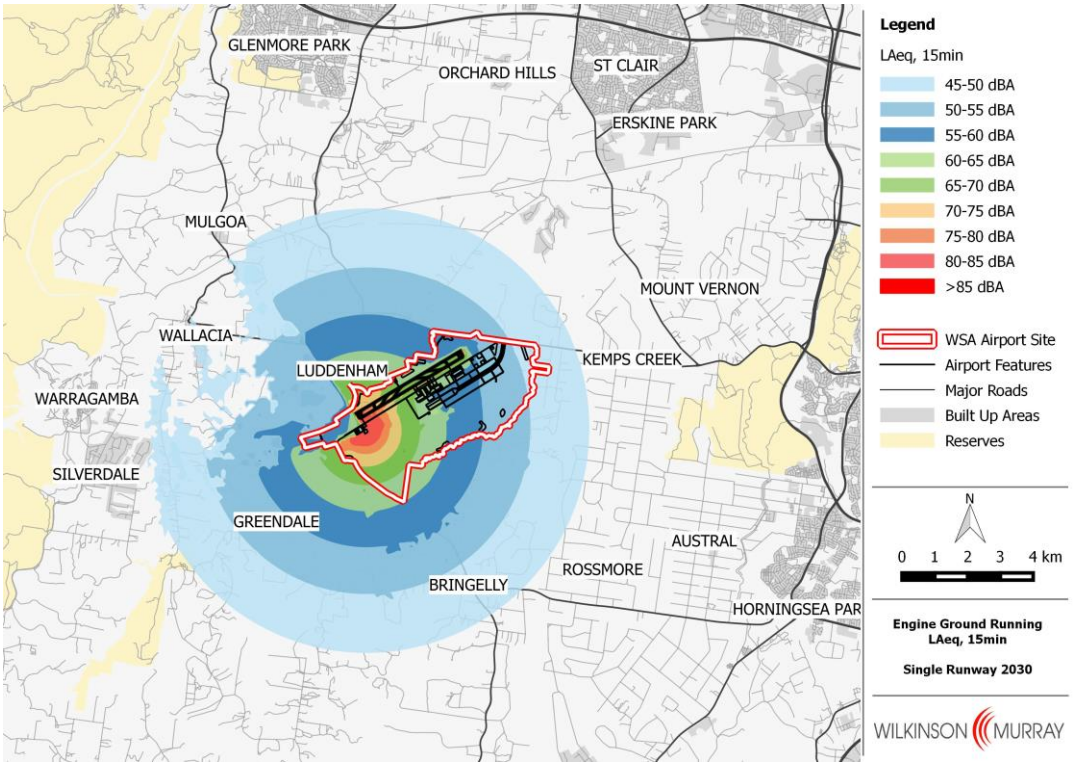
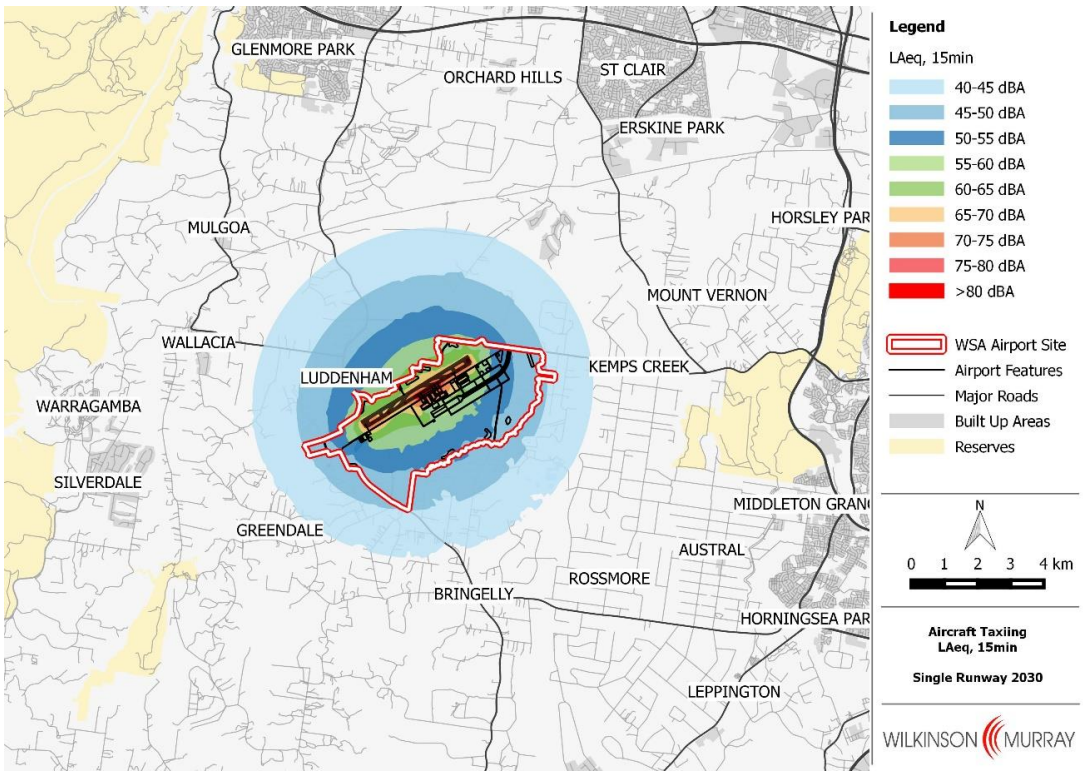


Figure 3-3 Worst-Case $L_{Aeq,15min}$ Taxiing Noise Contours – Night 2030



3.6 Assessment of Initial (Stage 1) Airport Development

Noise impact contours for engine ground running and aircraft taxiing are shown in Figure 3-2 and Figure 3-2, which depict the worst-case noise levels predicted to emanate from the proposed airport into adjacent areas in 2030.

Table 3-4 shows the estimated population that may be exposed to levels of ground-based operational noise above the residential criteria during the night time period in 2030 under worst-case conditions. Existing and forecast population estimates were developed by GHD, based on the September 2014 release of the NSW Bureau of Transport Statistics population forecasts. These forecasts take into account metropolitan planning development forecasts for future land use in Sydney as well as NSW Department of Planning and Environment population forecasts.

Table 3-4 Predicted Residential Noise Impact of Ground-Based Operational Noise under Worst-Case Conditions

Noise Type	Noise Criterion	Population Affected above Criterion
Engine Ground Running	45 dBA	7,258
Taxiing	40 dBA	3,117

Note: Population exposures are esitmates only

The impact of ground-based operational noise on other receiver types surrounding the airport is summarised in Table 3-5. This table shows the number of buildings and other land uses potentially affected by ground-based noise levels exceeding the criteria indicated in Table 3-2 above.

Table 3-5 Predicted Noise Impact of Ground-Based Operational Noise on Other Receiver Types under Worst-Case Conditions

Noise Type	Other Buildings and Land Uses Affected Above Criterion		
	Building or Land Use Type	Criterion	Number
Engine Ground Running	Educational Institutions	55 dBA	5
	Hospitals	60 dBA	0
	Place of Worship	60 dBA	2
	Passive Recreation	60 dBA	2
	Active Recreation	65 dBA	0
Taxiing	Educational Institutions	50 dBA	1
	Hospitals	55 dBA	0
	Place of Worship	55 dBA	0
	Passive Recreation	55 dBA	0
	Active Recreation	60 dBA	0

Note: Building numbers are based on information obtained in 2015, however datasets may be older. No verficiation of building types or uses has been undetaken.

As indicated in the contour plots and the tables above, under worst-case conditions and in the absence of operational controls (e.g. the restriction of certain operations such as engine ground running and use of reverse thrust at night), ground-based operational noise has the potential to extend over an area close to the airport site.

Under worst-case meteorological conditions, the impact from aircraft engine ground running at high power levels and taxiing has the potential to affect:

- Luddenham;
- Badgerys Creek;
- Bringelly;
- Wallacia; and
- Greendale.

The other uses likely to be affected by at least one of these noise types are shown in Table 3-6.

Table 3-6 Other Receiver Types Potentially Affected by One or More Operational Noise Types

Type of Use	Facilities
Education	Holy Family Catholic Primary & Church
	Luddenham Childcare Centre
	Schoolies at Mulgoa
	Luddenham Public School
	Mulgoa Pre School
Places of Worship	Holy Family Catholic Primary & Church
	St James Luddenham
	Luddenham Uniting Church
Passive Recreation	Freeburn Park, Luddenham
	Willmington Reserve, Luddenham
Active Recreation	Hubertus Country Club
	Sales Park, Luddenham
	Luddenham Showground
	Luddenham Raceway

3.7 Assessment of Longer Term Airport Development

The noise impacts discussed in Section 3.6 above relate to the proposed initial airport development of one runway in 2030. The longer term airport development is expected to involve the development of a second parallel runway some time before 2063. Such longer term development would be associated with a larger number of aircraft movements and more aircraft activity at the airport and consequently changed ground-based noise levels.

Ground-based noise levels have been predicted for the longer term airport development using the same methods as for the initial airport development. The noise source locations are shown in Figure 3-4 and the resulting contours are shown in Figure 3-5 and Figure 3-6.

Figure 3-4 Ground-Based Operational Noise Source Locations – 2063

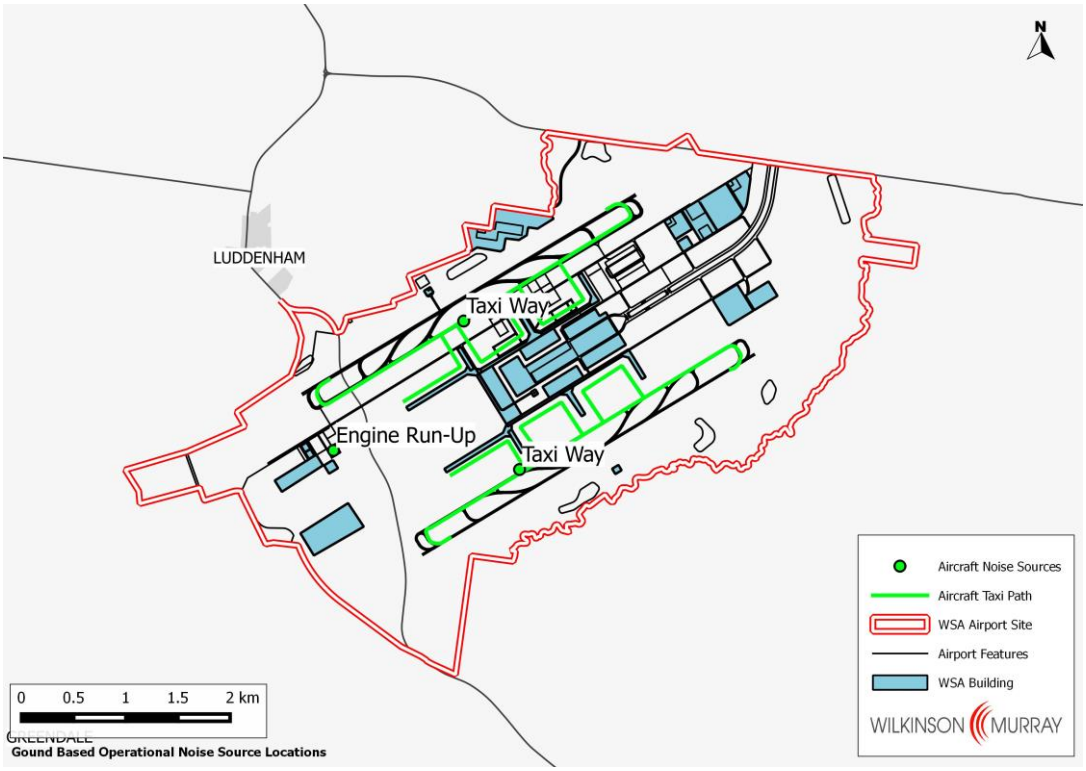


Figure 3-5 Worst-Case $L_{Aeq,15min}$ Engine Ground Running Noise Contours – 2063

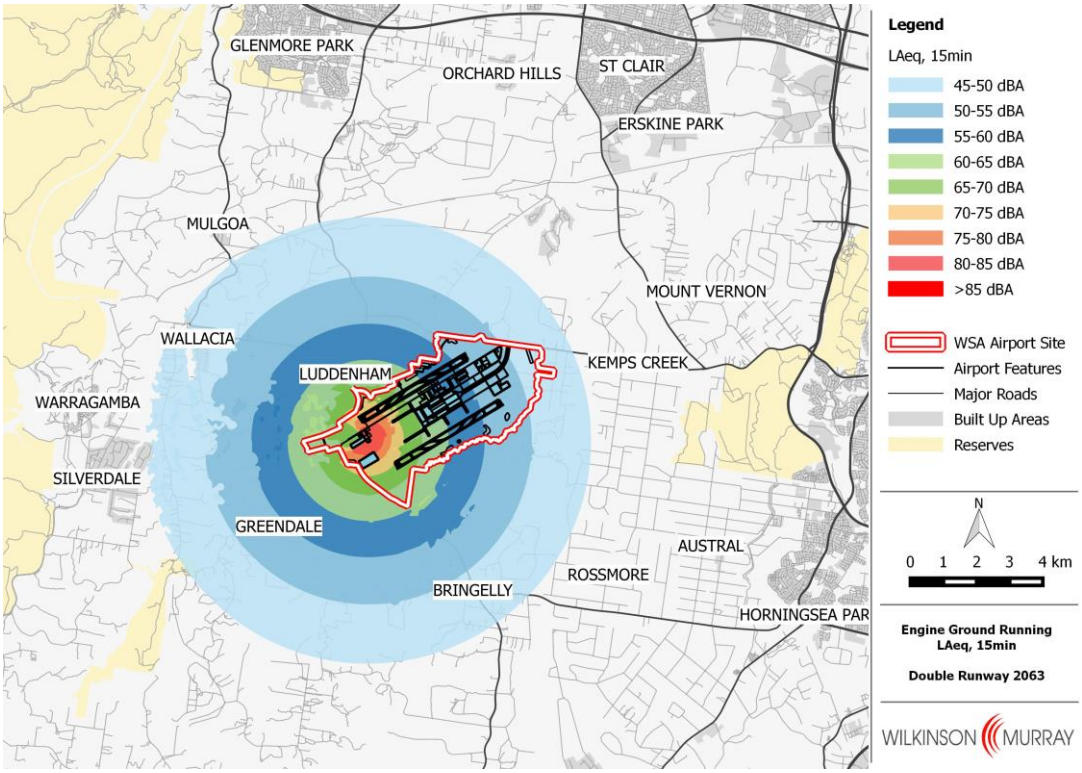
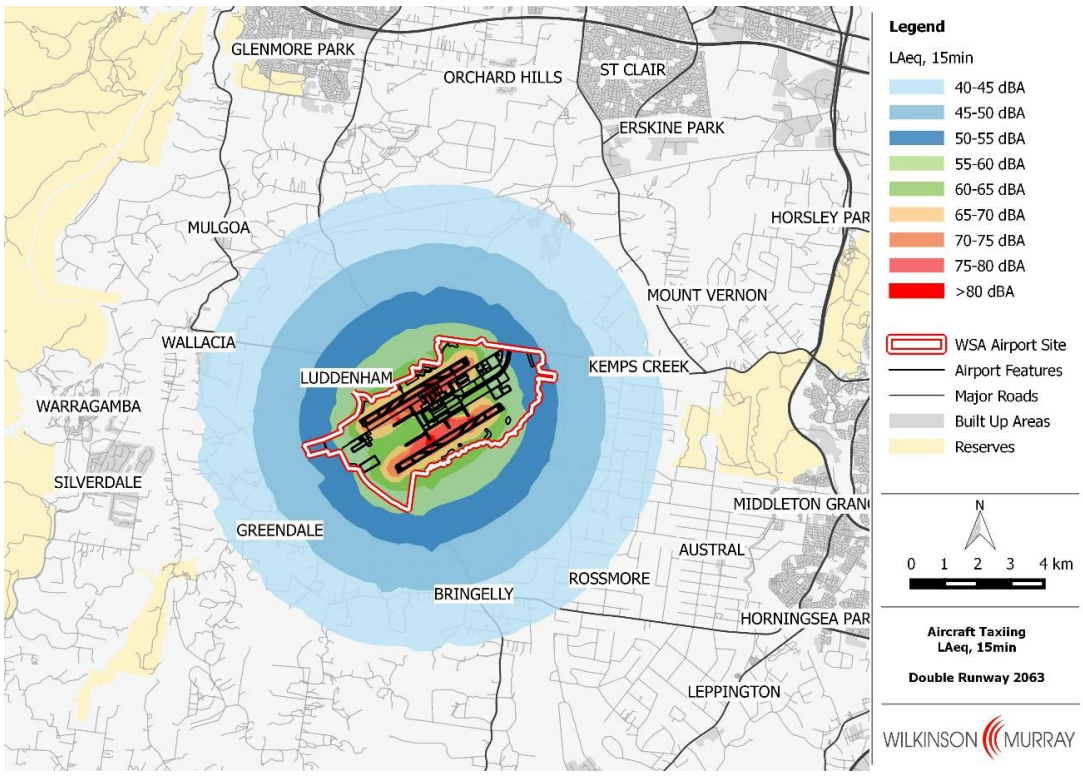


Figure 3-6 Worst-Case $L_{Aeq,15min}$ Taxiing Noise Contours – Night 2063



Engine ground running noise is not predicted to change substantially and will be generally shielded by buildings developed for the longer term development. The taxiing noise contours reflect the increased aircraft movements.

3.8 Mitigation of Ground-Based Operational Noise Impact

There are practical limits on the mitigation measures that can be applied to reduce the impact of ground-based operational noise sources and there are limited examples to assist in defining what is a practical strategy.

Engine ground running on high power would normally be carried out during daytime and night time. High power running at night time should be restricted to special circumstances where high power testing is required after maintenance activity prior to an aircraft taking off, as is the case for many major airports in Australia now. Restricting the amount of high power running at night time would substantially reduce the impact of ground running noise. It may also be practical to construct buildings, mounds or barriers near the run-up area to provide greater noise shielding, particularly on the northern side to shield the closest area of Luddenham. It is possible that reductions of around 10 dBA could be achieved with mounds or buildings at least 10 m high, but moderate residual impacts would still occur under worst-case meteorological conditions. There may also be a benefit in relocating the run up area further to the south-east to reduce the noise impact on Luddenham, but practical operational issues would need to be considered for this.

Aircraft taxiing noise would be relatively low in comparison to other noise associated with operation of the airport. There would be little that could be done to reduce noise levels emanating from the airport as a result of taxiing.

Many of the localities predicted to be affected by ground-based operational noise would also be affected by aircraft overflight noise. Luddenham is one such locality. It would be affected by typically 5-10 aircraft movements per day over 70 dBA (N70 5-10)[R11] from operation of the proposed initial airport development. Accordingly, a holistic approach is best adopted to the assessment and control of airport noise. One of the best methods of limiting any increase in impact over time is good planning around the airport site, including limiting residential development near the site.

The proposed use of ground power and pre-conditioned air for aircraft at the gates avoids the use of aircraft auxiliary power units and the associated noise.

4 ASSESSMENT OF AIRPORT CONSTRUCTION NOISE & VIBRATION

This section addresses the likely impact of airport construction noise and vibration on the surrounding area. The assessment is limited to construction within the airport site, given that construction outside, such as construction of new roads or realignment of roads, is not part of the proposed action and would be subject to separate approval processes by the relevant authorities.

Airport construction noise is governed by the Airports (Environment Protection) Regulations, but other noise criteria are also addressed in this section.

4.1 Relevant Criteria

4.1.1 NSW *Interim Construction Noise Guideline (ICNG)*[R8] and Construction Noise Criteria

The *ICNG* provides the method for management of noise levels emanating from construction sites in New South Wales. It recommends a process and noise management levels (NML) which can be used to assist in the process. Where it is predicted that the NML will be exceeded, specific action is recommended. For standard construction hours, it is recommended that all feasible and reasonable work practices be applied to meet the NML and that potentially impacted residents be informed of the nature of the work, the expected noise levels and duration, as well as contact details. Outside of standard hours, all feasible and reasonable work practices should be applied and, where the noise remains above the NML, there should be consultation with the affected community.

Standard construction hours are defined in the document as:

- Monday to Friday 7.00am to 6.00pm
- Saturday 8.00am to 1.00pm

For construction during standard construction hours, particularly daytime construction, the (noise affected) NML is background +10 dB for residential locations. For works outside of normal construction hours, the NML is background + 5 dB. The highly affected NML is set as 75 dBA. This is the acceptable standard set in the Airports (Environment Protection) Regulations for construction noise.

Airport construction works are proposed to occur primarily between 6.00am and 6.00pm, 6 days a week[R2]. Some work will be carried out outside these hours. Work between 6.00am and 7.00am and during Saturday afternoon (i.e. after 1.00pm) would fall outside of the standard hours within the NSW guidelines.

Based on the daytime background noise levels shown in Table 2-1, the daytime residential NML would be between 39 dBA and 49 dBA for standard hours. For assessment of construction noise, a NML of 45 dBA may reasonably be adopted for all residential receivers, for week-day construction. Equally, for weekend works and early morning works, an NML of 40 dBA may be adopted.

For other receiver types, the criteria NMLs are shown in Table 4-1.

Table 4-1 Noise Management Levels for Other Uses

Building Type / Use	NML (dBA)
Schools	55
Hospitals	55
Places of worship	55
Passive recreation	60

4.1.2 Vibration Criteria

Potential damage from vibration caused by construction of the proposed airport is addressed in this section. In Australia, the most stringent vibration standard, the German Standard DIN 4150-3: 1999[R5], is mostly used to protect buildings from vibration damage. This standard recommends guideline values which are frequency dependent. The lowest and most conservative values are normally adopted, as shown in Table 4-2.

Table 4-2 Vibration Damage Guideline Values (DIN 4150-3)

Type of Structure	Guideline Value, PCPV (mm/s)
Dwellings and buildings of similar design	5
Vibration sensitive buildings (heritage)	3

4.2 Construction Noise Sources

At this early stage in the airport planning process, only limited information is available about likely construction methods and equipment. The exact details of each construction stage would be established by the successful construction contractors. However, GHD 2015[R2] provides information to assist in predicting construction noise levels.

There are two basic stages of construction: bulk earthworks and aviation infrastructure construction. The bulk earthworks stage is expected to be the noisiest and Table 4-3 provides a summary of typical Sound Power Levels (at source) of the plant which may to be used during this stage.

Table 4-3 Typical Construction Sound Power Levels (SWL, Noise at Source)

Plant	SWL (dBA)
Caterpillar 657 Scraper	118
Caterpillar 825 Compactor	108
Caterpillar 966 Loader	114
Caterpillar D11 Bulldozer	120
Caterpillar D8 Bulldozer	110
30,000L Water Truck	103
200t Excavator	117
30t Excavator	105
Dump Truck	105
Moving Floor Truck	105
B-double Truck	105
Concrete Truck	105
16' Grader	111
14' Grader	109
Bobcat	103
Pad Foot Roller	104
Smooth Drum Roller	105
Multi-tyre Roller	100
Gravel Paver	109
Asphalt Paver	109
Paver Train	110
Concrete Cutting	115
Concrete Batch Plant	110
Asphalt Batch Plant	114

4.3 Construction Noise Scenarios and Predicted Levels

The bulk earthworks will generate the most noise during construction and the likely fleet of equipment is shown in Table 4-4, based on the GHD Construction Planning Report[R2].

Table 4-4 Construction Noise Scenario for Bulk Earthworks

Description	Equipment	Quantity
Bulk Earthworks • East Sector • North Sector • North West Sector • South West Sector	Caterpillar 657 Scrapper	16
	D11 Bulldozer	4
	200 t Excavator	3
	50 t Dump Truck	15
	Caterpillar 825 Compactor	3
	30,000 Water Cart	7
	16' Grader	7
	Pad Foot Roller	7
	Smooth Drum Roller	7

Bulk earthworks are expected to occur over four areas of the airport site at different times: North Sector, North West Sector, South West Sector and East Sector. For assessment purposes, the equipment shown in Table 4-4 has been assumed to operate in each sector at a time. The bulk earthworks in the East Sector are expected to take approximately nine months and in the other sectors one month each (according to the Construction Planning Report).

The CadnaA model was used to predict construction noise levels in the surrounding area. A Concawe worst weather condition has been modelled to represent a temperature inversion that may occur early in the morning in winter. A still isothermal weather condition has also been modelled to represent the rest of a typical day.

The four sets of construction noise contours generated are shown in Figure 4-1 to Figure 4-4 for a temperature inversion and Figure 4-5 to Figure 4-8 for isothermal conditions. There will be some construction noise impact for a limited period of time. The total effected population likely to be affected by noise levels above the NML during standard hours is shown in Table 4-5 and Table 4-6. No other uses will be affected by construction noise levels over the relevant NML.

Figure 4-1 East Sector Bulk Earthworks $L_{Aeq,15min}$ Contours – Temperature Inversion

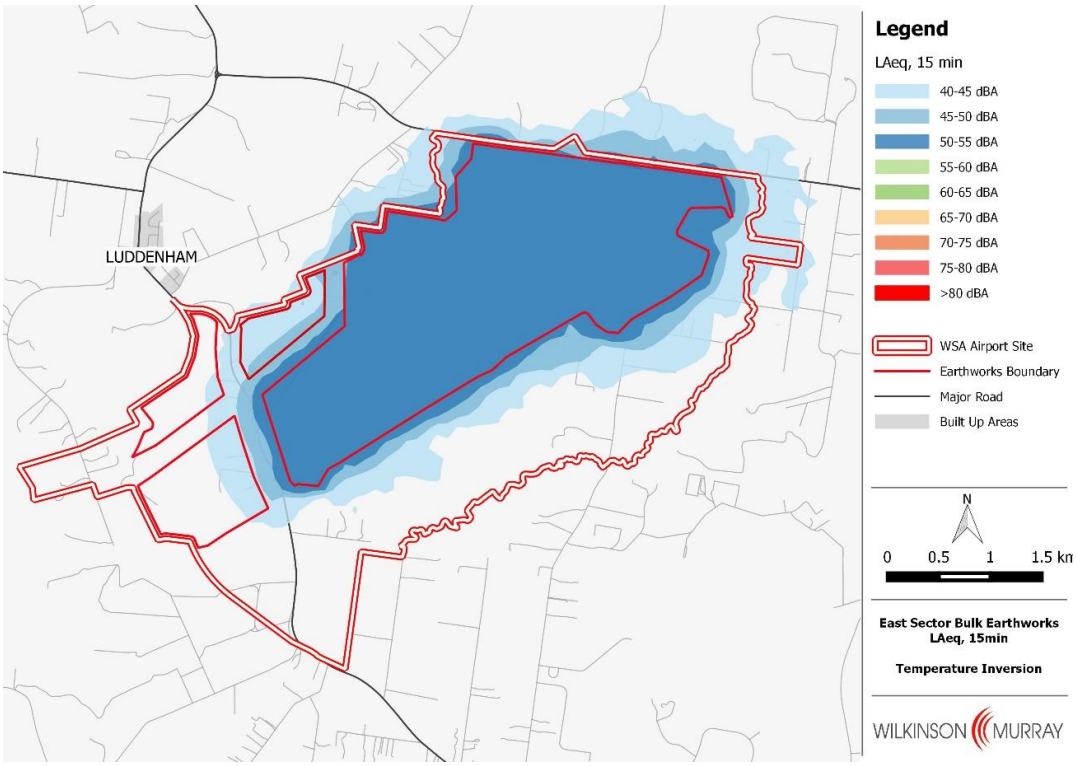


Figure 4-2 North Sector Bulk Earthworks $L_{Aeq,15min}$ Contours – Temperature Inversion

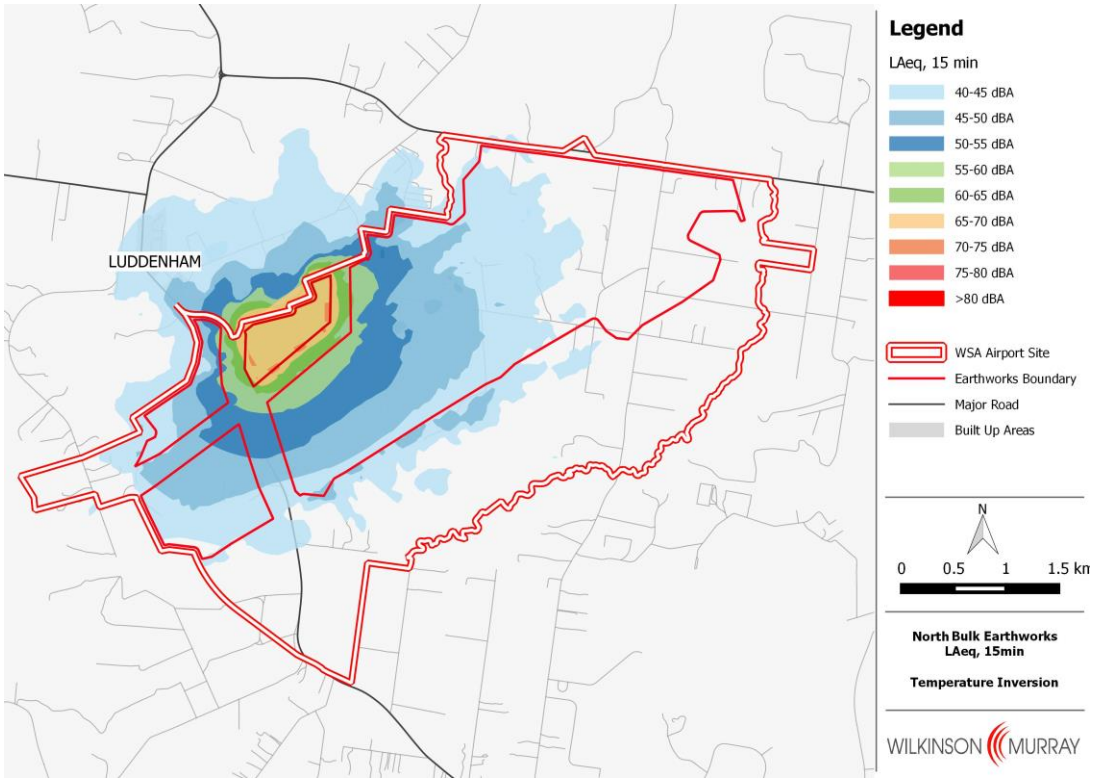


Figure 4-3 North West Sector Bulk Earthworks $L_{Aeq,15min}$ Contours – Temperature Inversion

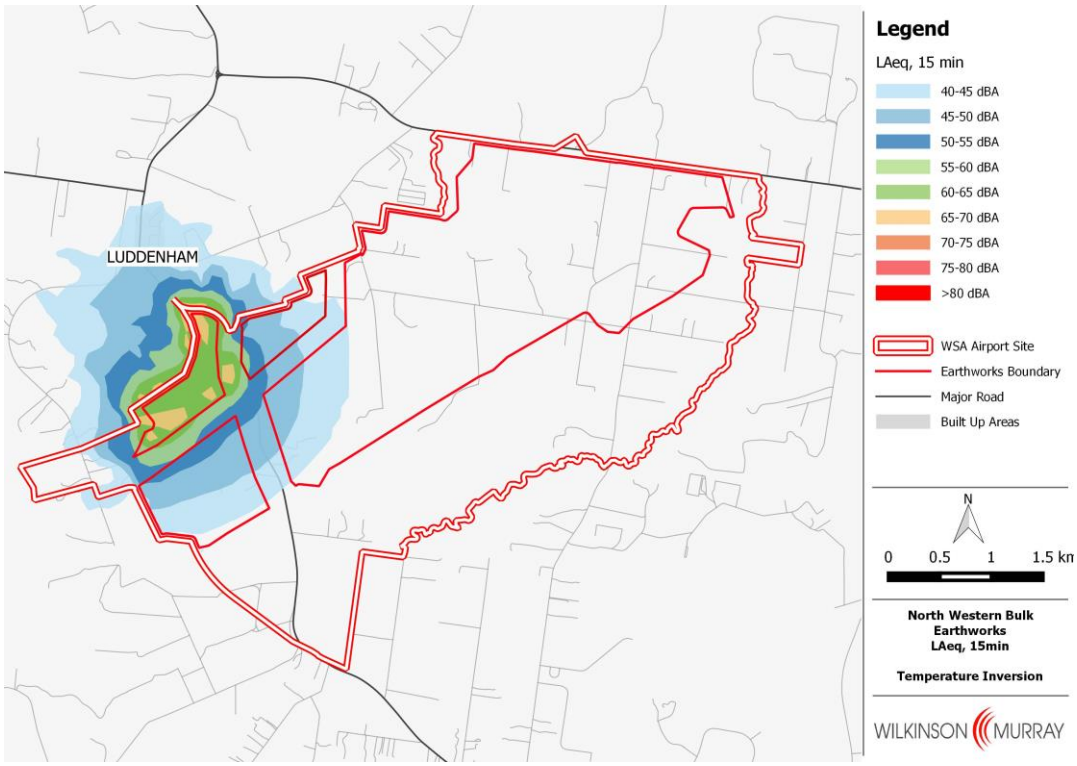


Figure 4-4 South West Sector Bulk Earthworks $L_{Aeq,15min}$ Contours – Temperature Inversion

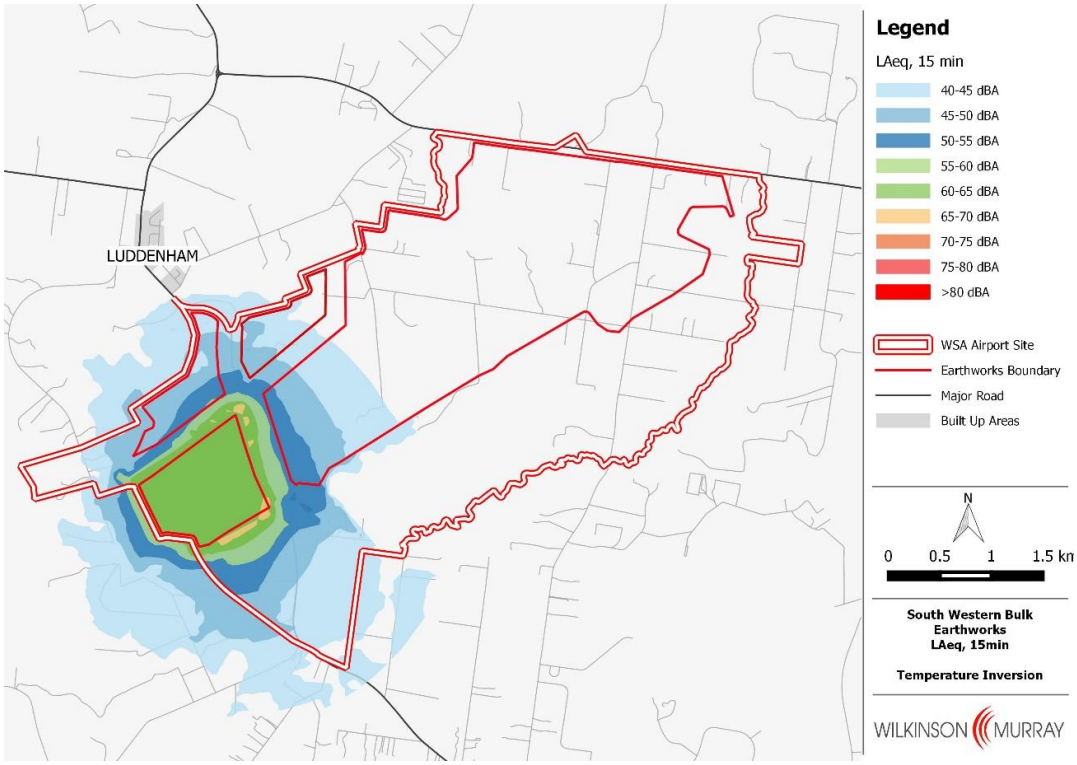


Figure 4-5 East Sector Bulk Earthworks $L_{Aeq,15min}$ Contours – Isothermal

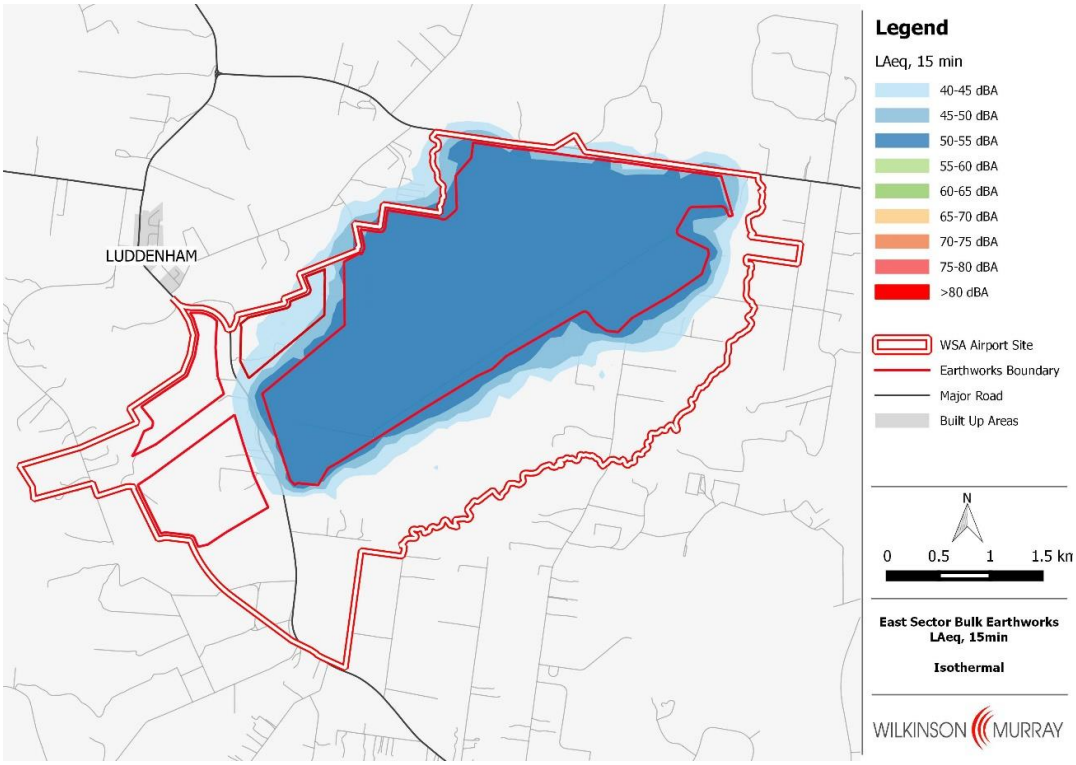


Figure 4-6 North Sector Bulk Earthworks $L_{Aeq,15min}$ Contours – Isothermal

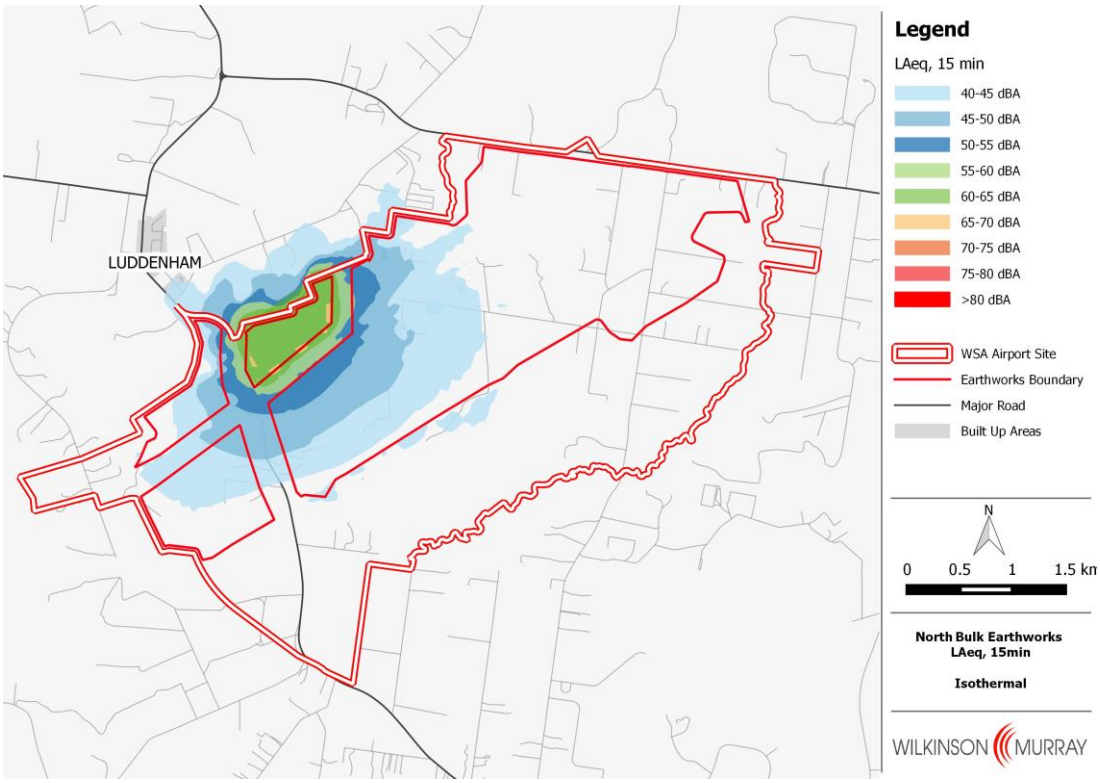


Figure 4-7 North West Sector Bulk Earthworks $L_{Aeq,15min}$ Contours – Isothermal

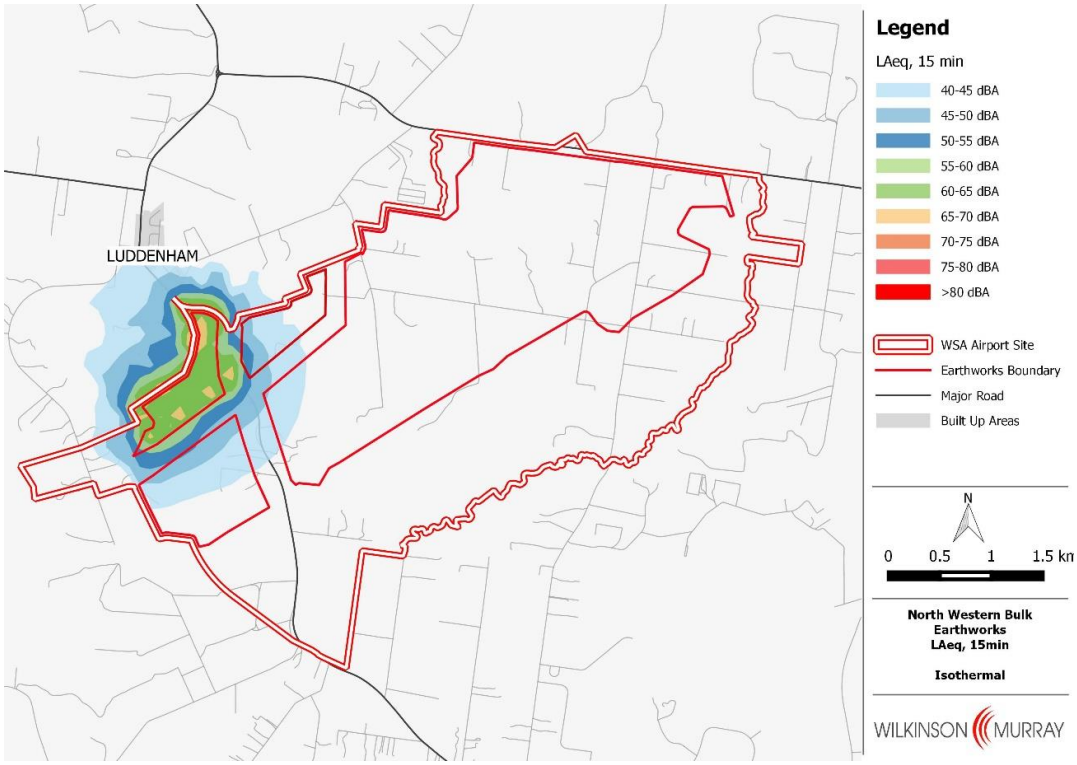


Figure 4-8 South West Sector Bulk Earthworks $L_{Aeq,15min}$ Contours – Isothermal

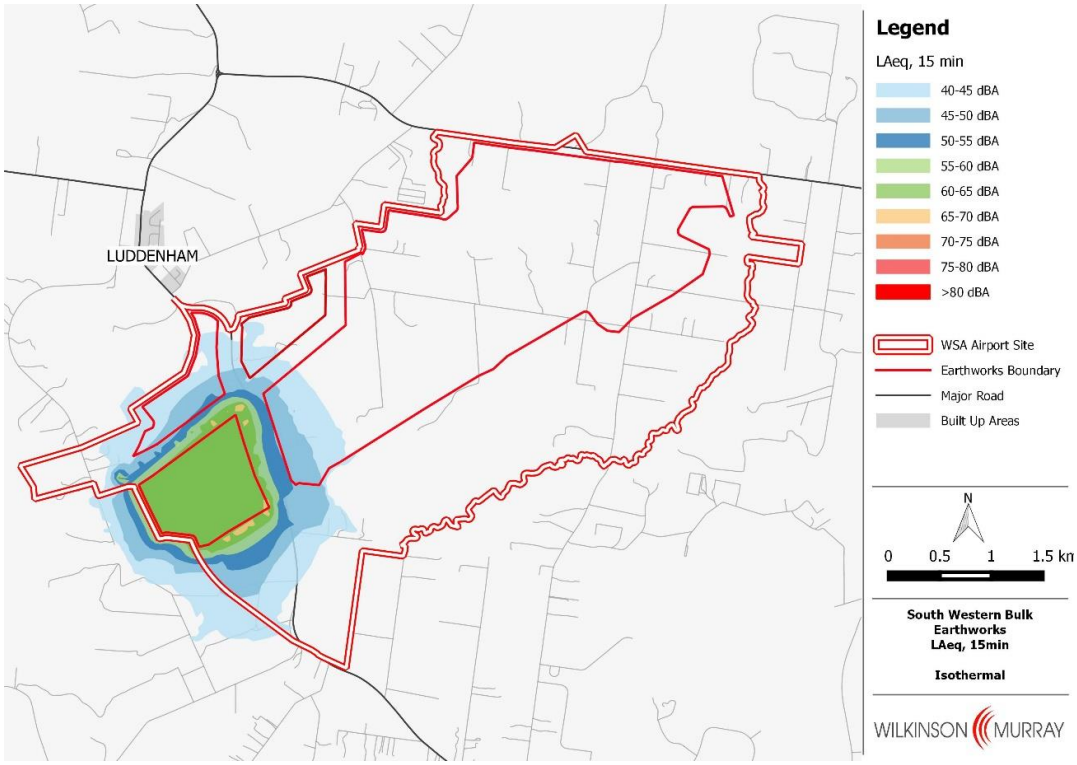


Table 4-5 Population affected by Levels above NML during Standard Construction Hours – Worst-Case of Temperature Inversion

Noise Type	Noise Criterion	Population affected above Criterion
East Sector	45 dBA	0
North	45 dBA	103
North West	45 dBA	199
South West	45 dBA	14

Note: Population exposures are esitmates only.

Table 4-6 Population affected by Levels above NML outside of Standard Construction Hours – Worst-Case of Temperature Inversion

Noise Type	Noise Criterion	Population affected above Criterion
East Sector	40 dBA	48
North	40 dBA	527
North West	40 dBA	531
South West	40 dBA	140

Note: Population exposures are esitmates only.

The impact of construction noise is not predicted to extend far beyond the airport boundary, largely because construction noise would be generated during daytime only, but sometimes during non-standard hours. The localities likely to be affected by construction noise are Luddenham and Badgerys Creek.

No residential receivers would be affected by construction noise levels above the acceptable standard in the Airports (Environment Protection) Regulations.

4.4 Construction Noise Mitigation Measures

Without mitigation, noise levels from construction activities have been predicted to exceed the nominated design criteria at numerous residential receivers and a number of other noise sensitive facilities. Therefore, noise control measures should be considered to ensure that construction noise levels are minimised at sensitive receivers.

A range of possible approaches to reducing the impact of construction noise is possible. It is proposed that these strategies be applied to areas of exceedance identified in the preceding section. The contractors responsible for the construction works should implement a *Construction Noise & Vibration Management Plan.* The Plan should provide for ongoing communication with potentially-affected residents and establish a complaint management and response system.

The plan should also address the following issues relating to construction noise impact management:

- construction hours (having regard to day of the week, work locations and distance to sensitive receivers);
- best practice noise levels for equipment (including use of noise compliant equipment, periodic compliance audit of equipment, use of clackers instead of reversing beepers etc.);
- operator training; and
- noise monitoring.

In practice, there is limited action that can be taken to reduce construction noise levels, but the impacts can often be reduced by management measures, such as restricting noisy activities outside of standard construction hours.

4.5 Construction Vibration Assessment

Vibration would be generated by the proposed construction works. As a very conservative approach, the lower guideline value applying to vibration sensitive buildings (3 mm/s) has been considered to test the risk of damage from construction vibration.

Figure 4-9 shows vibration levels previously measured on construction sites at a range of distances. The vibration levels from impact piling during the construction works would likely generate the highest vibration levels.

Figure 4-9 Previously Measured Vibration Levels

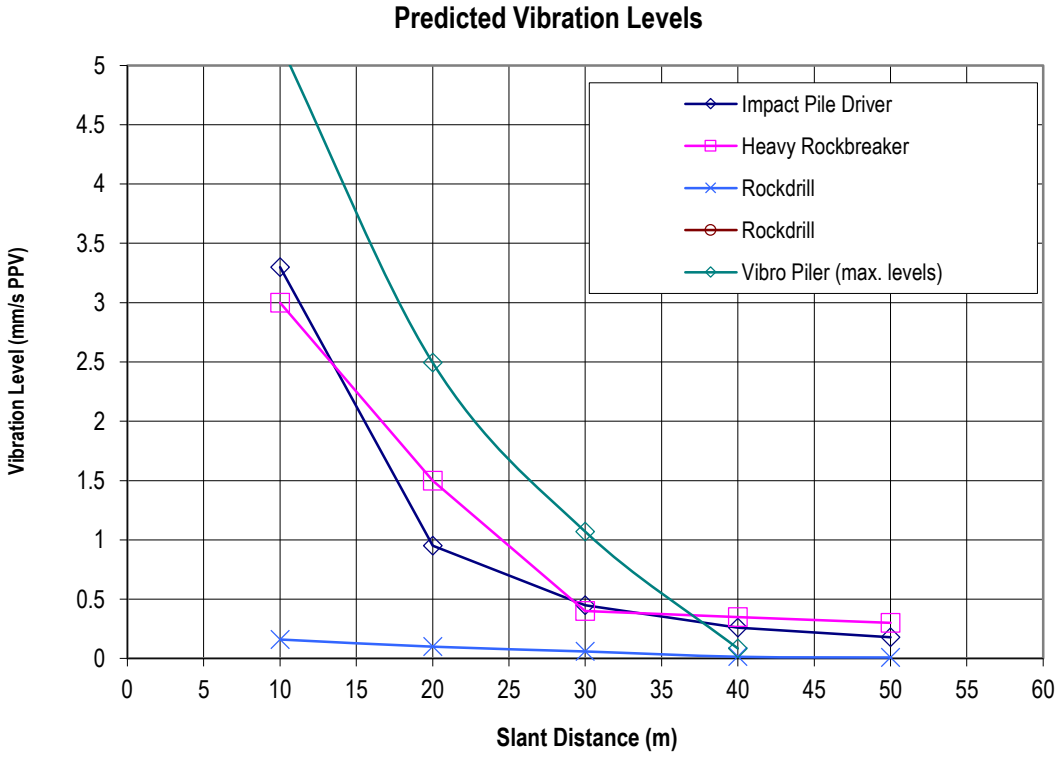


Figure 4-9 shows that the 3 mm/s value could be achieved even when using the piling method generating the highest vibration level at a distance of less than 20 m. Given that piling would occur well within the proposed airport boundary to construct the buildings, there would be no risk of damage to buildings from vibration outside of the proposed airport site.

Vibration may also be generated by the ripping of rock, but again the 3 mm/s guideline value is likely to be complied with inside the airport boundary and there is no risk of damage outside the airport boundary.

4.6 Construction Traffic Noise Assessment

The proposed construction works would require the use of the nearby road network for traffic to and from the construction site. Both heavy and light vehicles would need to access the site during this period. The number of movements of these vehicles during the busiest stage of construction is identified in GHD 2015(R2) and this information has been used to predict the change in road traffic noise due to construction. All construction traffic is expected to travel to the site via Elizabeth Drive.

The construction traffic noise levels have been calculated as described below in Section 5 and the calculated increases are shown in Table 4-7. These increases are based on the increase over the measured 2011 traffic flows and, therefore, the real impact would be expected to be less than predicted.

Table 4-7 Construction Traffic Noise Increases on Elizabeth Drive

Road	Section	L_{Aeq} Noise Level Increase (dB)	
		Day	Night
Elizabeth Dr	West of Mamre Rd	0.6	1.1
	West of Devonshire Rd	0.9	0.5
	West of Lawson Rd	0.9	0.6

Note: Analysis based on measured 2011 traffic and forecast construction traffic.

Along all sections of Elizabeth Drive the increase in noise level expected from construction traffic would be less than 2 dBA. Using the traffic noise criterion discussed in Section 5.2 below, it is concluded that this level of noise change resulting from the proposed construction works would not represent a perceptible noise increase.

5 ROAD TRAFFIC NOISE

The development of the proposed airport would result in increased airport-bound traffic. Planning for a proposed new M12 Motorway from the M7 to The Northern Road is being progressed by the NSW Government. When constructed, this motorway would provide the primary road link to the proposed airport. A detailed alignment for this motorway is not currently known.

Future road works would be the subject of separate approval processes by the relevant authorities undertaking these actions and the assessment of these is not covered in this document. However, a preliminary assessment of the general impact of the expected change in road traffic associated with operation of the proposed airport has been undertaken.

5.1 Relevant Criteria

Reference has been made to the NSW *Road Noise Policy* (*RNP*)[R4] to assess the effect of the proposed airport on road traffic noise in the area. The *RNP* recommends noise assessment criteria for residential and non-residential land uses affected by traffic generating developments. These criteria are more relevant to the assessment of new road infrastructure works, and they do not assist greatly in determining the impact of road traffic noise increases on existing roads due to the proposed airport and associated development.

In Section 3.4, the *RNP* document indicates that …. "*an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person*". It is this statement which is useful in assessing the significance of traffic noise level increases due to the proposed airport development.

5.2 Noise Impact of Traffic on Specific Roads

Road traffic projections for major roads in the vicinity of the airport have been provided by traffic planners for the year 2030 (GHD 2015a[R9]) with and without the airport. Noise levels at typical distances from these roads have been calculated using the *CoRTN*[R7] procedure which has allowed the increase in road traffic noise due to the proposed airport development to be forecast.

Table 5-1 shows the change in noise level expected as a result of the proposed airport on the major roads which the traffic report expects airport traffic to use. This table shows that there would be a decrease in road traffic noise on some roads which is due to anticipated development of the future M12 motorway. The highest noise level increase expected is less than 2 dB and accordingly, it is concluded that there would not likely be a perceptible noise increase resulting from road traffic as a result of the proposed airport development.

Table 5-1 Predicted Road Traffic Noise Level increases due to Airport Development (2030)

		Day	Night
Elizabeth Drive	West of Mamre Rd	0.8	0.5
	West of Devonshire Rd	1.3	0.8
	West of Lawson Rd	-0.4	-1.8
	West of Badgerys Creek Rd	1.6	0.0
	West of Luddenham Rd	1.3	-0.1
Luddenham Road	South of South Creek	-0.4	-0.6
	South of Twin Creeks Golf Club	-0.8	-1.4
Mamre Road	North of Elizabeth Dr	-0.1	-0.1
	North of Bakers Ln	0.5	0.4
	North of Banks Dr	0.0	0.0
The Northern Road	North of Homestead Rd	-0.4	-0.6
	South of Glenmore Pkwy	-0.6	-1.1
	North of Littlefields Rd	-0.9	-1.3
	North of Adams Rd	-0.6	-0.9
	North of Northern Rd	-0.1	-0.4
	North of Cobbitty Rd	-0.2	-0.3
	North of Camden Valley Way	-0.1	-0.2

Note: Source of traffic flows – GHD (2015).

6 CONCLUSIONS

Ground-based operational noise would be generated by aircraft engine ground running and taxiing. Predicted noise levels for these activities under assumed worst-case meteorological conditions are shown in contour form in Figure 3-2 and Figure 3-3 during the initial airport development.

Under worst-case conditions, engine running noise would affect a greater area around the airport compared to aircraft taxiing. Localities that may experience noise from engine runs based on the current conceptual layout includeeLuddenham, Badgerys Creek, Bringelly, Wallacia and Greendale. Residences in these localities would be affected by these noises along with schools and other educational institutions, places of worship, passive recreation and active recreation.

In reality, for any individual engine run not all of the above areas would be affected to the degree shown in Figure 3-2. This is because aircraft would be oriented in a particular direction during an engine run, usually facing into the prevailing wind, and noise would not be emitted equally in all directions as assumed by the modelling. High power engine runs during night time should be restricted to special circumstances where high power testing is required after maintenance activity prior to an aircraft taking off, as is the case for many major airports in Australia now. In addition, it may prove practicable to locate buildings, walls or earth mounds around the run up area. These structures could reduce noise levels by up to 10 dB.

Aircraft taxiing would generate relatively lower noise levels which are predicted to affect primarily Luddenham.

The design for the proposed airport is indicative, and the noise modelling resulting from that will be subject to further detailed design and assessment closer to the commencement of operations of the proposed airport. Some aspects of airport operations could be introduced to mitigate noise impacts on the community such as the establishment of ground running procedures.

It is important to note that the proposed airport has a lengthy construction period and current planning is for the airport to commence operations in about 2025. In this timeframe, technological improvements, including the upgrading of airline fleets, are expected to continue to reduce the industry's noise impacts on communities. These and other potential improvements will be considered in formal airport design and assessment processes in the future.

It is anticipated that a noise management strategy would be developed in consultation with appropriate stakeholders prior to the commencement of operations. This strategy would be developed in parallel with the detailed airport design to provide the local community and other important stakeholders with the chance to be consulted and fully informed of the final expected impacts before the airport commences operations.

Noise during the construction stage of the proposed airport would be confined primarily to within the airport boundary. However, some noise impact would occur outside of the airport boundary, particularly in the Luddenham and Badgerys Creek areas, but no residences would be affected by noise levels in excess of the acceptable criteria in the Airports (Environment Protection) Regulations. To minimise construction noise impacts, a *Construction Noise and Vibration Management Plan* should be developed by the construction contractors. This plan should address construction hours, equipment noise controls and complaint / response procedures.

Although heavy and light vehicles would need to access the proposed airport during the construction stage, the resulting increase in traffic noise would not be significant. Vibration generated by construction activities is considered unlikely to cause building damage outside of the site.

During operation of the proposed airport, road traffic noise level increases in the surrounding area are predicted to be insignificant. This is without considering the impact of the newly proposed M12 motorway and any road realignments which would be subject to separate applications and approvals by the relevant authorities.

7 REFERENCES

R1: Concawe, *The Propagation of Noise from Petroleum and Petrochemical Complexes to Neighbouring Communities*, Concawe, May 1981

R2: GHD 2015, *Western Sydney Airport Environmental Impact Statement Construction Planning Report*, GHD, July 2015

R3: *INP*, NSW *Industrial Noise Policy*, NSW EPA, January 2000

R4: *RNP*, NSW *Road Noise Policy*, NSW EPA, March 2011

R5: DIN 4150-3, *Structural Vibration: Effects of Vibration on Structures*, May 1986

R6: AS2021: 2015, *Acoustics – Aircraft Noise Intrusion – Building Siting and Construction*, March 2015

R7: *CoRTN*, *Calculation of Road Traffic Noise*, UK Department of Transport, 1988

R8: *ICNG*, *Interim Construction Noise Guideline*, NSW EPA, July 2009

R9: GHD 2015a, *Western Sydney Airport Traffic Report*, GHD, 2015

R10: Transport for NSW, *Construction Noise Strategy*, 2012

R11: Wilkinson Murray Report No. 14168, *Western Sydney Airport EIS – Aircraft Overflight Noise*, August 2015

R12: Australian Standard 1055: 1997, *Acoustics – Description and Measurement of Environmental Noise,* Standards Association of Australia

GLOSSARY

ACOUSTICAL TERMINOLOGY

Most environments are affected by noise from a variety of sources. To describe the overall noise environment, a number of noise descriptors have been developed and these involve statistical and other analysis of the varying noise over sampling periods, typically taken as 15 minutes. These descriptors, which are demonstrated in the graph below, are defined here.

ABL – The Assessment Background Level is the single figure background level representing each assessment period (daytime, evening and night time) for each day. It is determined by calculating the 10th percentile (lowest 10th percent) background level (L_{A90}) for each period.

A-Weighted Noise Level (dBA) – This is a value representing the loudness of a sound at a specific time, allowing for the differential response of the human ear to different sound frequencies.

L_{A1} – The L_{A1} level is the A-weighted noise level which is exceeded for 1% of the sample period. During the sample period, the noise level is below the L_{A1} level for 99% of the time.

L_{A10} – The L_{A10} level is the A-weighted noise level which is exceeded for 10% of the sample period. During the sample period, the noise level is below the L_{A10} level for 90% of the time. The L_{A10} is a common noise descriptor for environmental noise and road traffic noise.

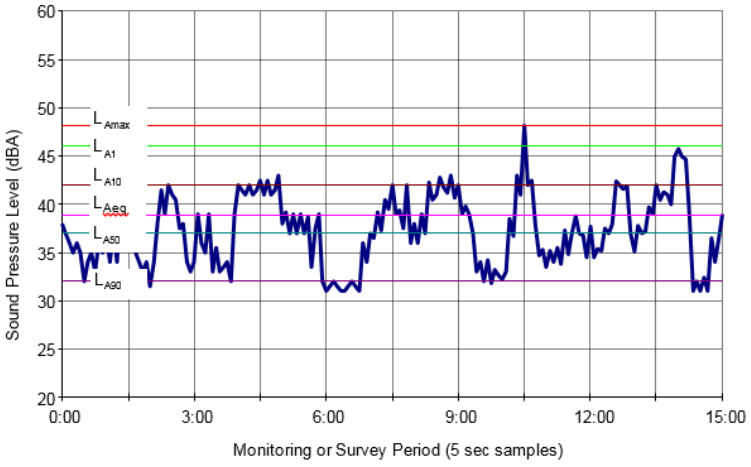
L_{A90} – The L_{A90} level is the A-weighted noise level which is exceeded for 90% of the sample period. During the sample period, the noise level is below the L_{A90} level for 10% of the time. This measure is commonly referred to as the background noise level.

L_{Aeq} – The equivalent continuous A-weighted sound level (L_{Aeq}) is the energy average of the varying noise over the sample period and is equivalent to the level of a constant noise which contains the same energy as the varying noise environment. This measure is also a common measure of environmental noise and road traffic noise.

Maximum Noise Level (L_{Amax}) – L_{Amax} over a sample period is the maximum A-weighted noise level measured during the period.

RBL – The Rating Background Level for each period is the median value of the ABL values for the period over all of the days measured. There is therefore an RBL value for each period **–** daytime, evening and night time.

Typical Graph of Sound Pressure Level vs Time



OTHER TERMINOLOGY

Aircraft Operation – In the context of this report, this refers to an aircraft arrival or departure.

Aircraft Engine Ground Running – Often after major engine maintenance, it is necessary to 'run-up' the engine for testing while the aircraft is on the ground. Whilst most of this occurs for engines running at idle or low power, it is often necessary to run the engine at full power for short periods of time.

Airport Site – The airport site is the total of all properties that may become part of Western Sydney Airport.

DIRD – The Australian Government Department of Infrastructure and Regional Development tasked with the detailed planning and investigation of the proposed Western Sydney Airport.

EIS – Environmental Impact Statement.

Initial Development – The first stage in the development of the Western Sydney Airport, including a single runway and associated infrastructure to handle up to approximately 10 million annual passenger movements, presently anticipated to occur in 2030. Also referred to as the Stage 1 development.

Longer Term Development – A longer term development at Western Sydney Airport could include dual runways and associated infrastructure to handle approximately 82 million annual passenger movements. The Western Sydney Airport EIS considers this patronage level could be reached around 2063.

Noise Management Levels – The Interim Construction Noise Guideline[R8] recommends Noise Management Levels (NMLs) which are to be used to manage construction noise levels at noise sensitive receivers. Where construction noise levels are predicted to be above the NMLs, the proponent should apply all feasible and reasonable work practices to meet the NMLs.

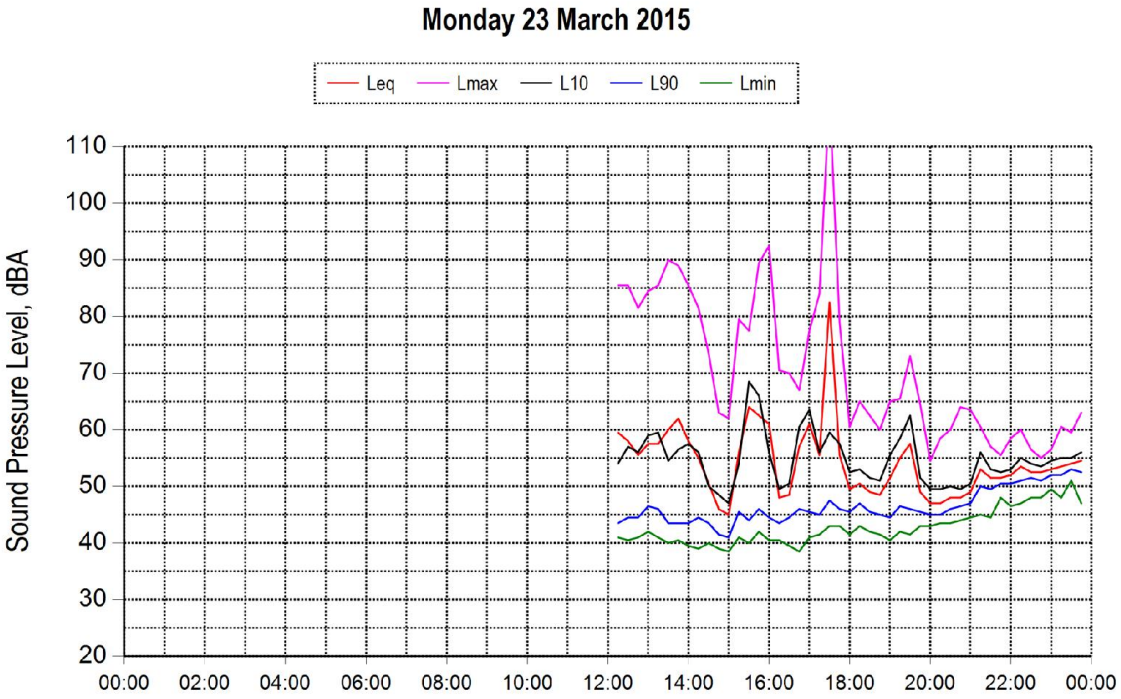
Taxiing – Aircraft at airports typically taxi from the terminals to the runway prior to take-off or from the runway to the terminal after landing. In calculating ground-based noise, taxiing noise has been calculated by modelling the movement of aircraft along the taxiways as shown on the designs for the initial development.

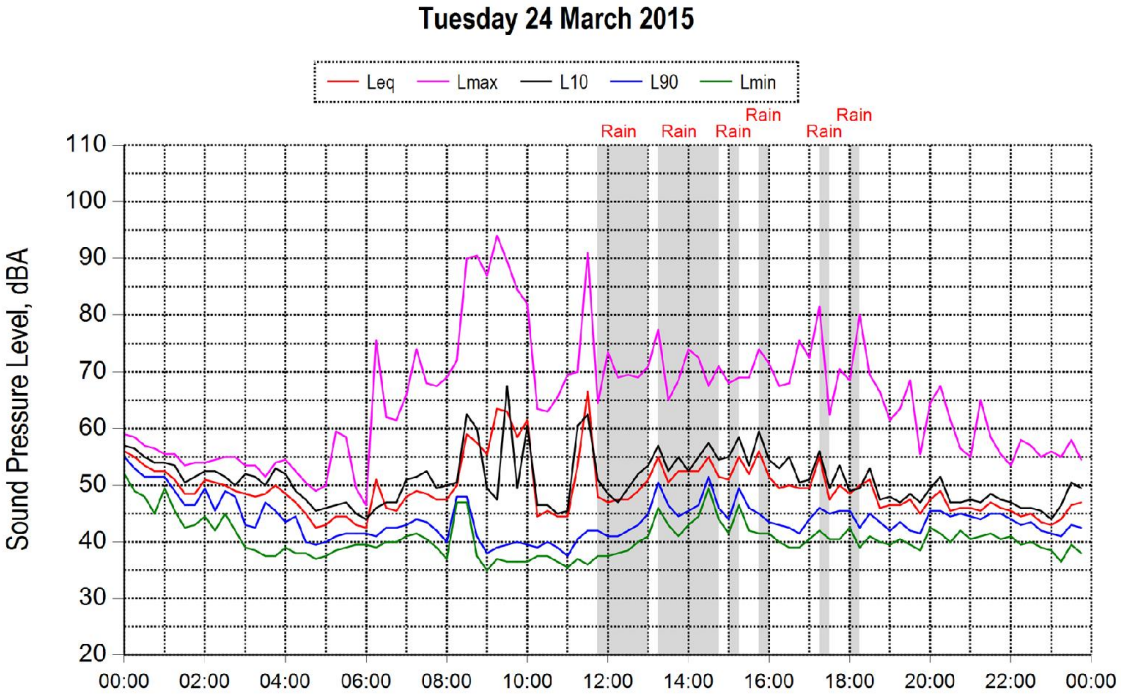
Western Sydney Airport (WSA) – The proposed airport at Badgerys Creek as assessed in the Western Sydney Airport environmental impact statement.

APPENDIX A

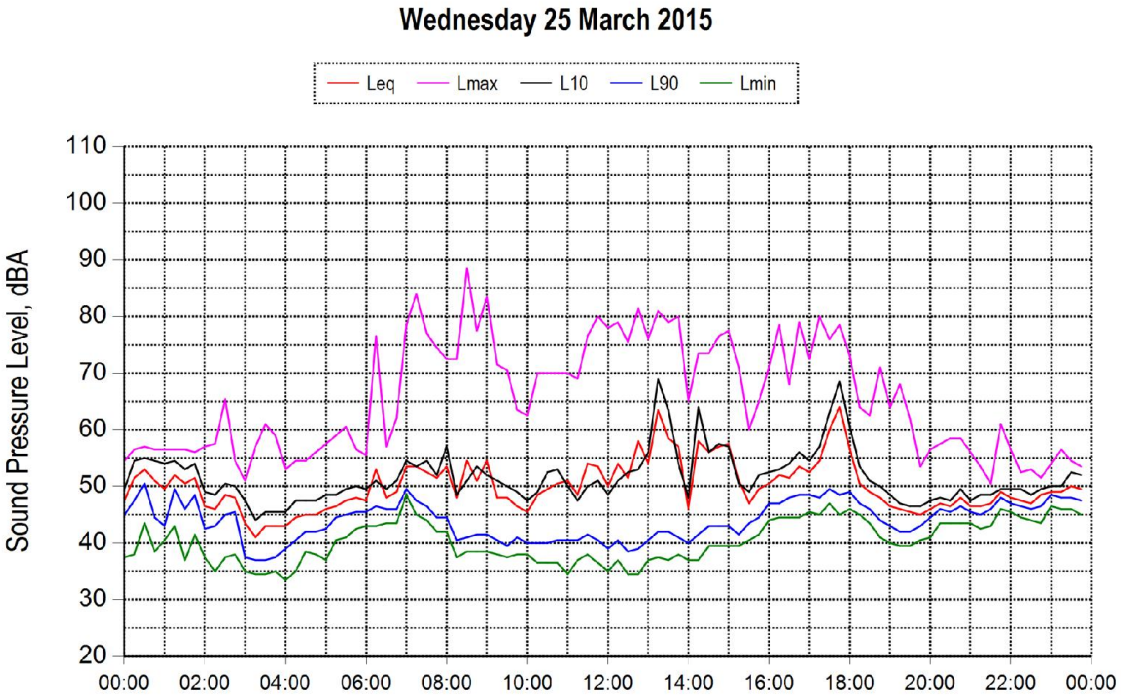
AMBIENT NOISE MEASUREMENTS

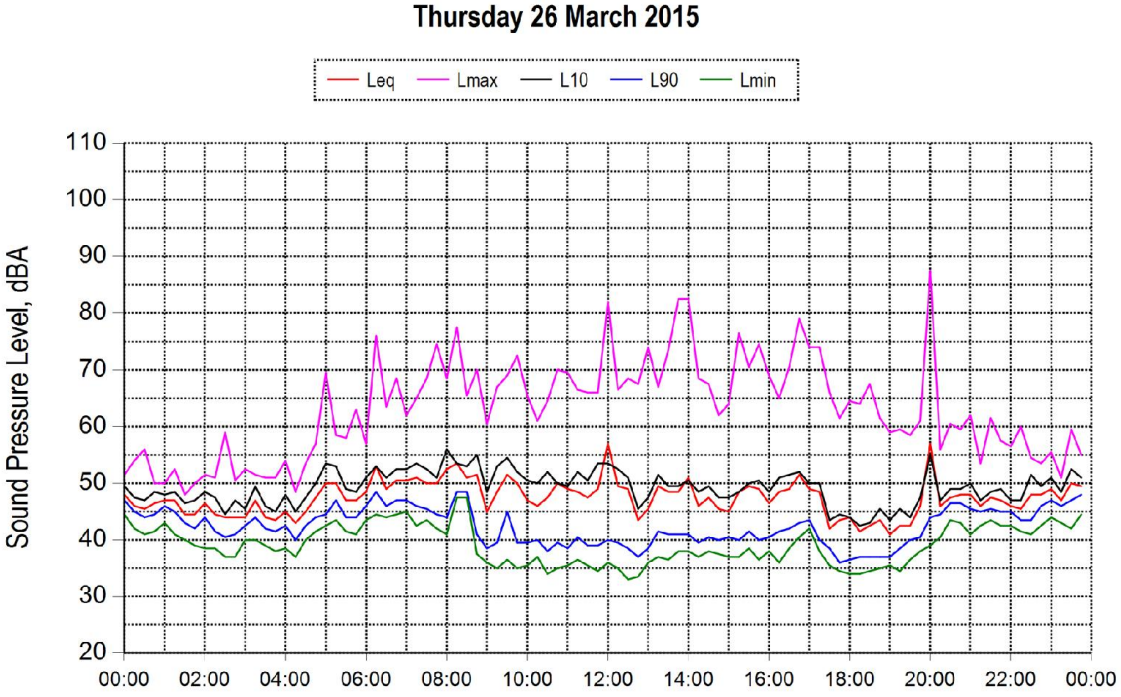
9 Harold Bentley Way, Glenmore Park





9 Harold Bentley Way, Glenmore Park





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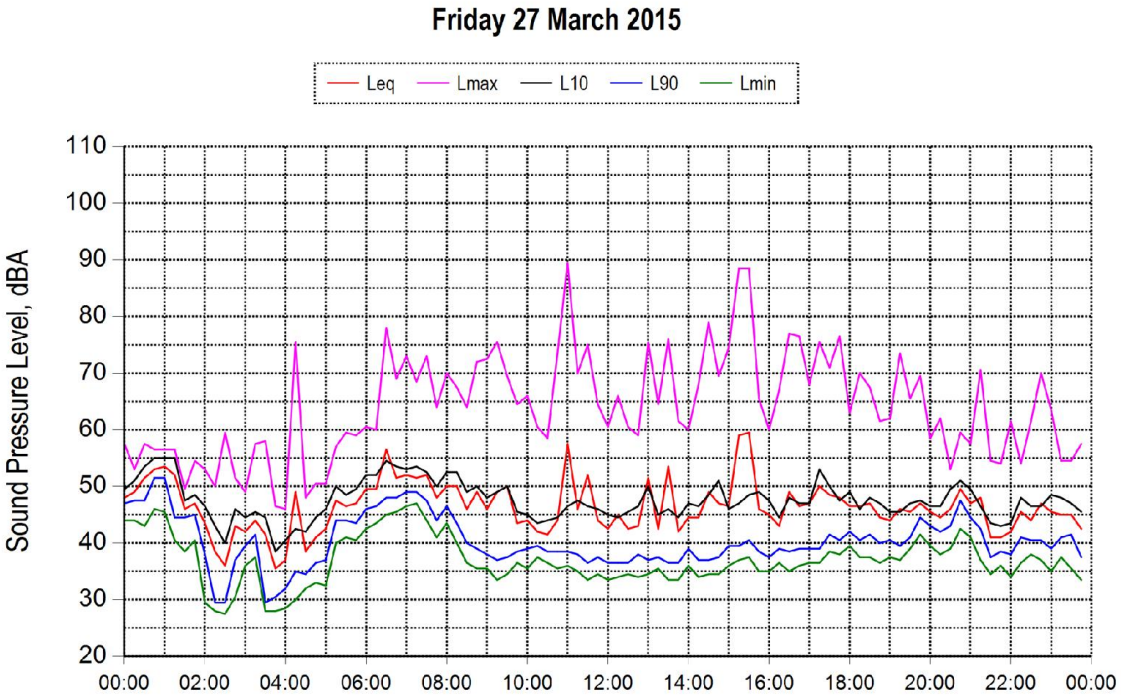

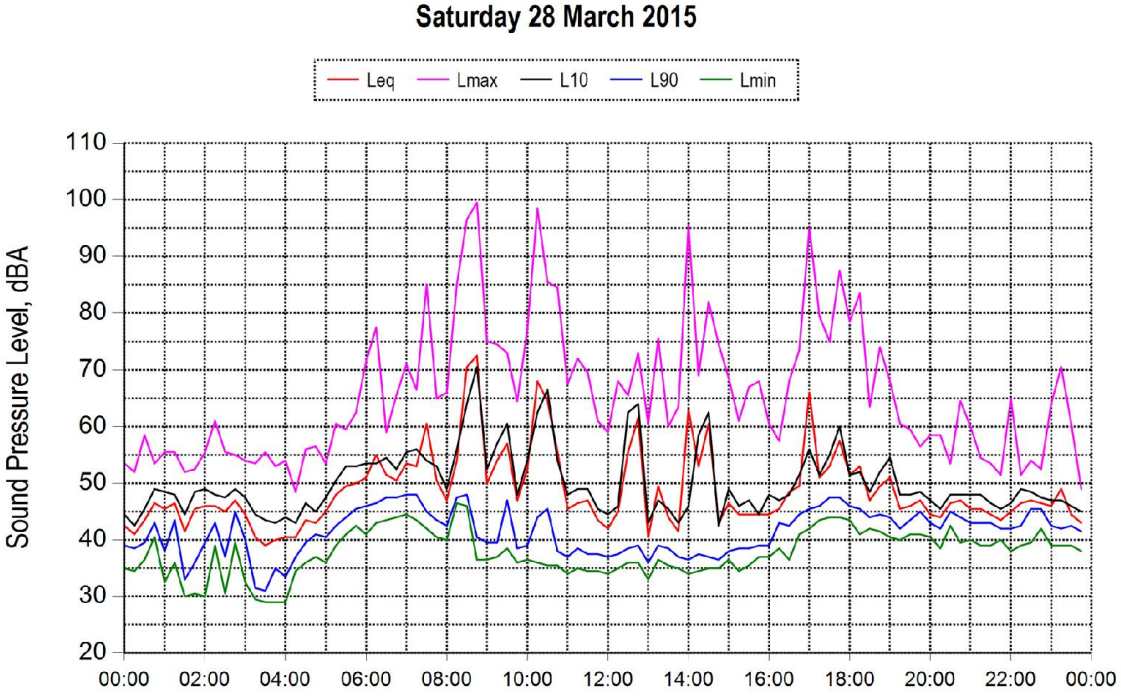

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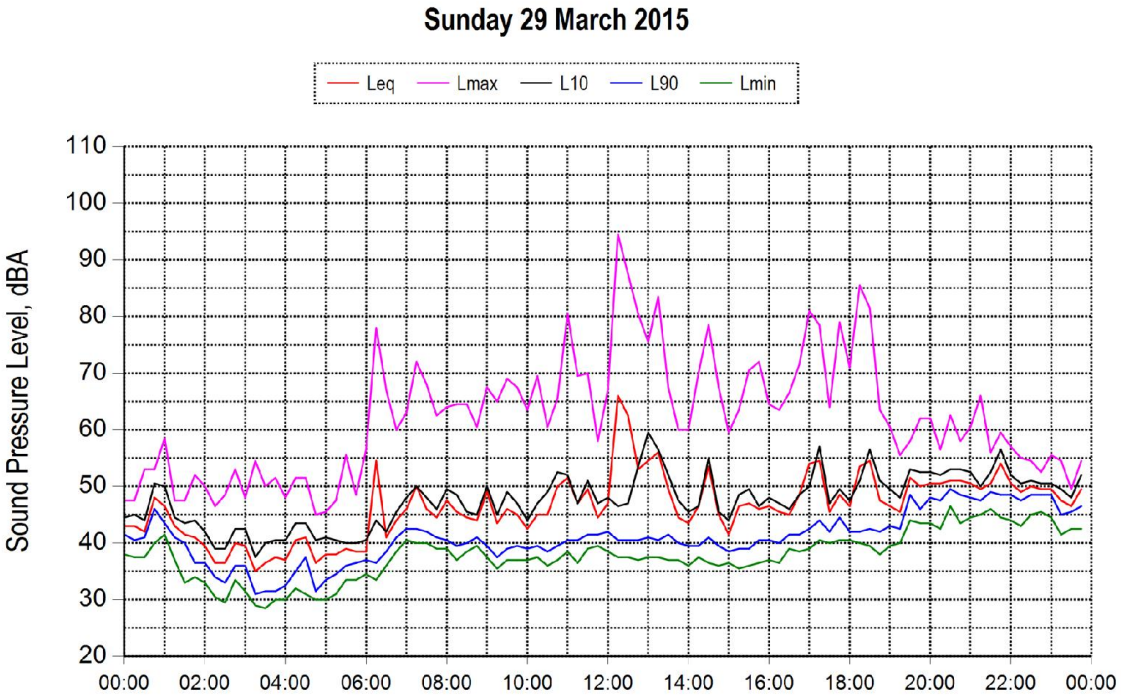

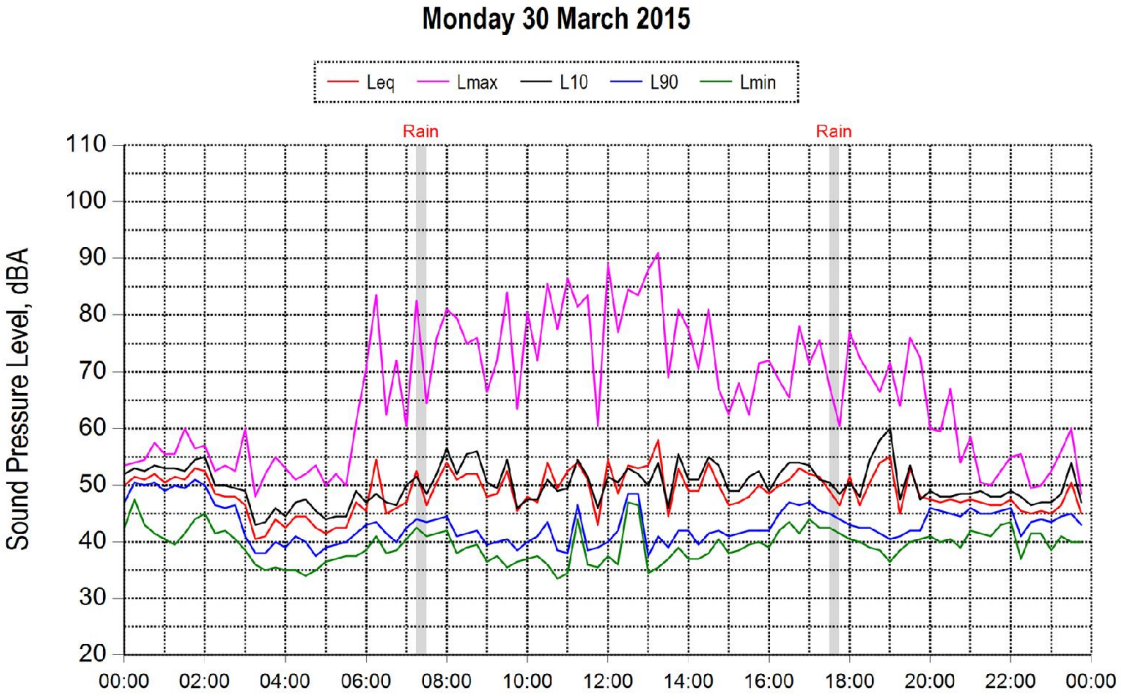

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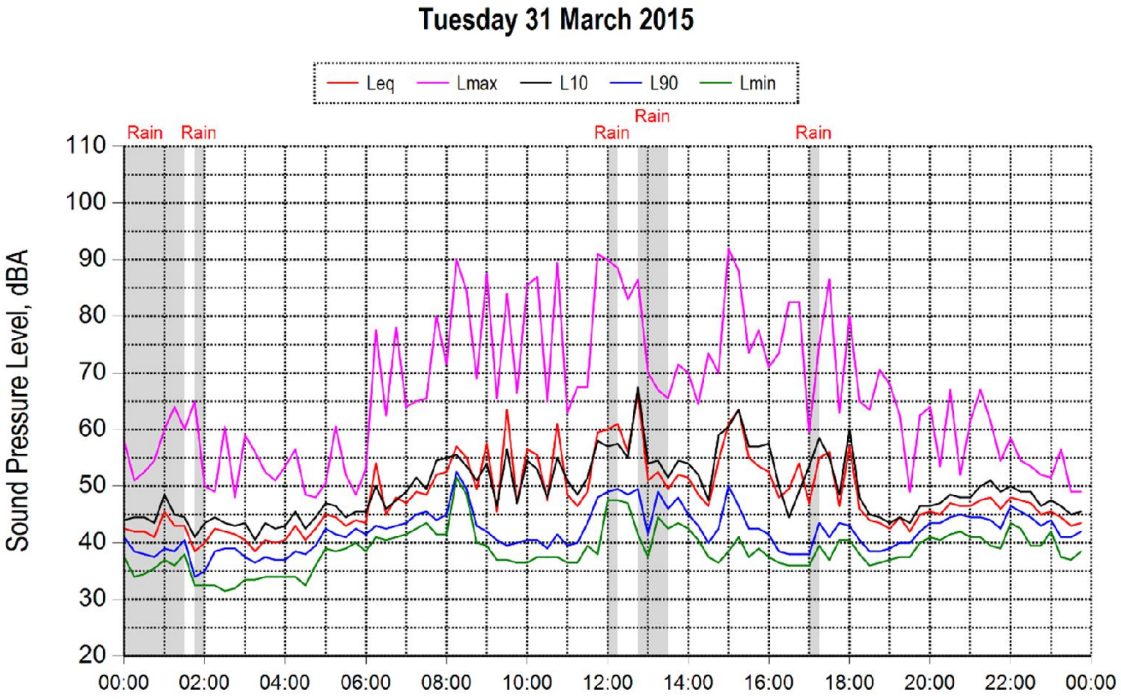

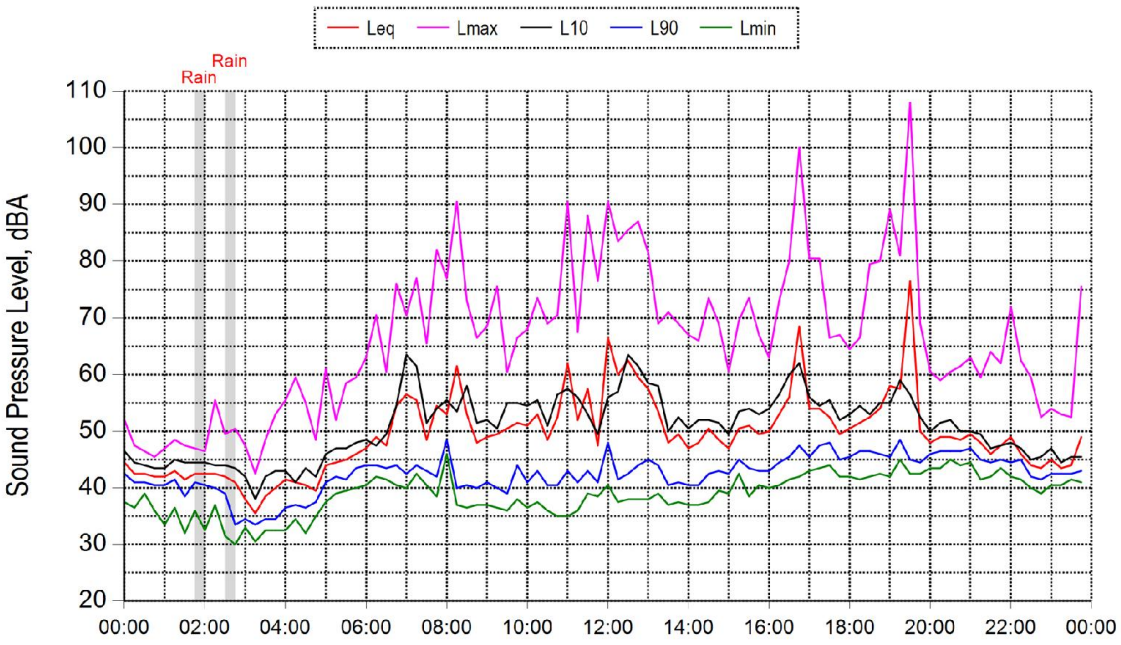

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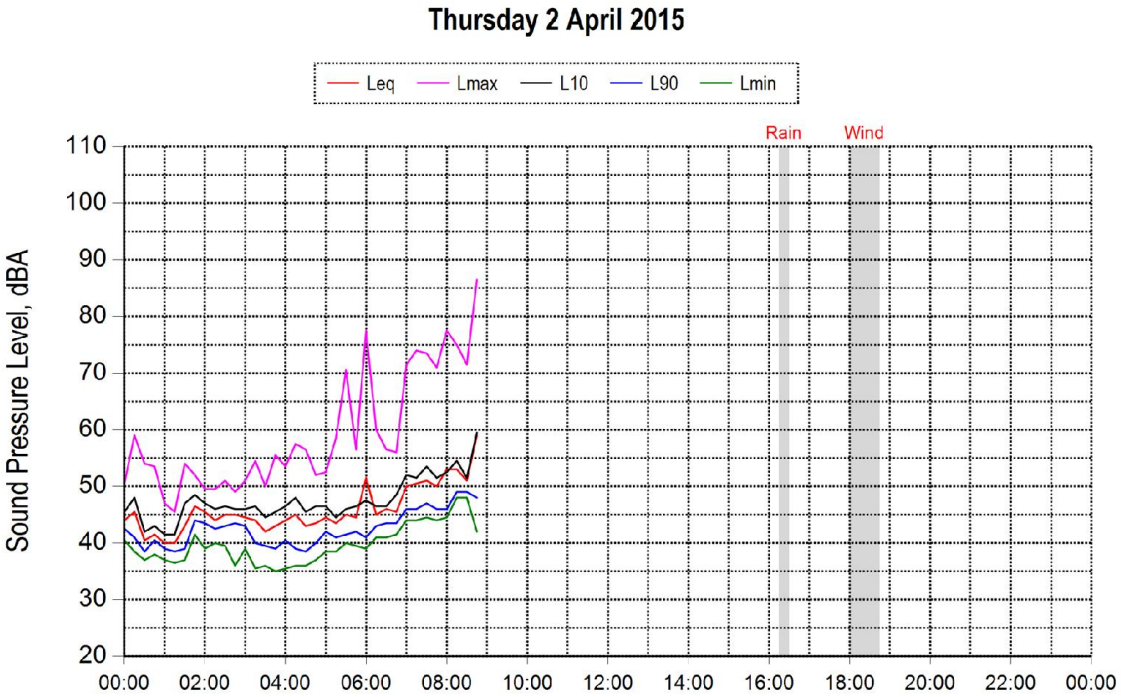

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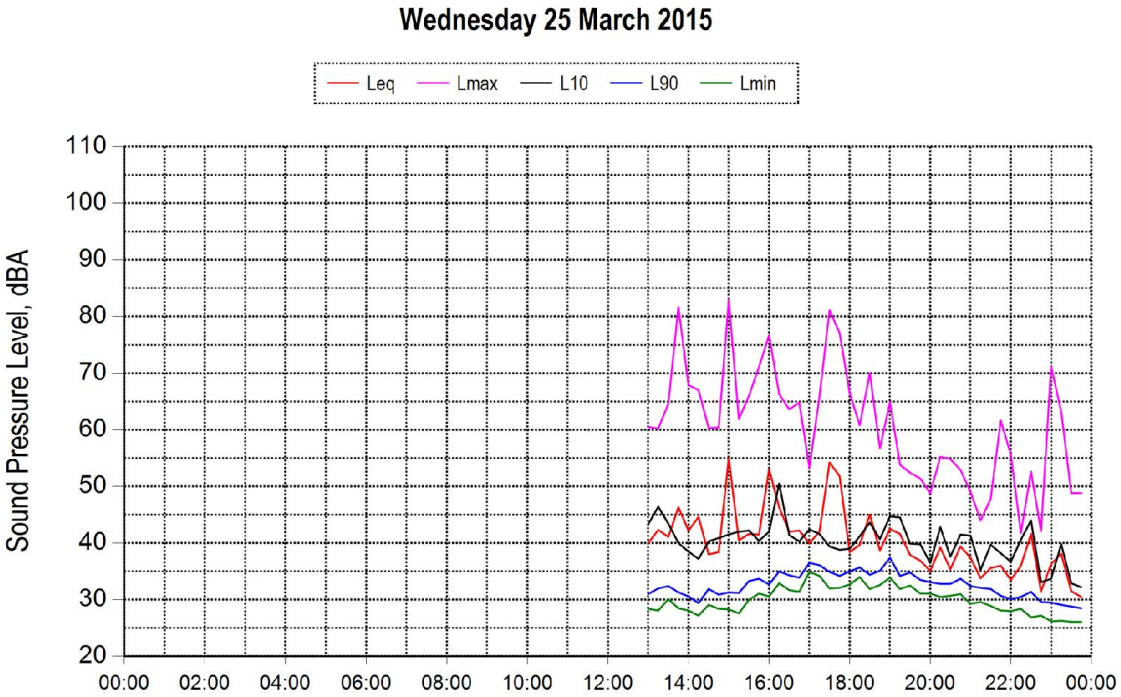
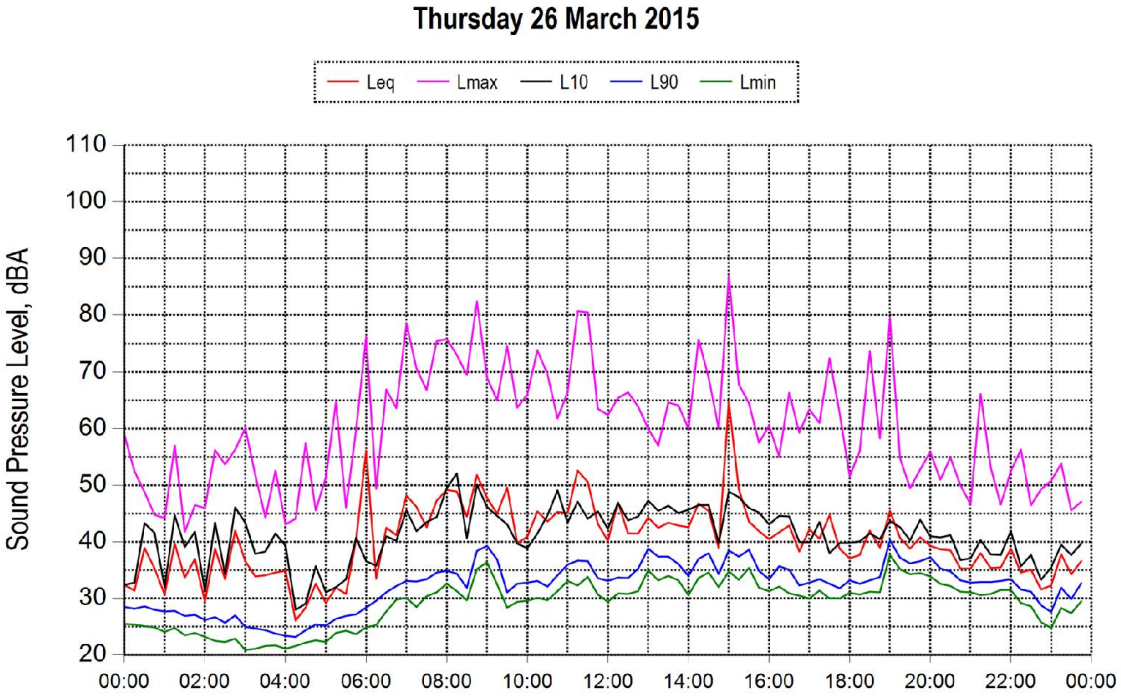
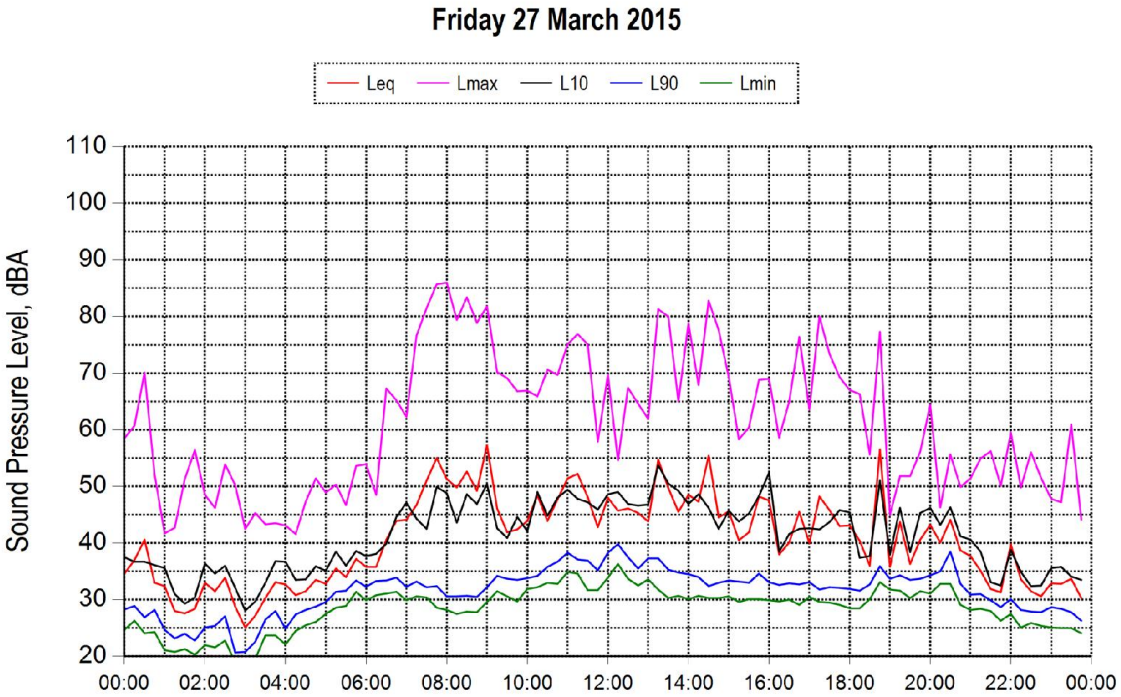
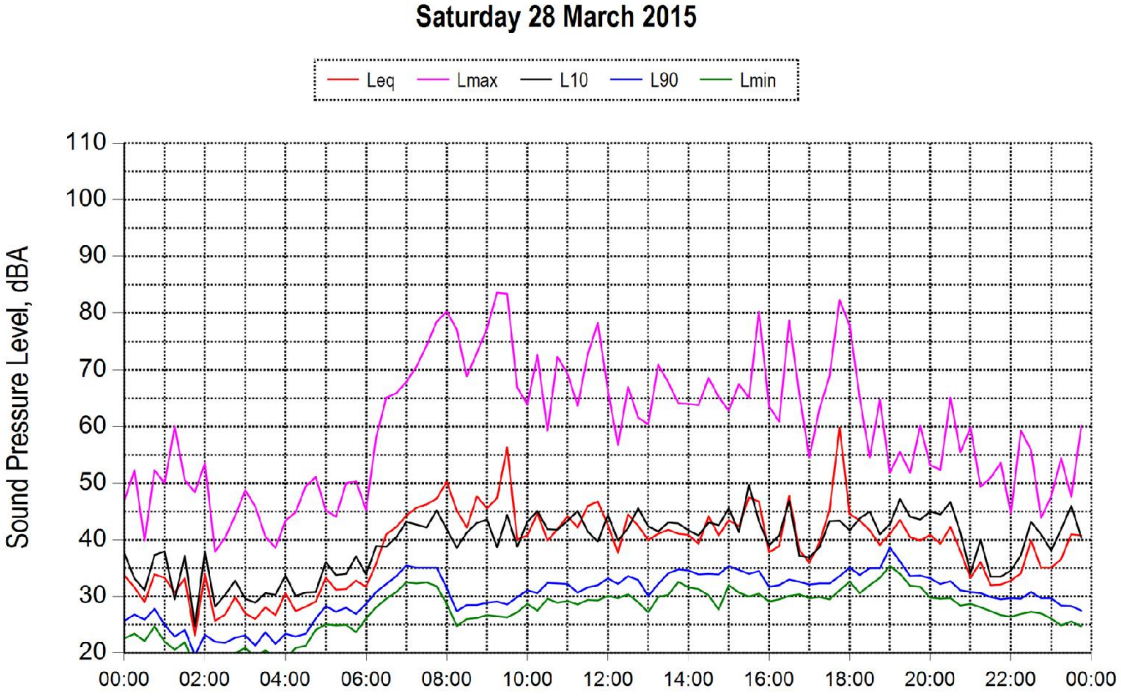




16 Park Avenue, Springwood





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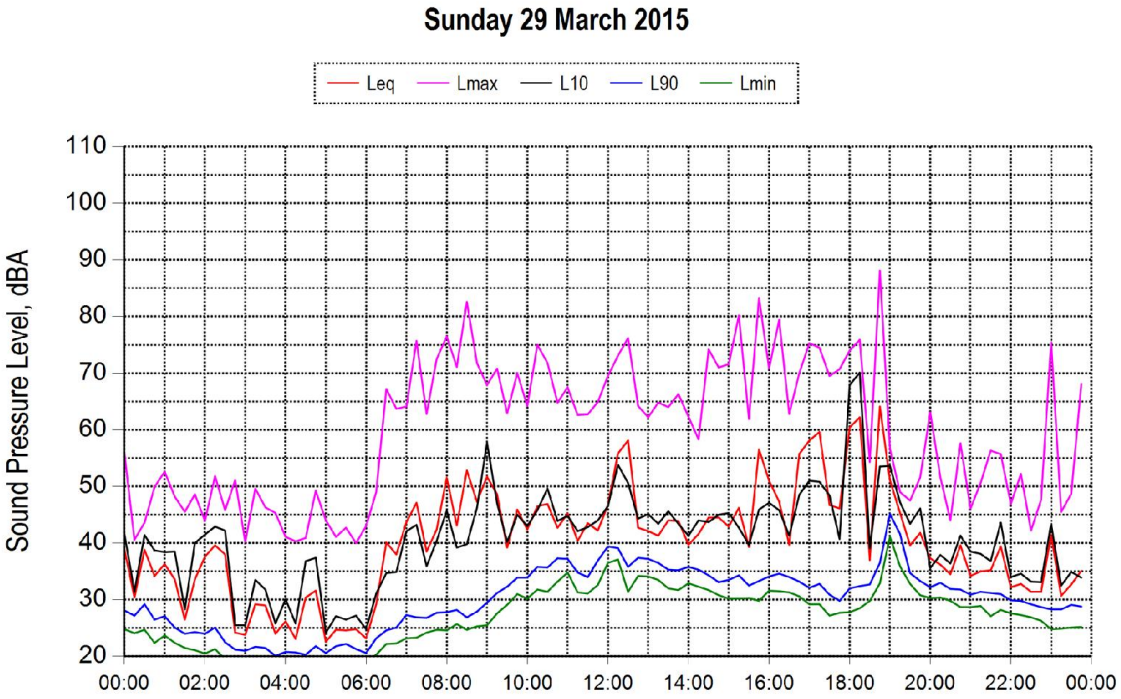
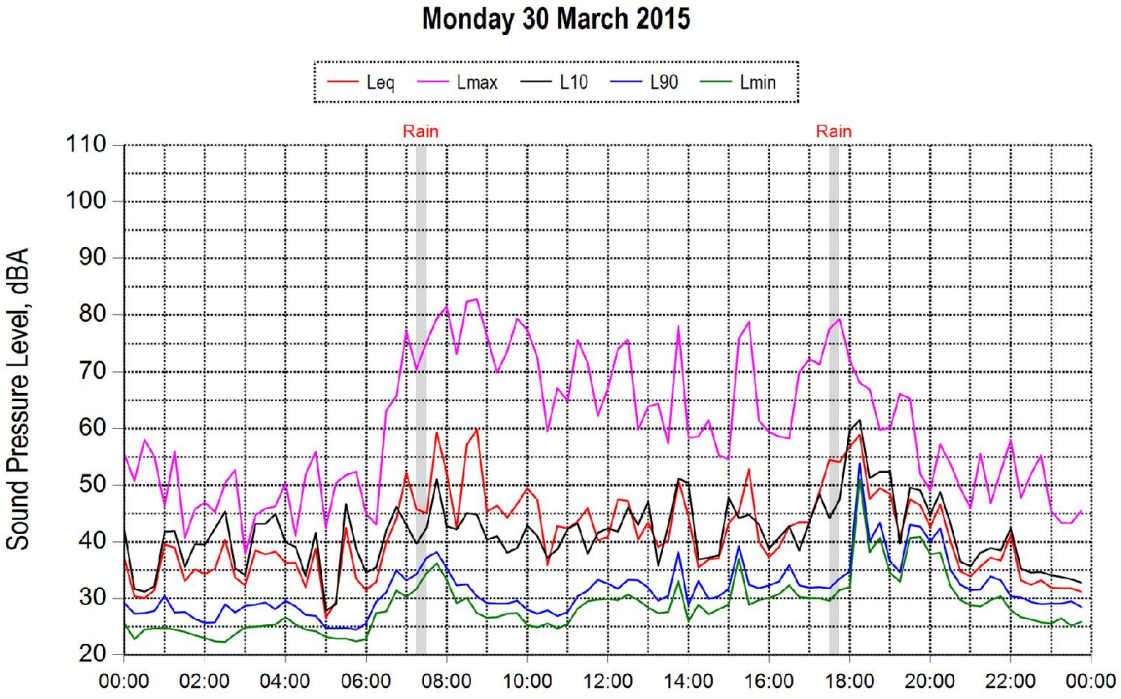
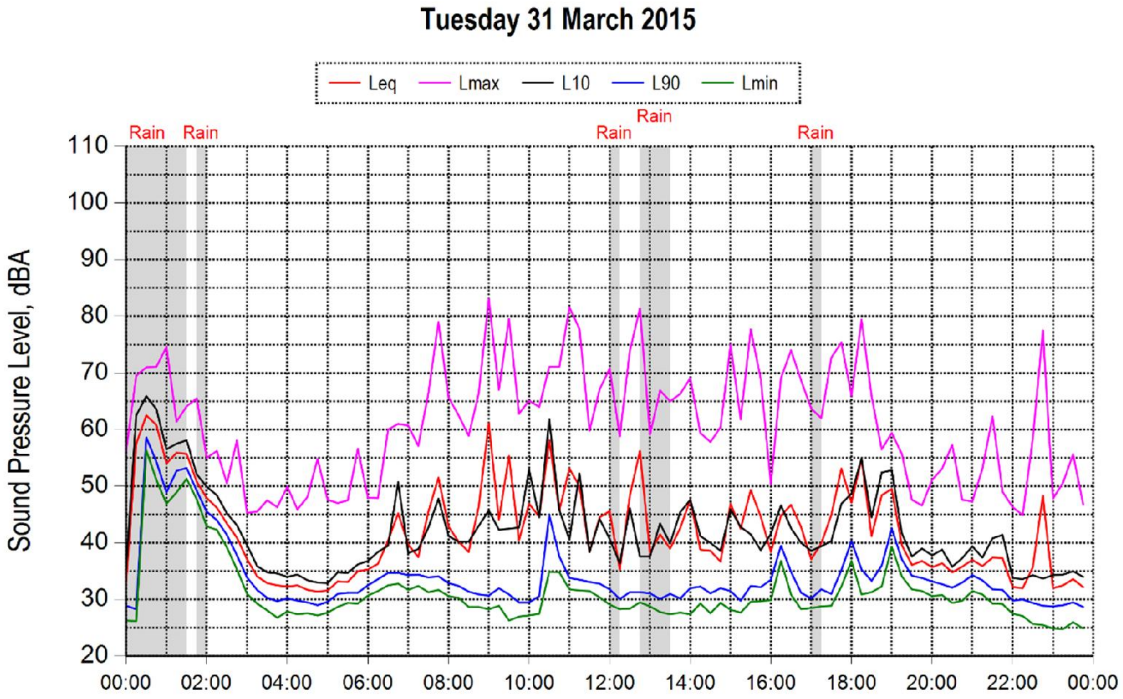
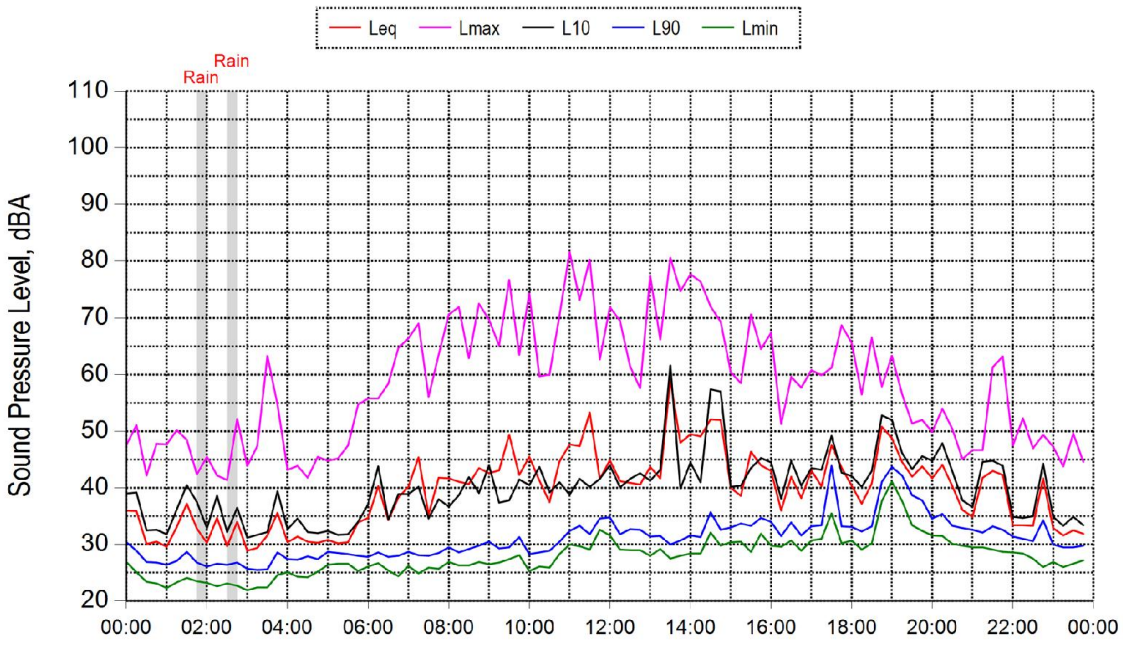




16 Park Avenue, Springwood





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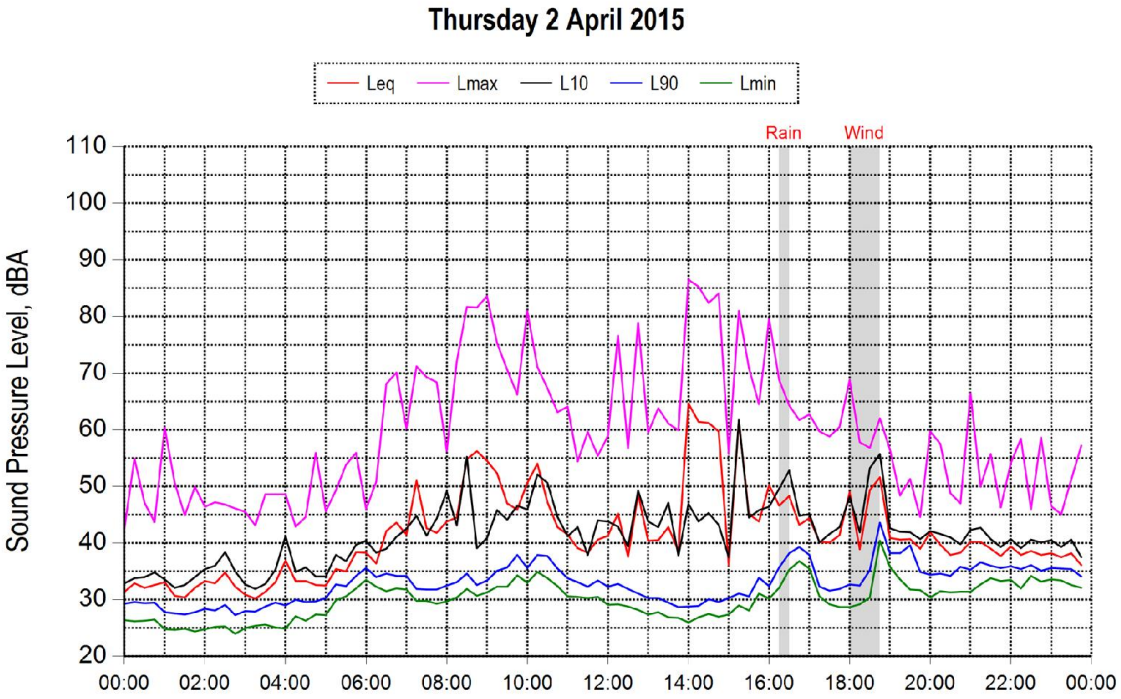

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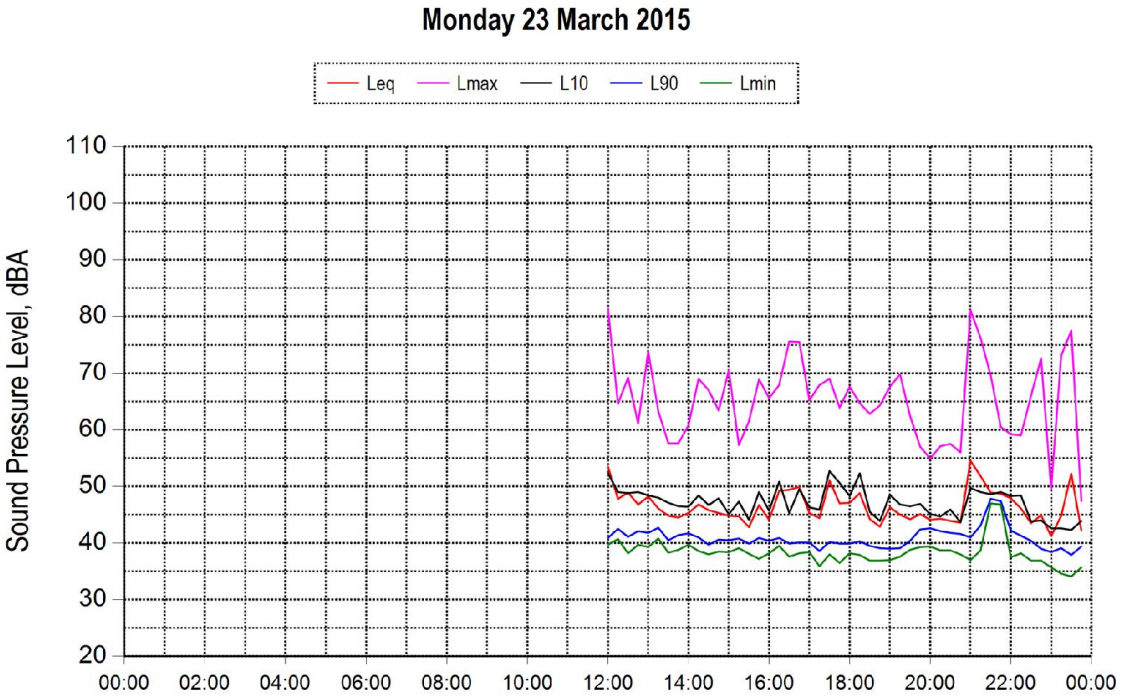

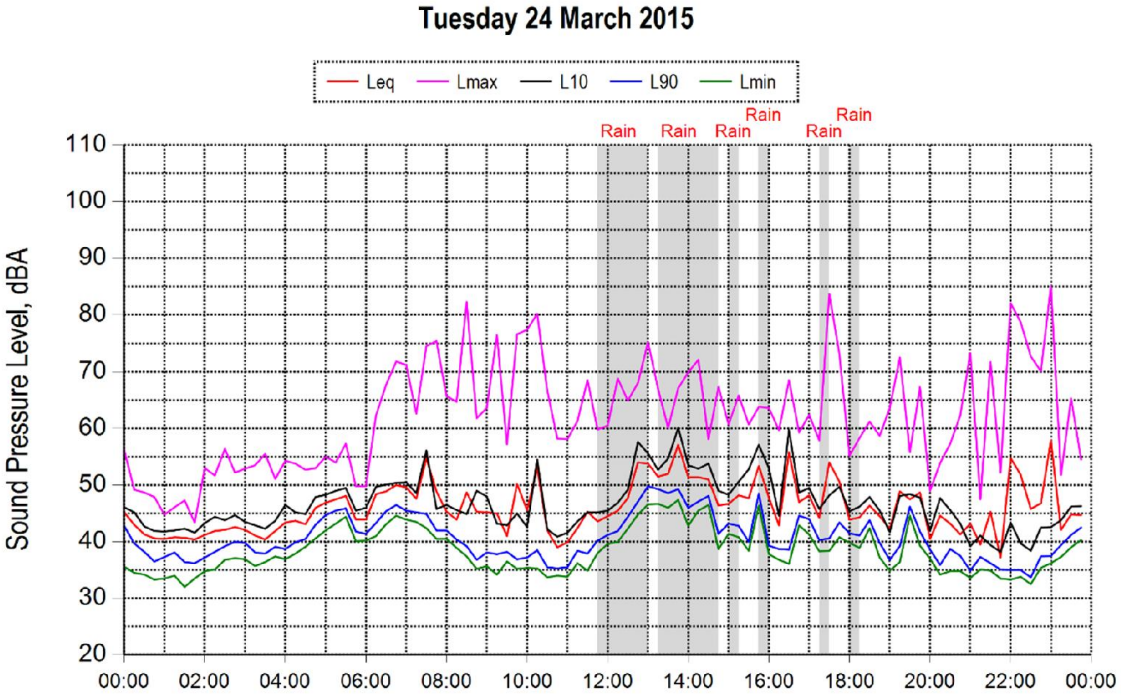

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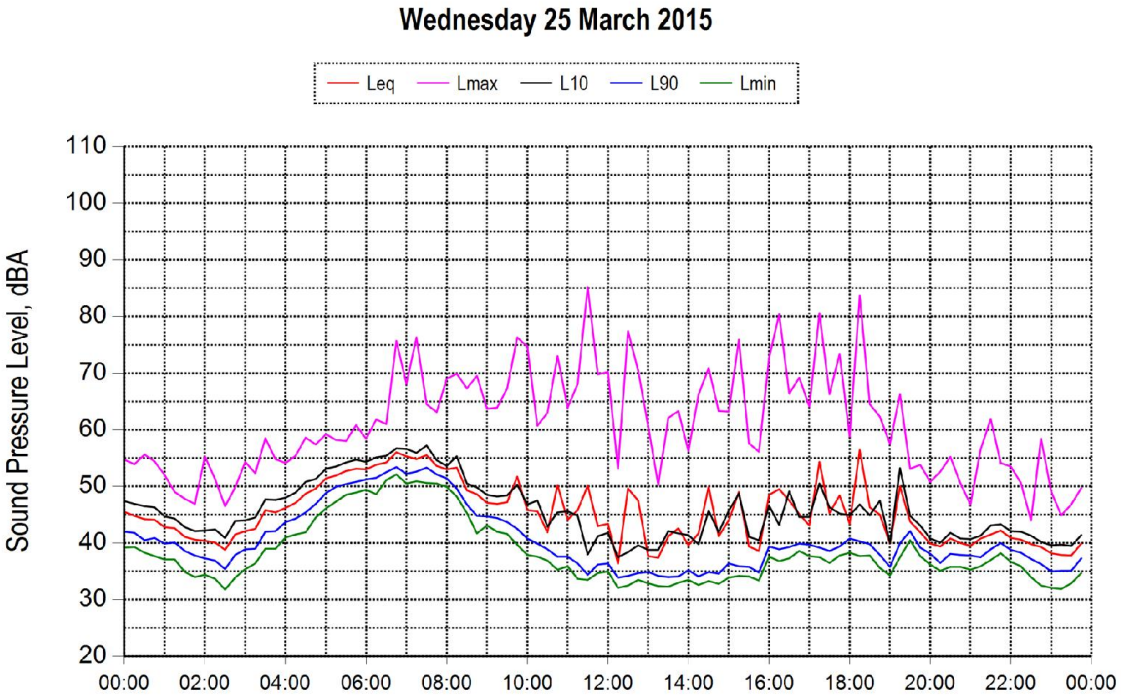

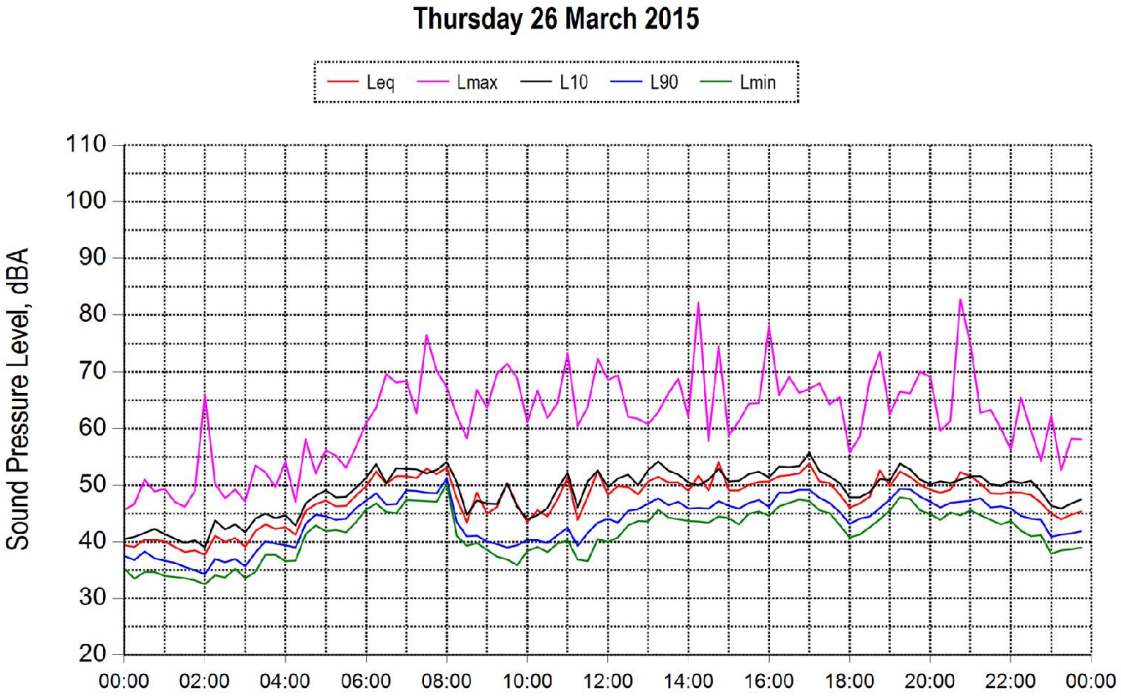

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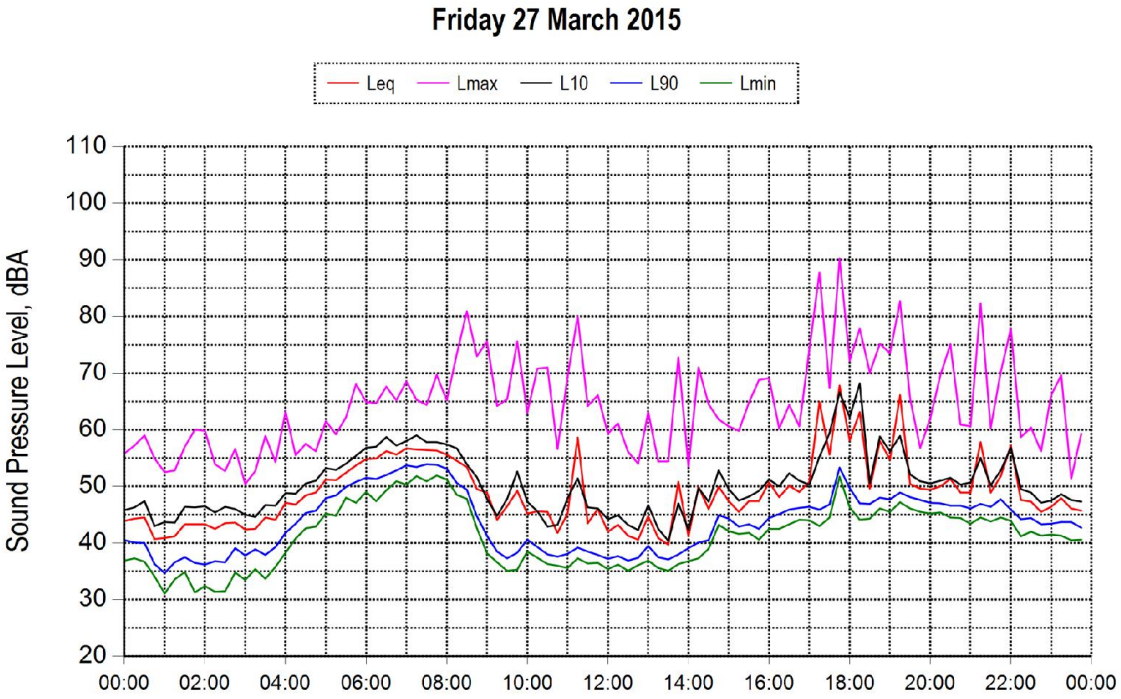

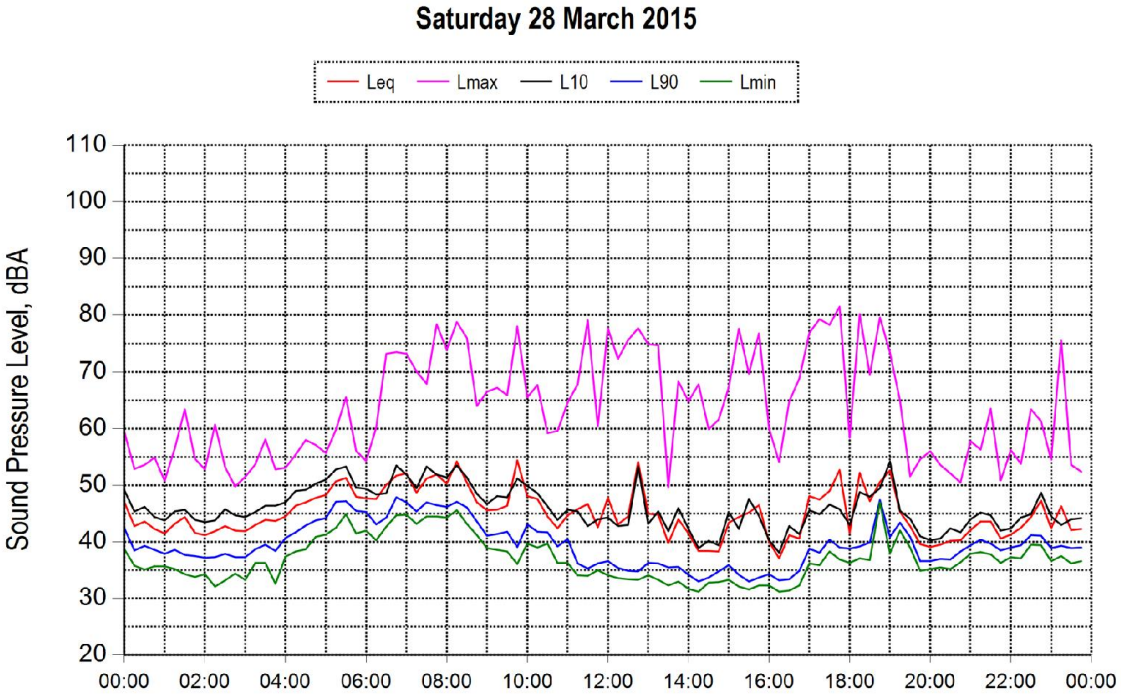

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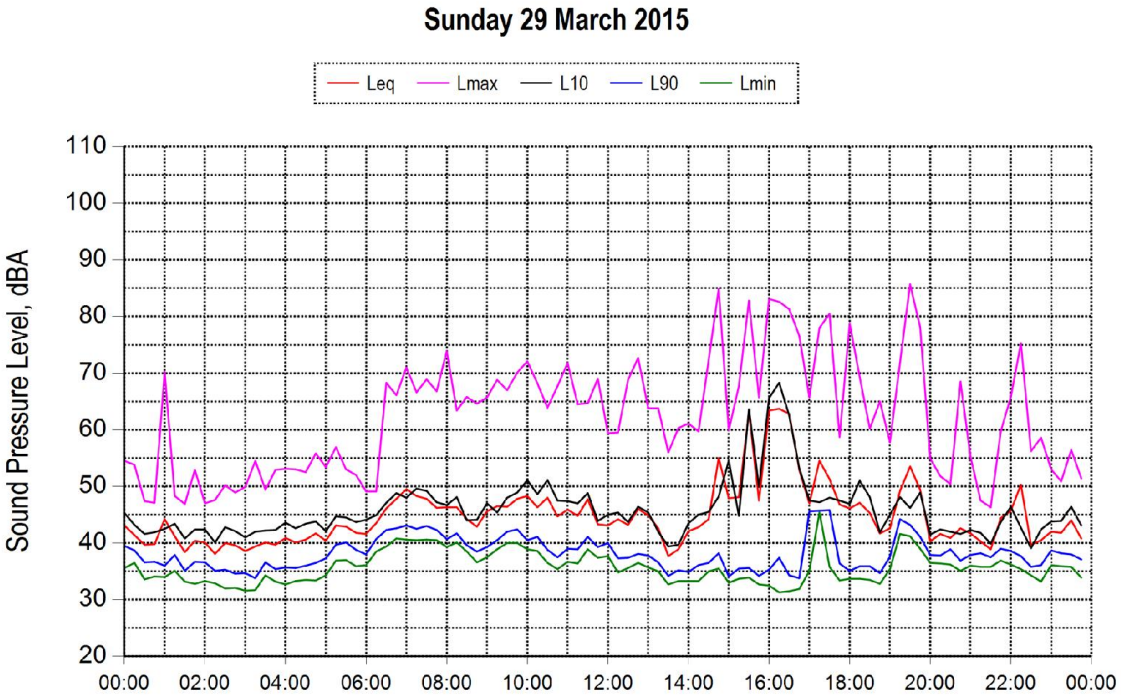

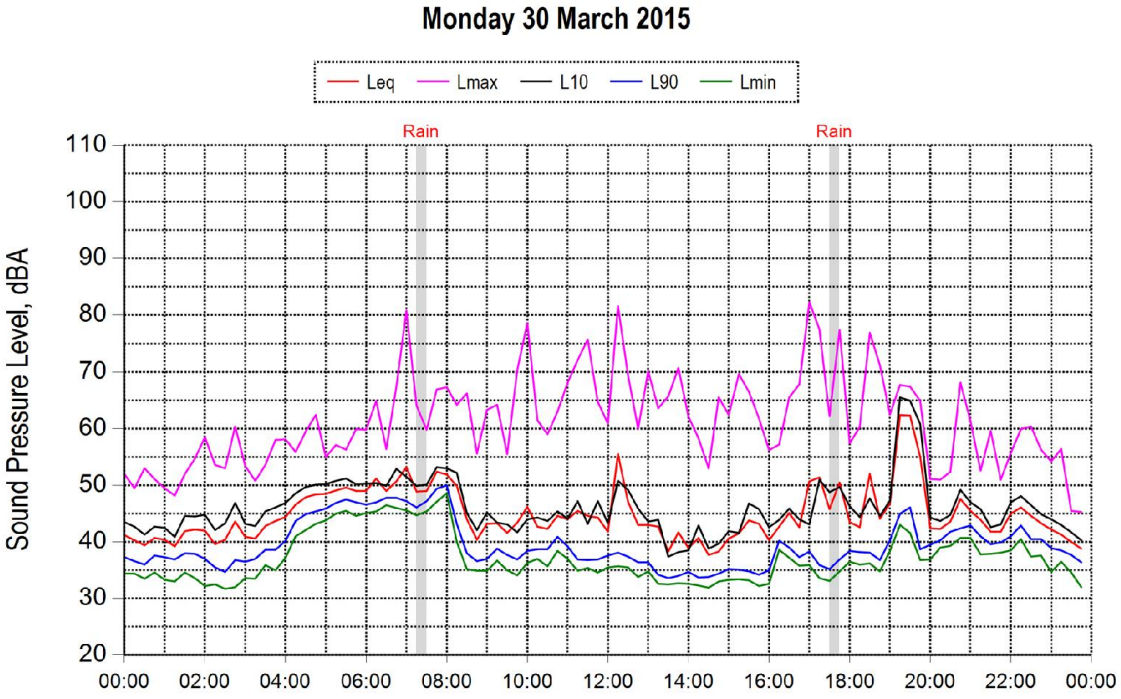

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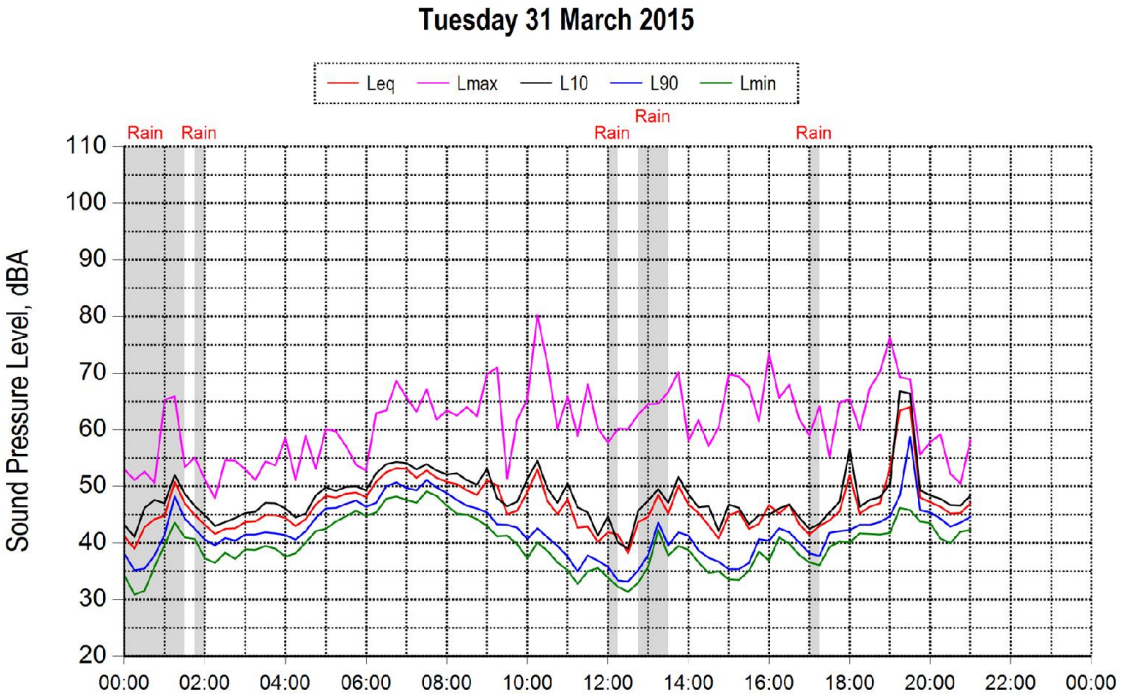
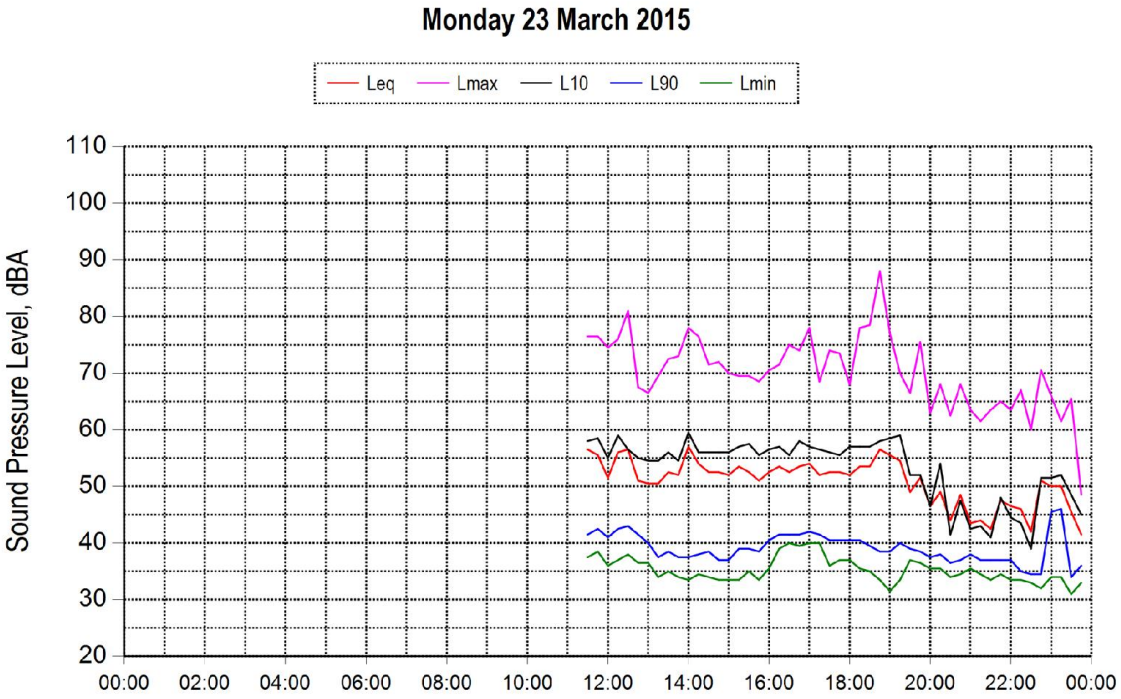
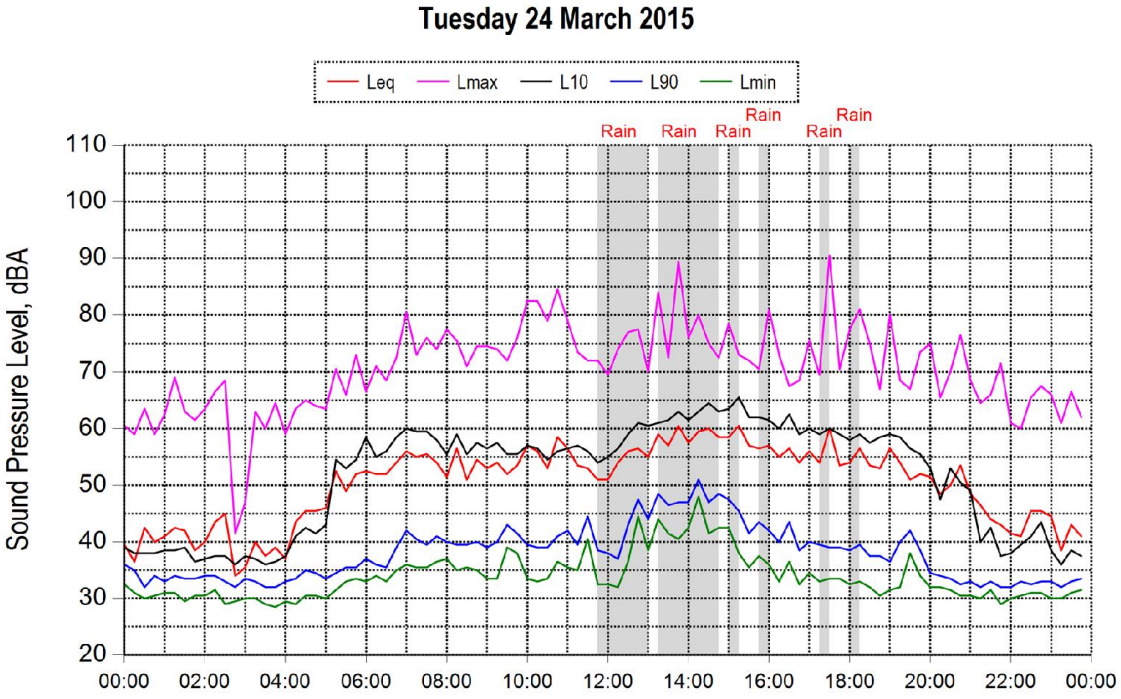


25 Peter Pan Avenue, Wallacia





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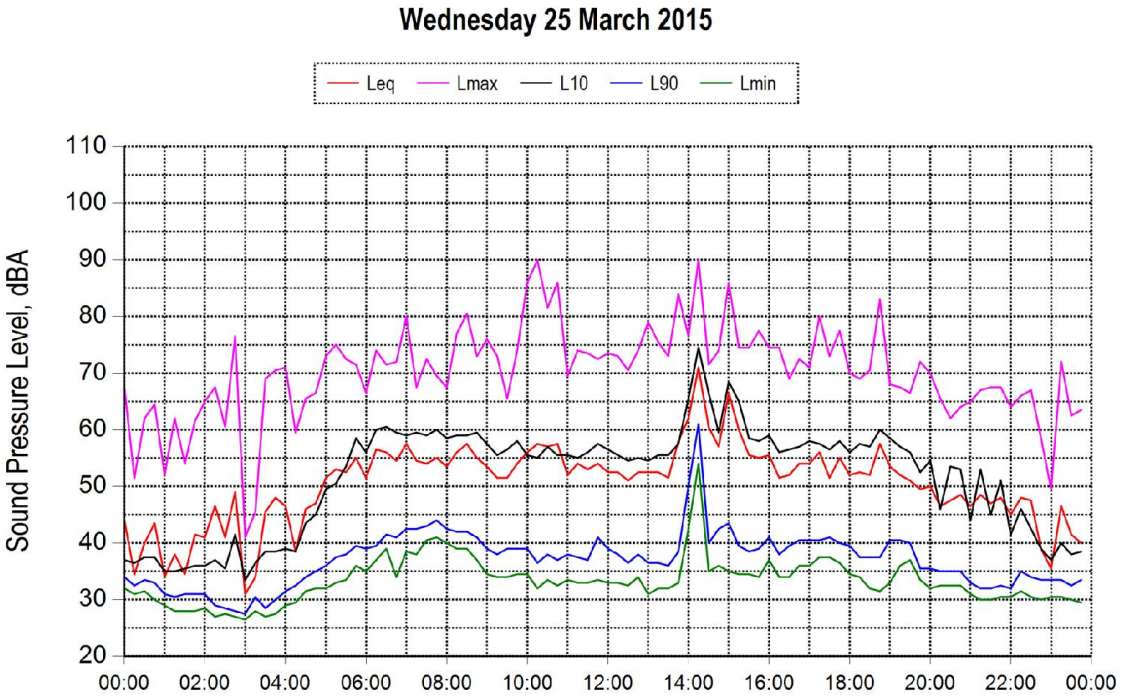

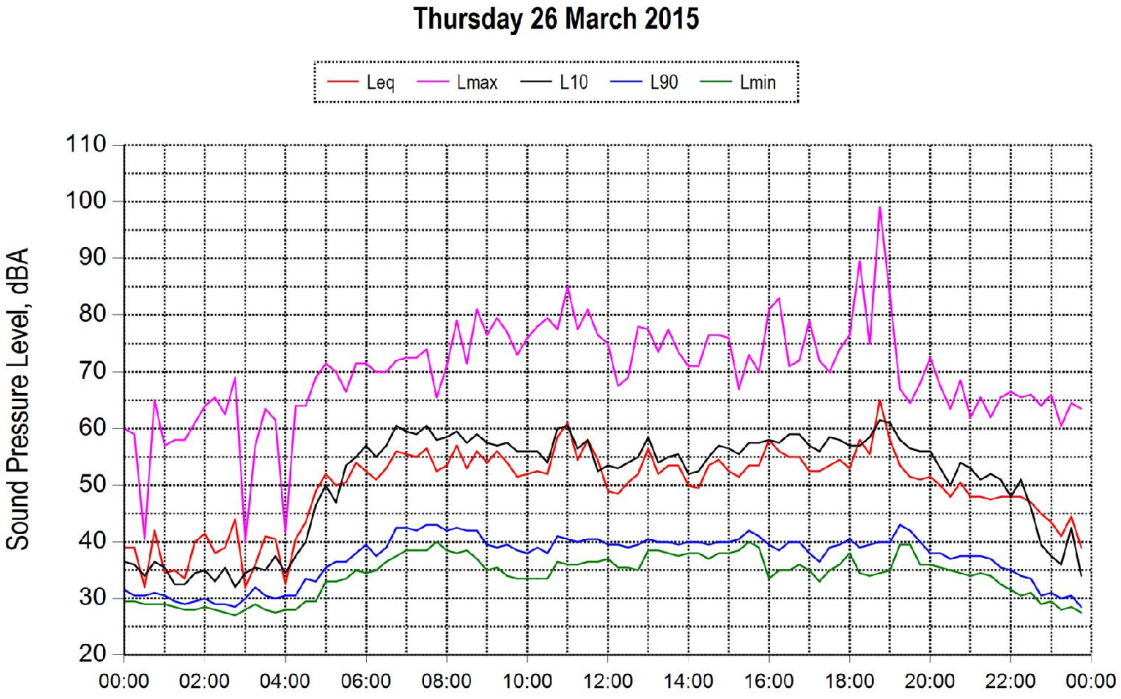

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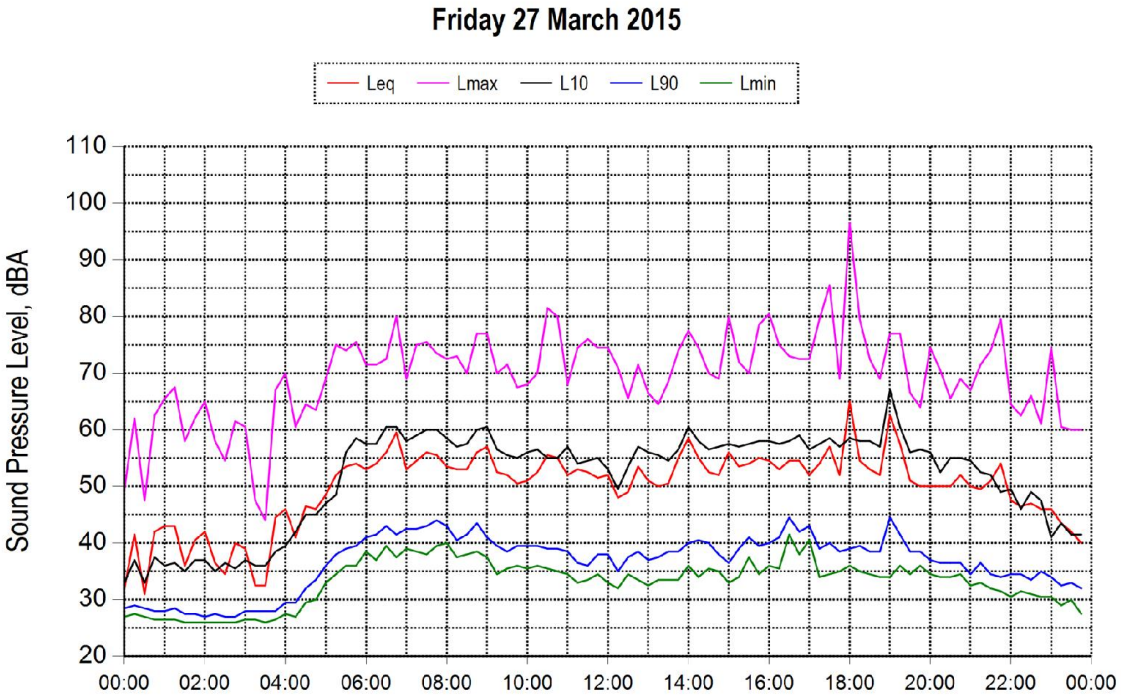

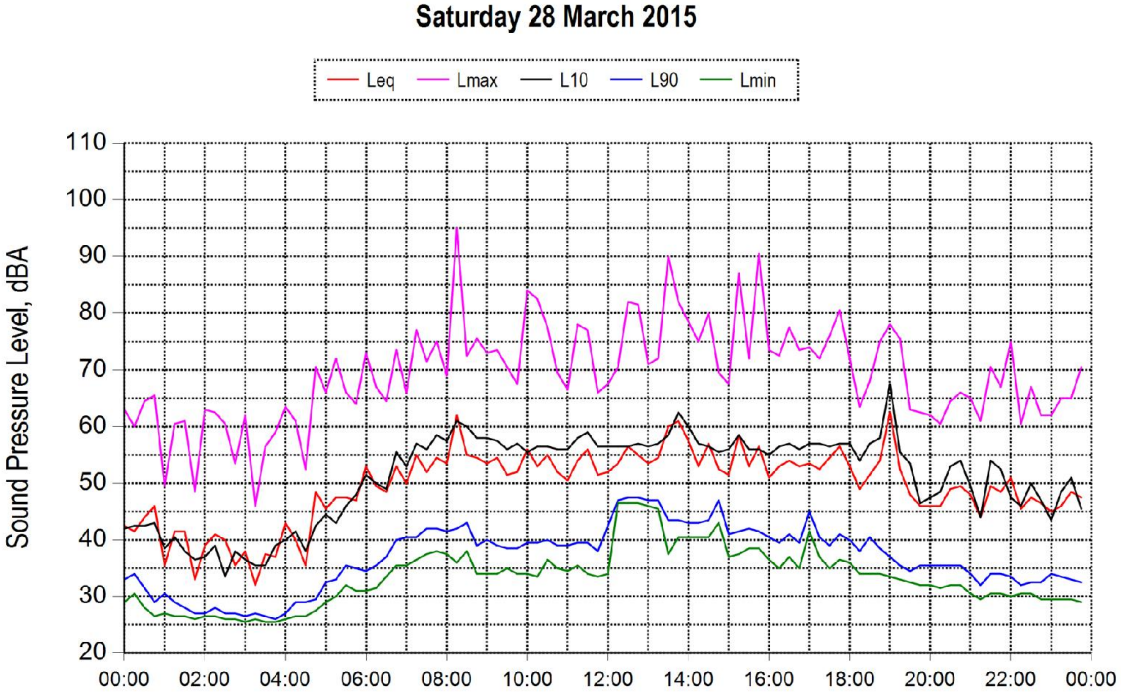

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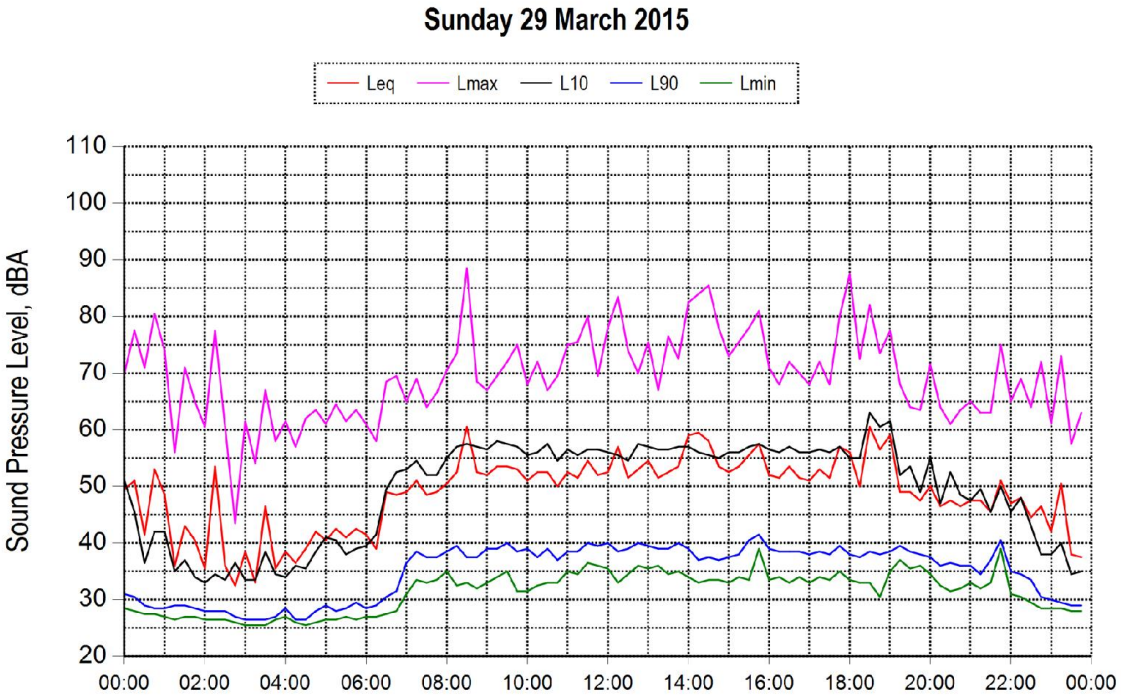

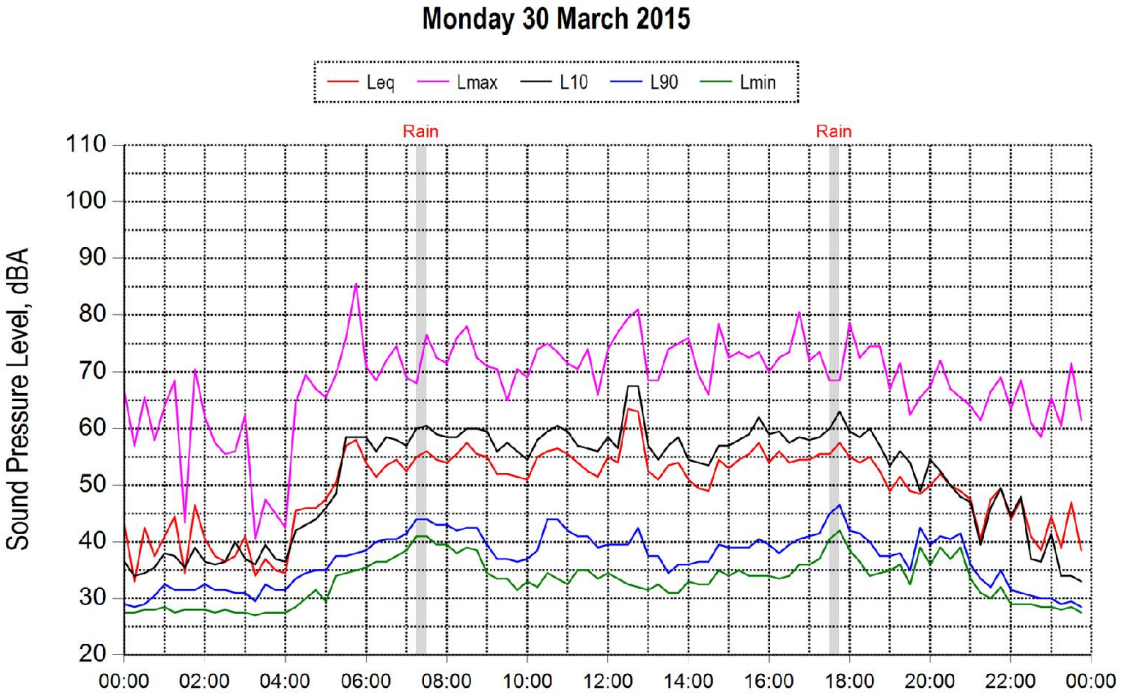

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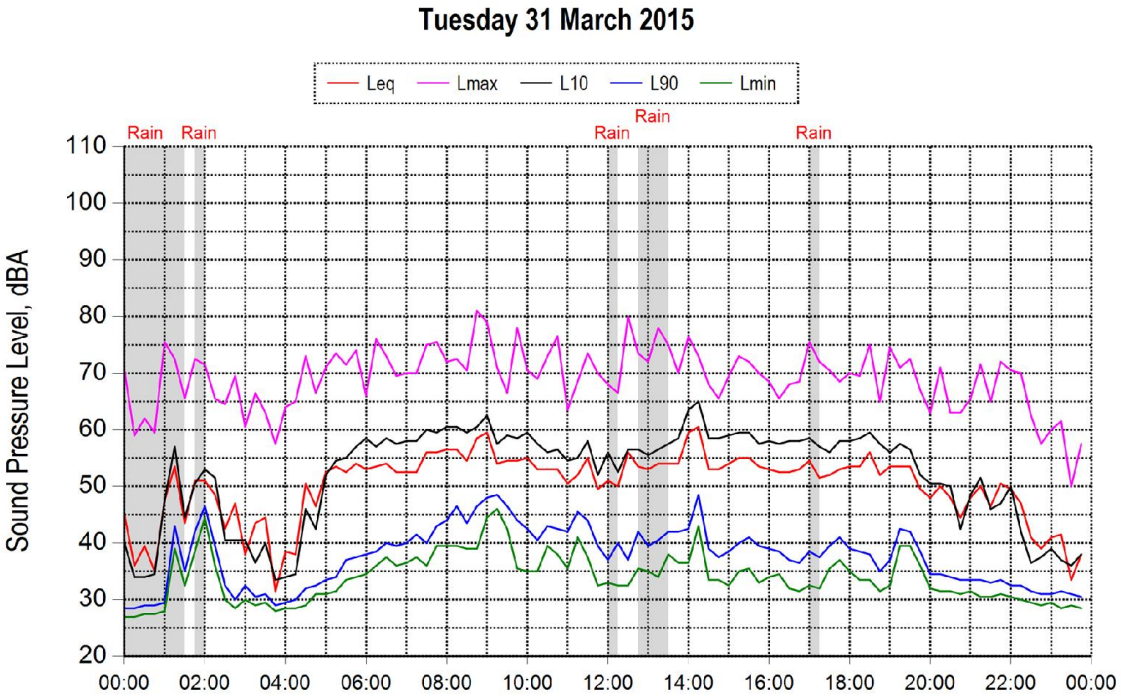

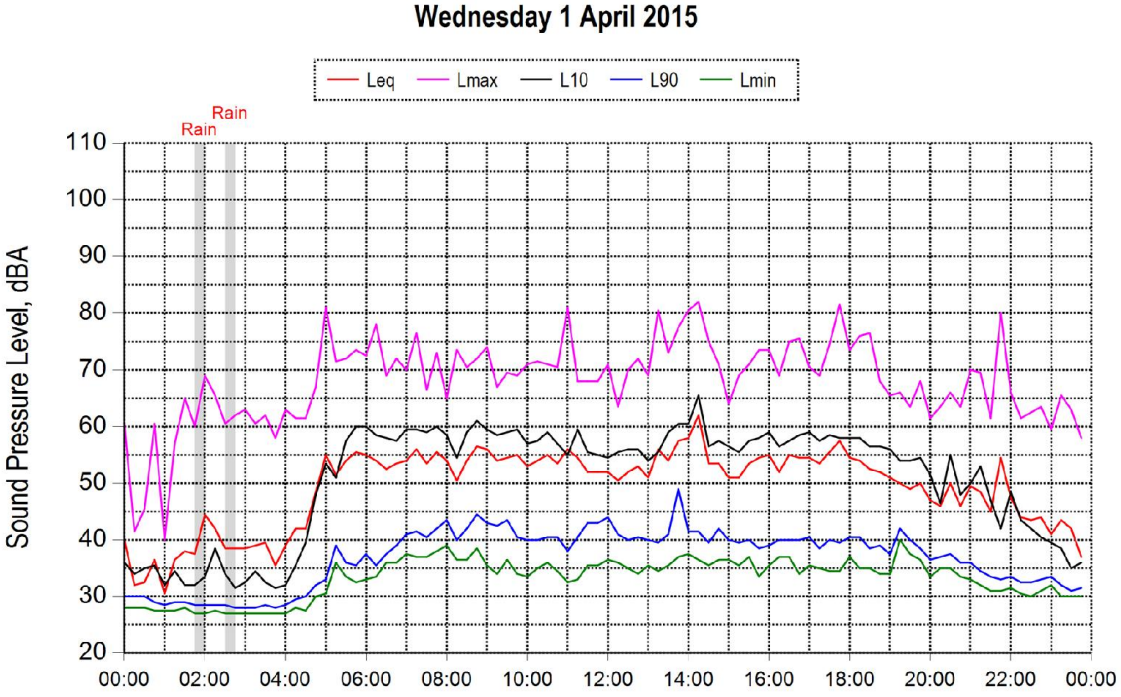

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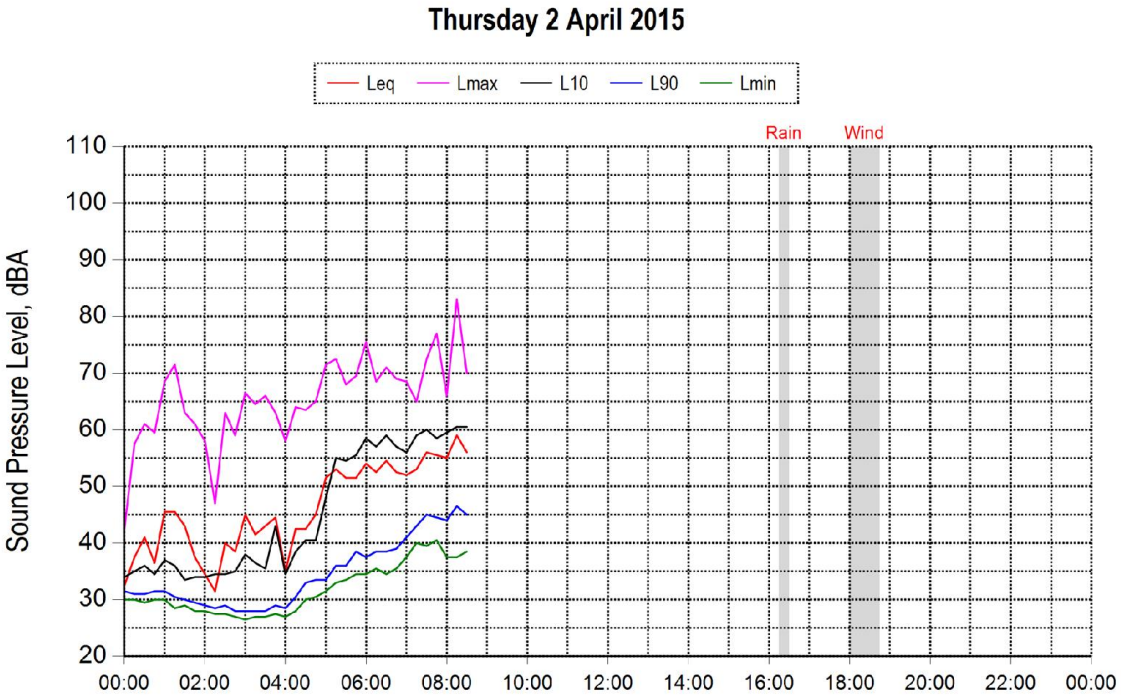
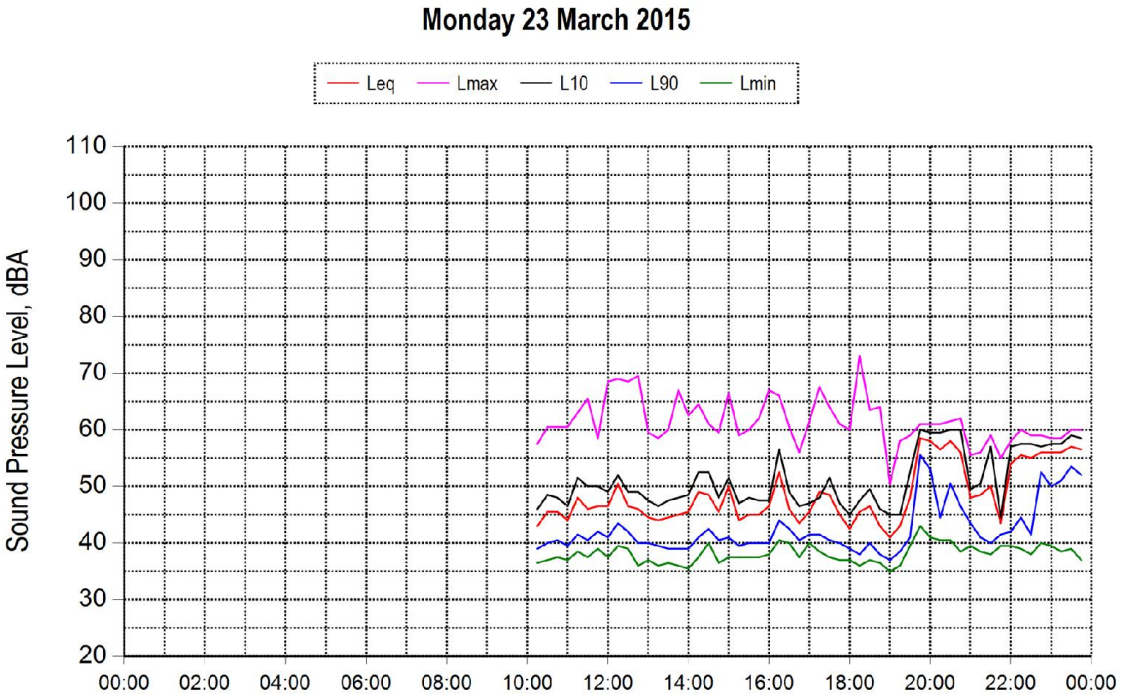
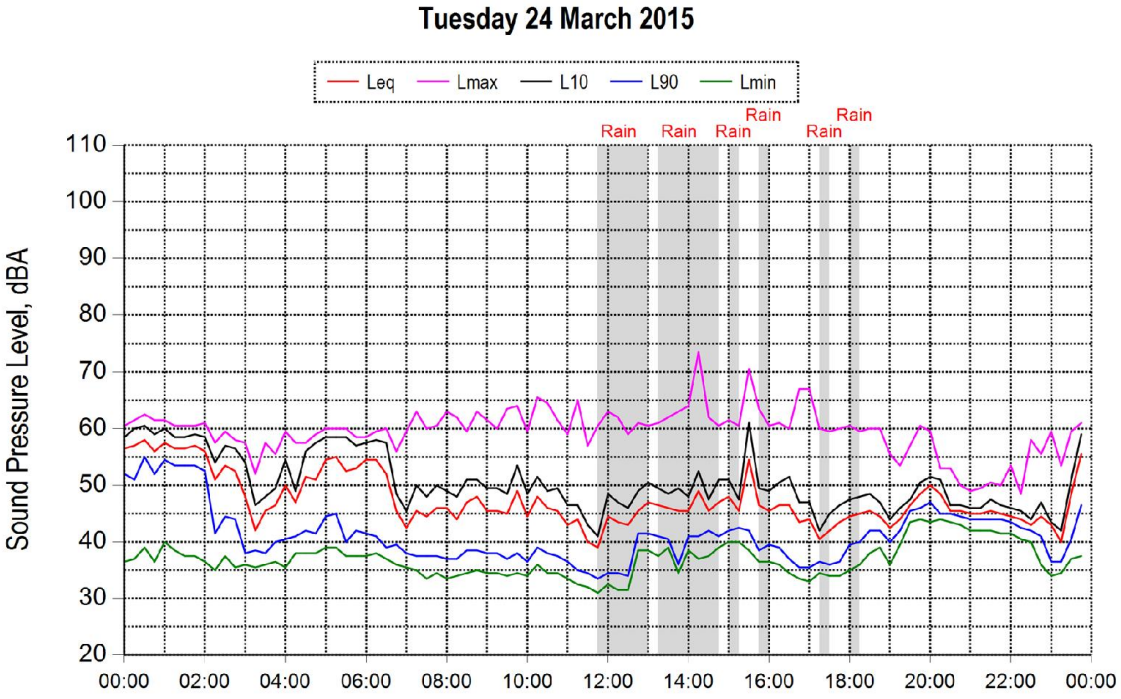


27 Dwyer Road, Bringelly





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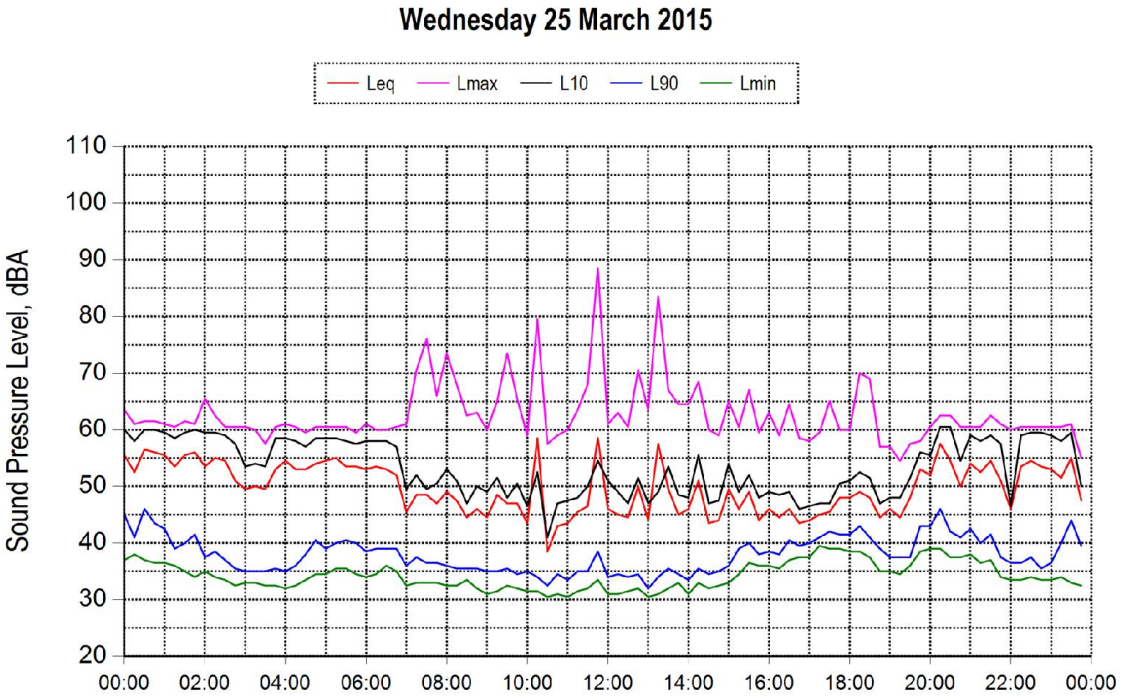

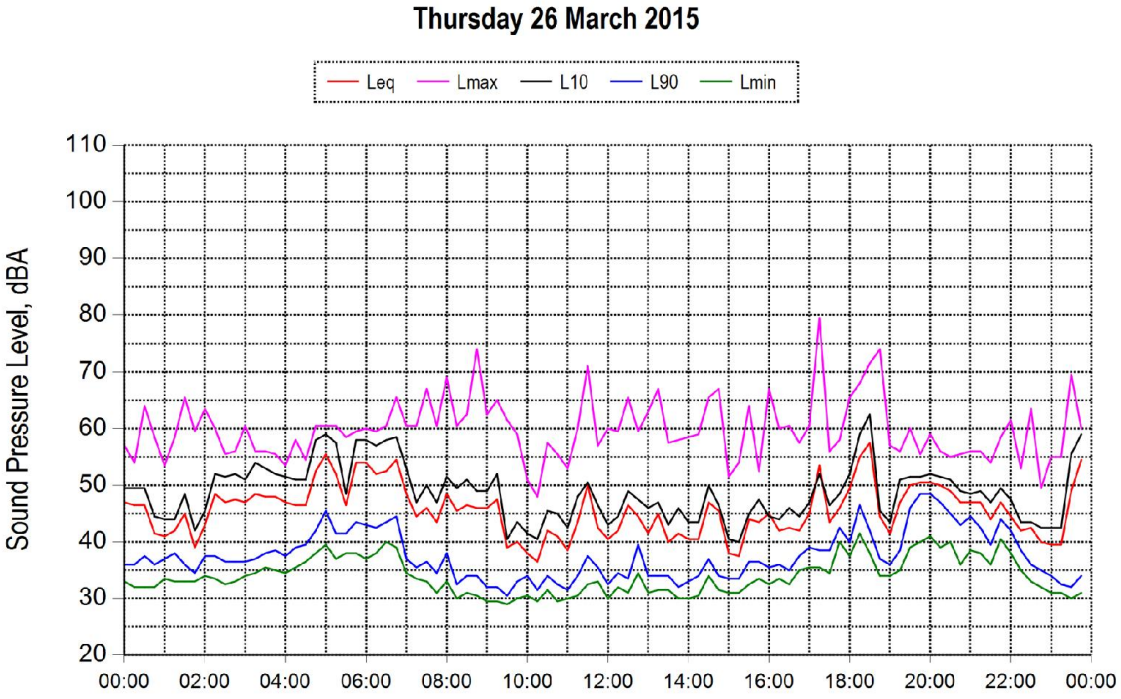

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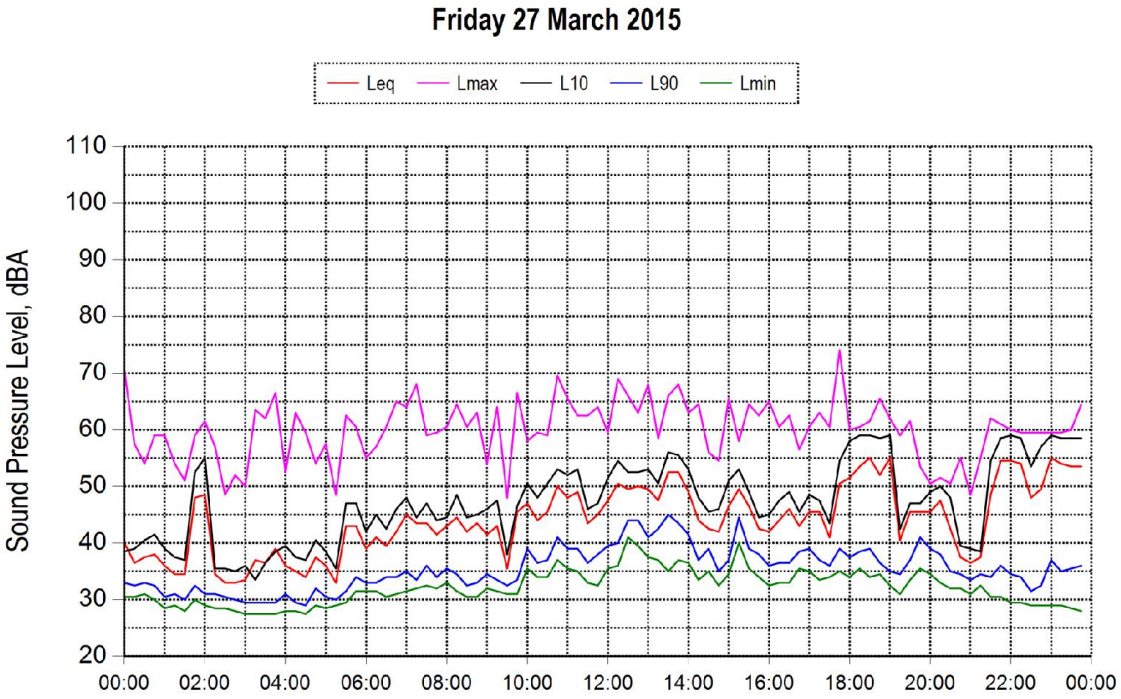

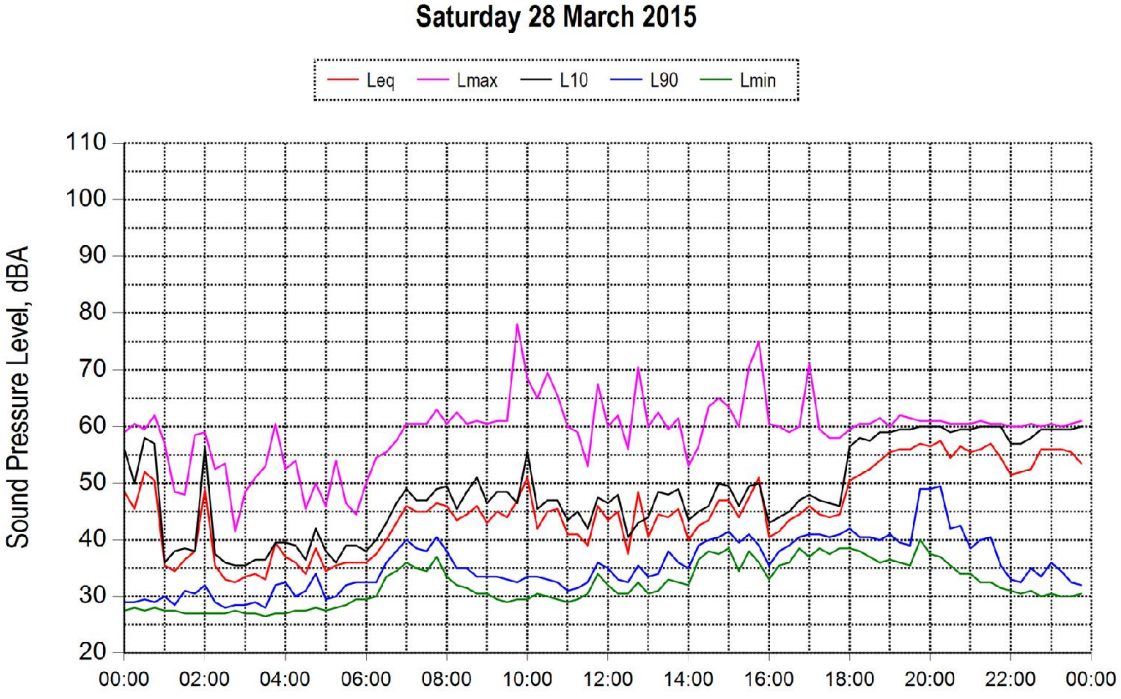

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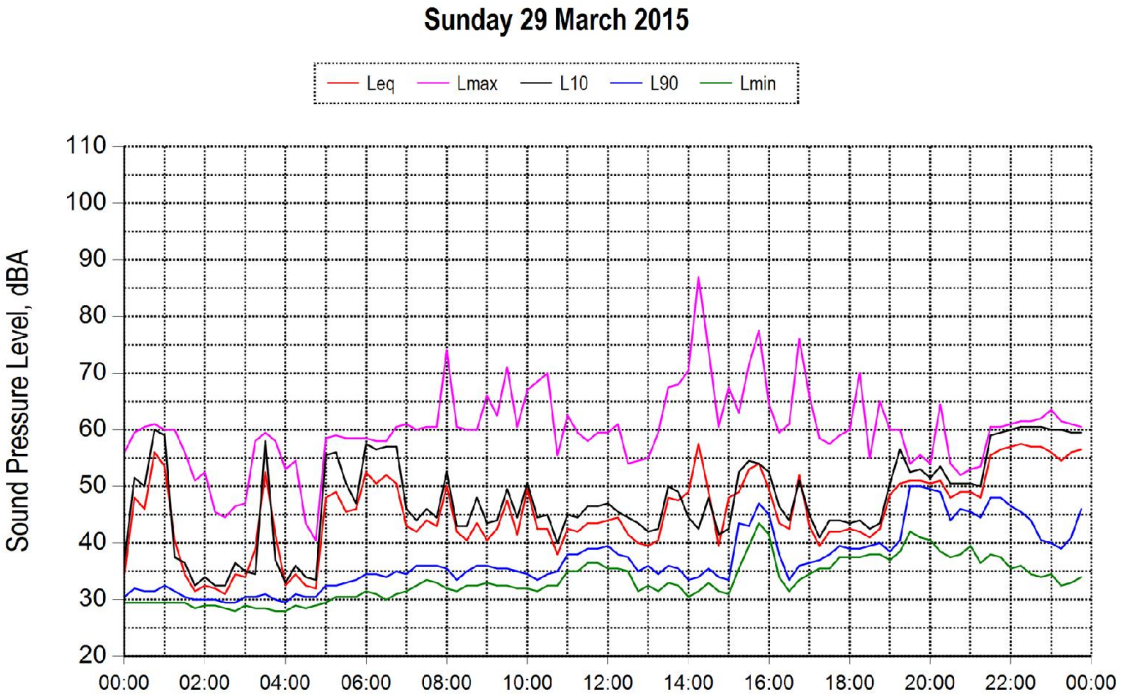

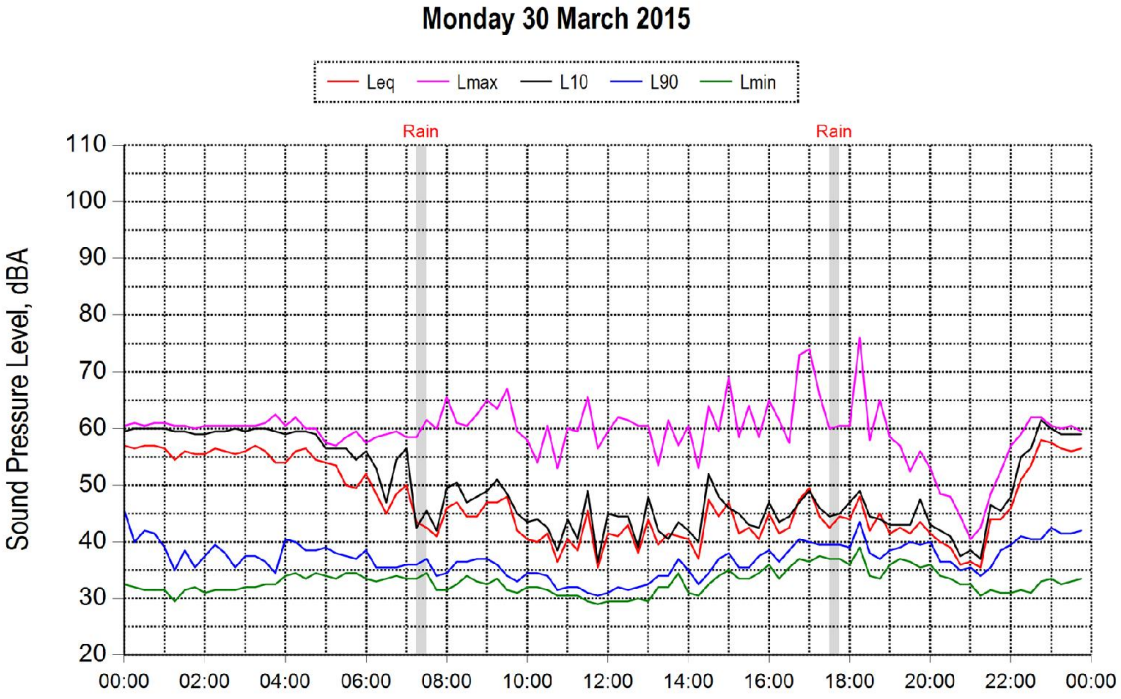

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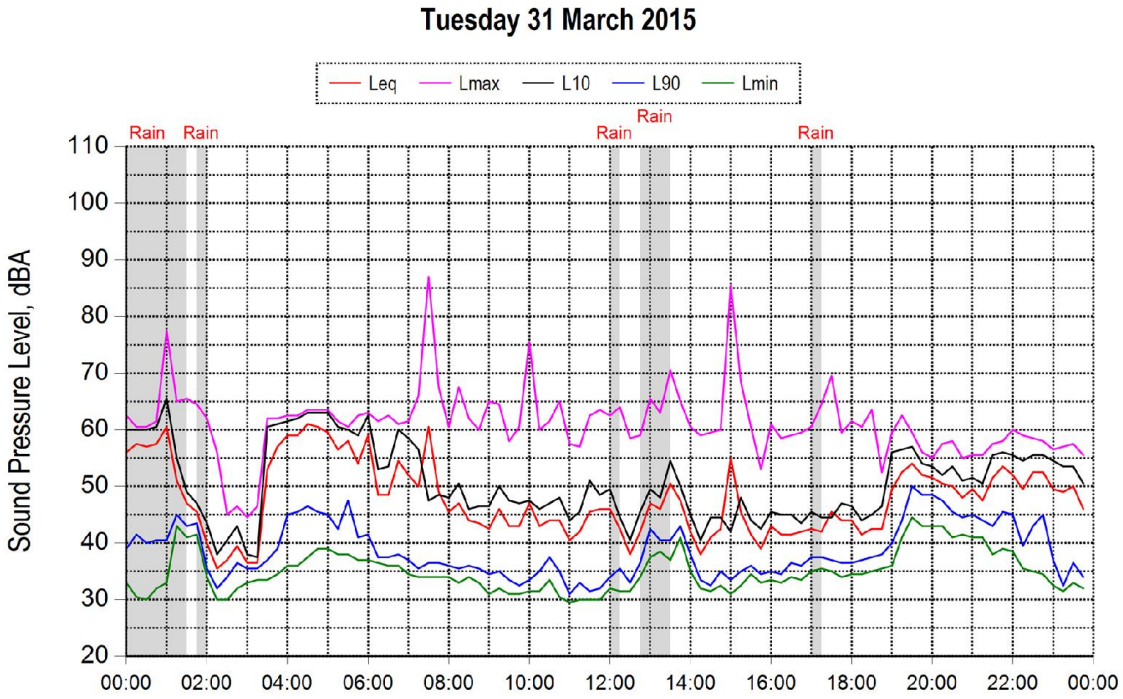

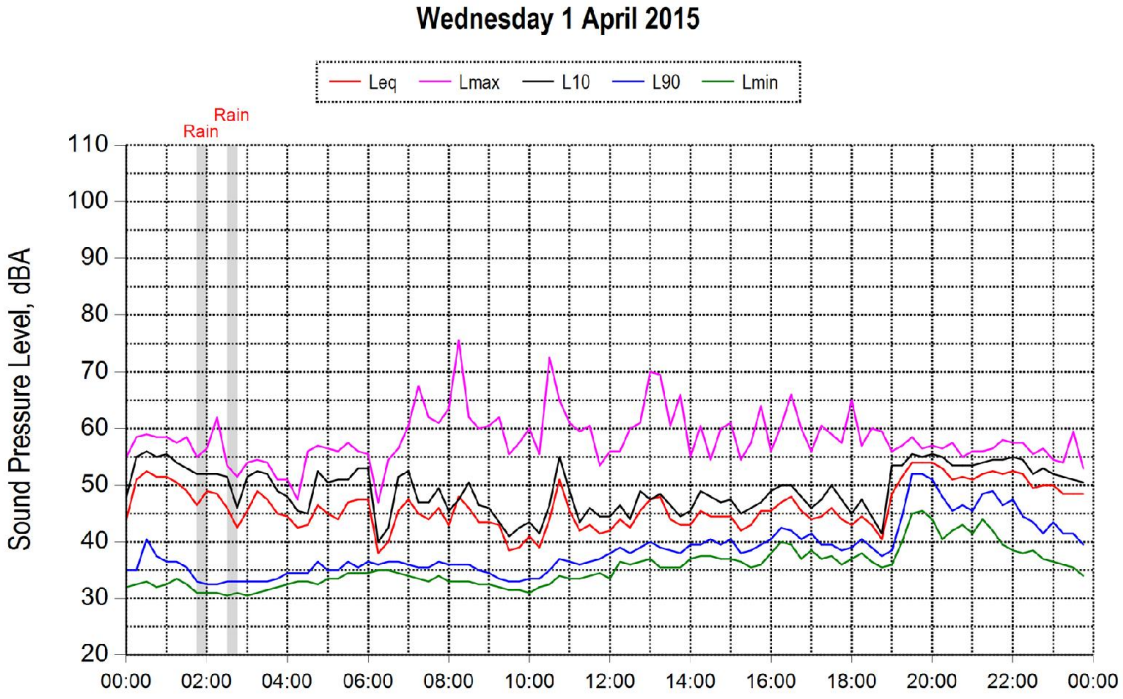

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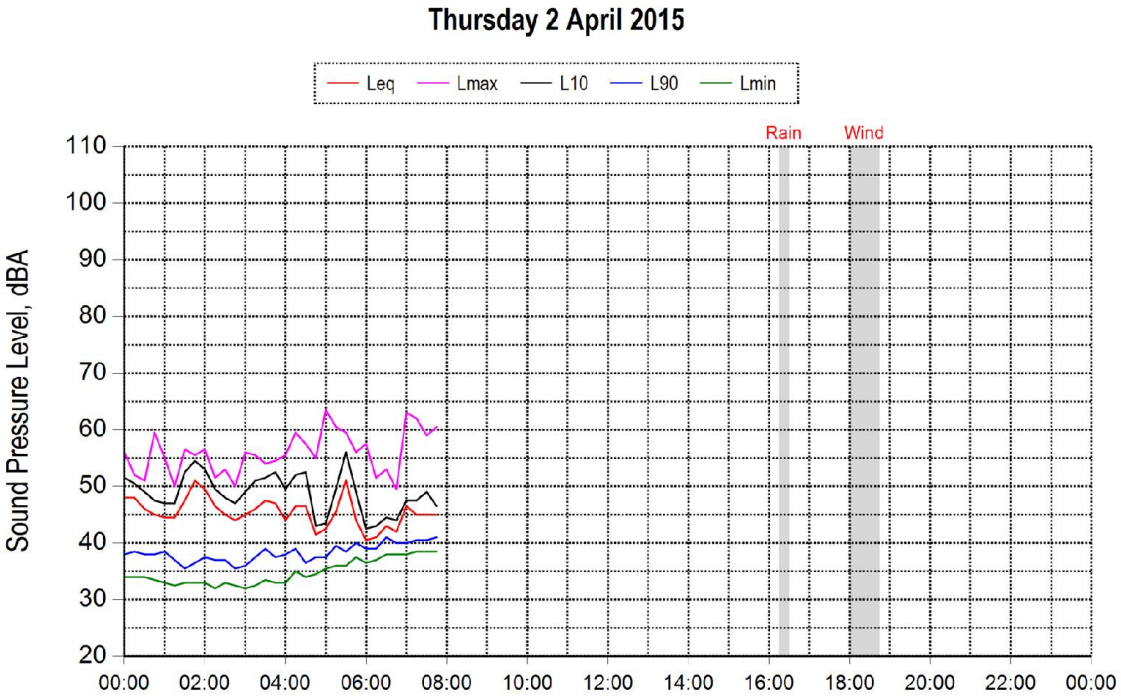
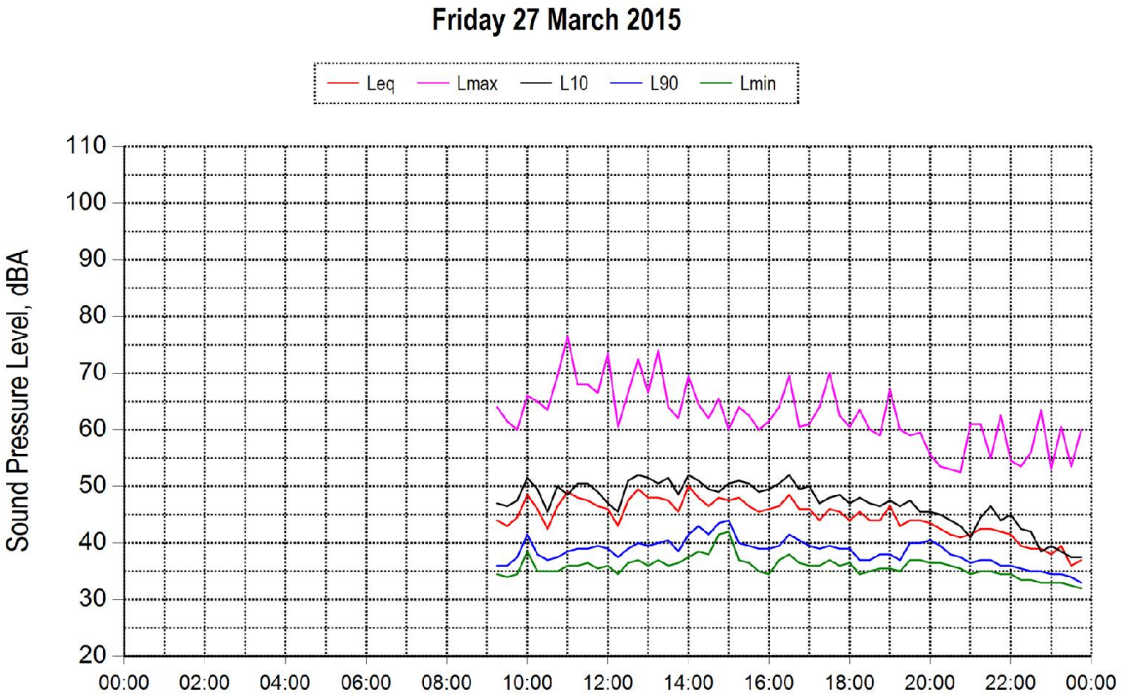
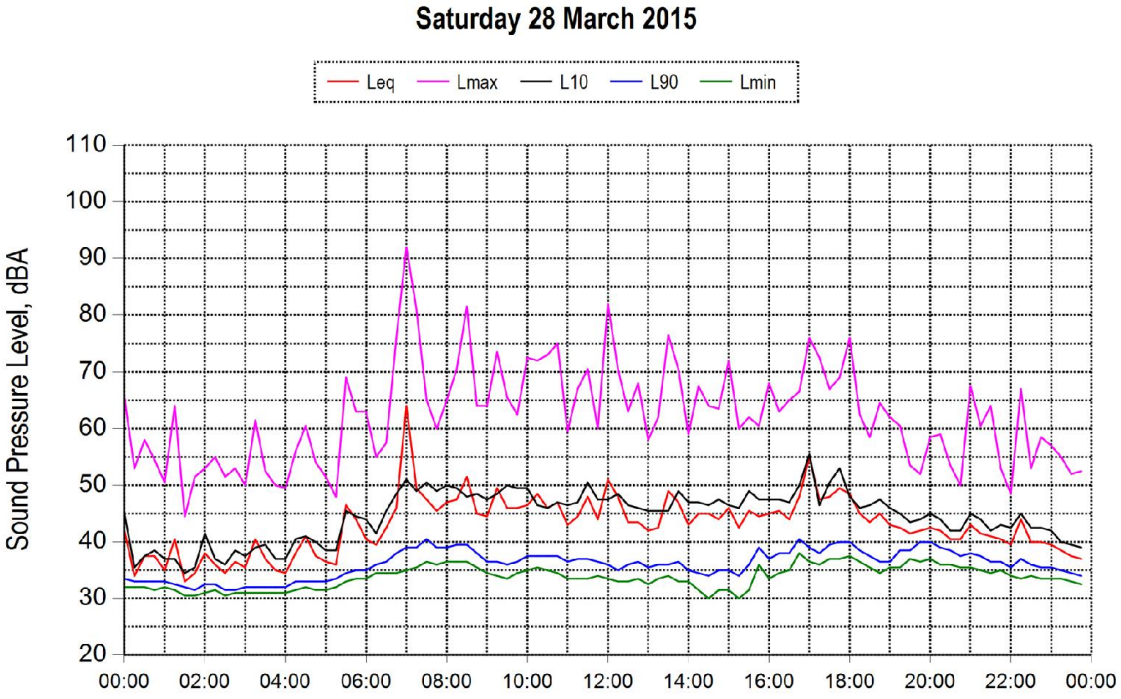


35 Ramsay Road, Rossmore





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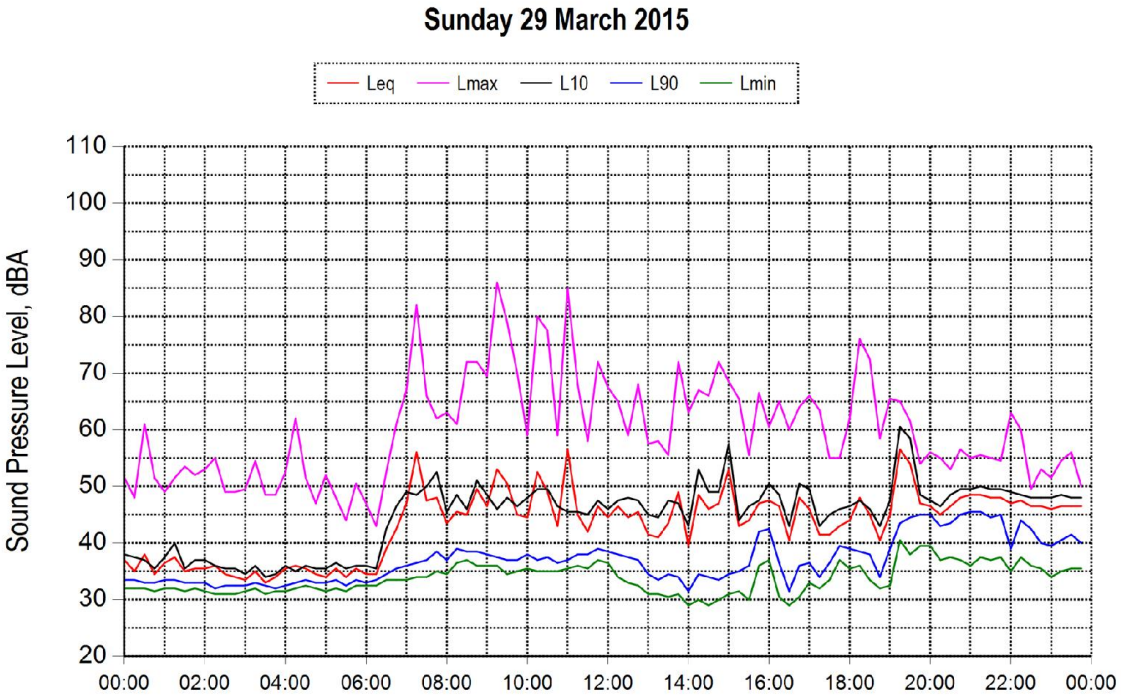

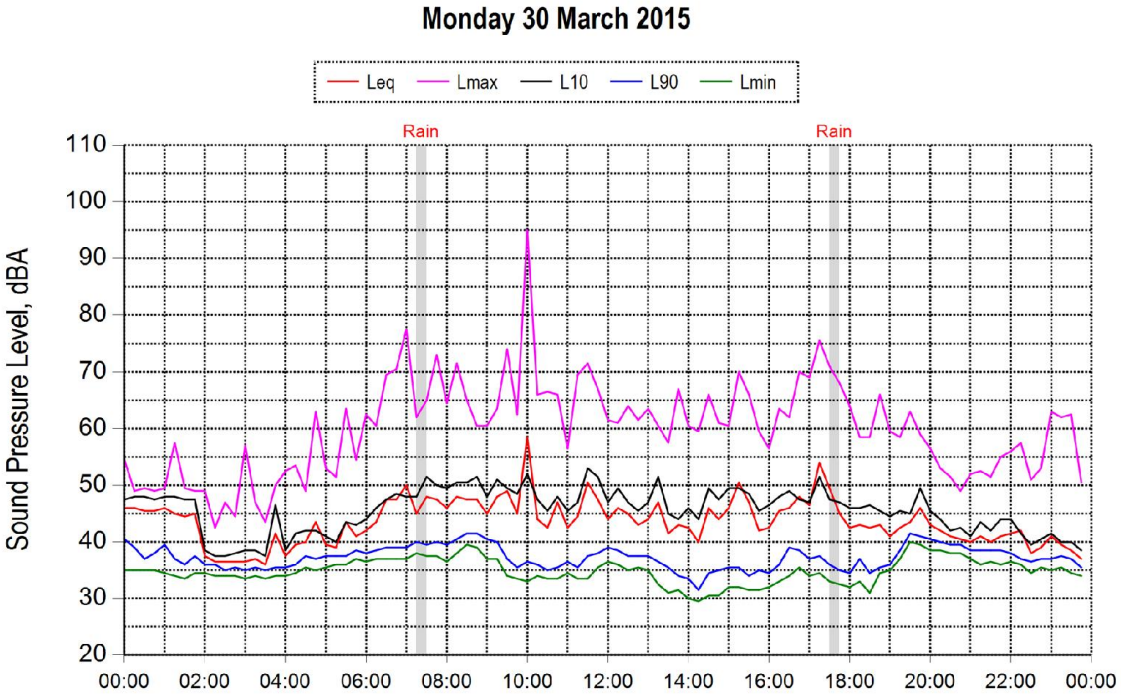

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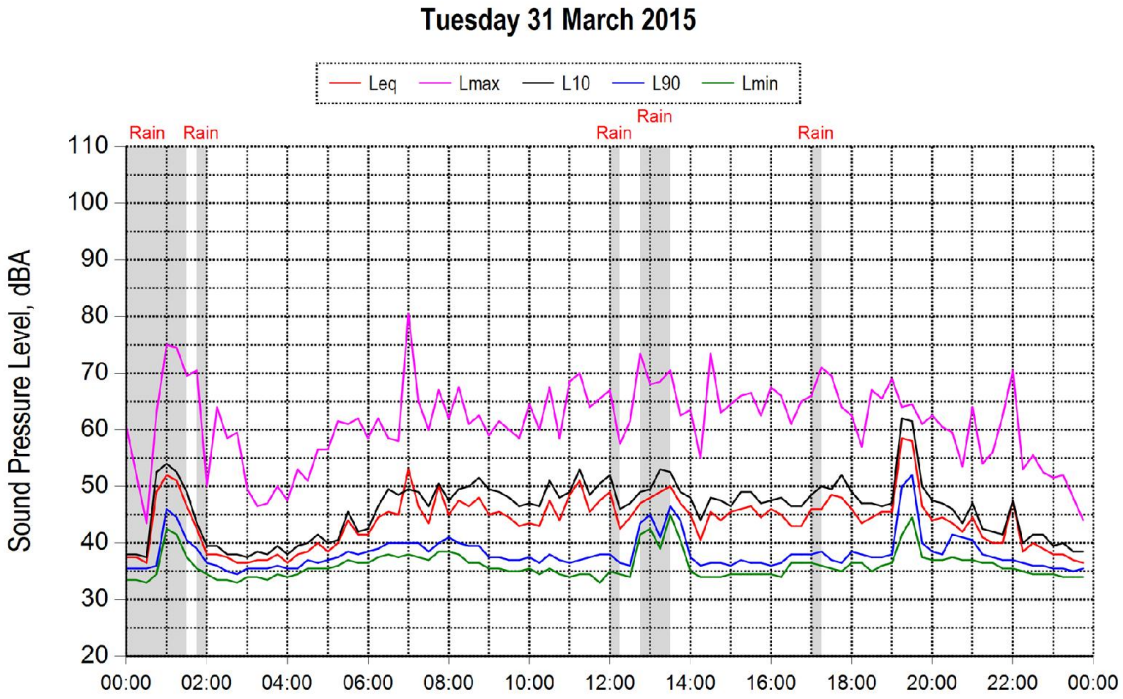

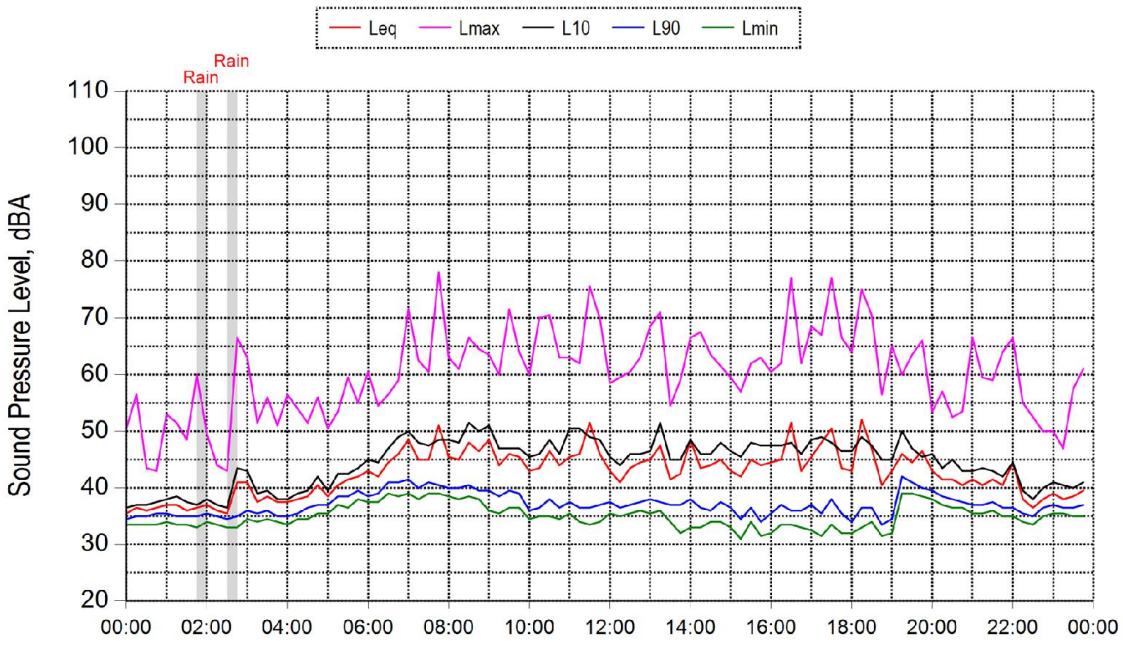

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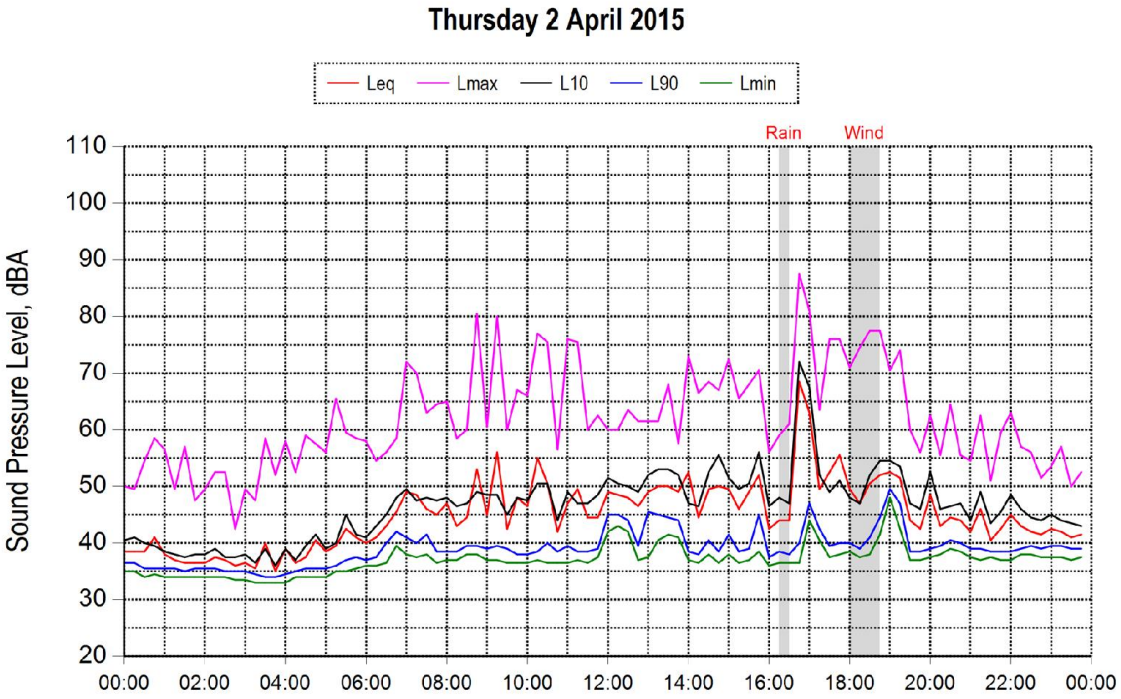
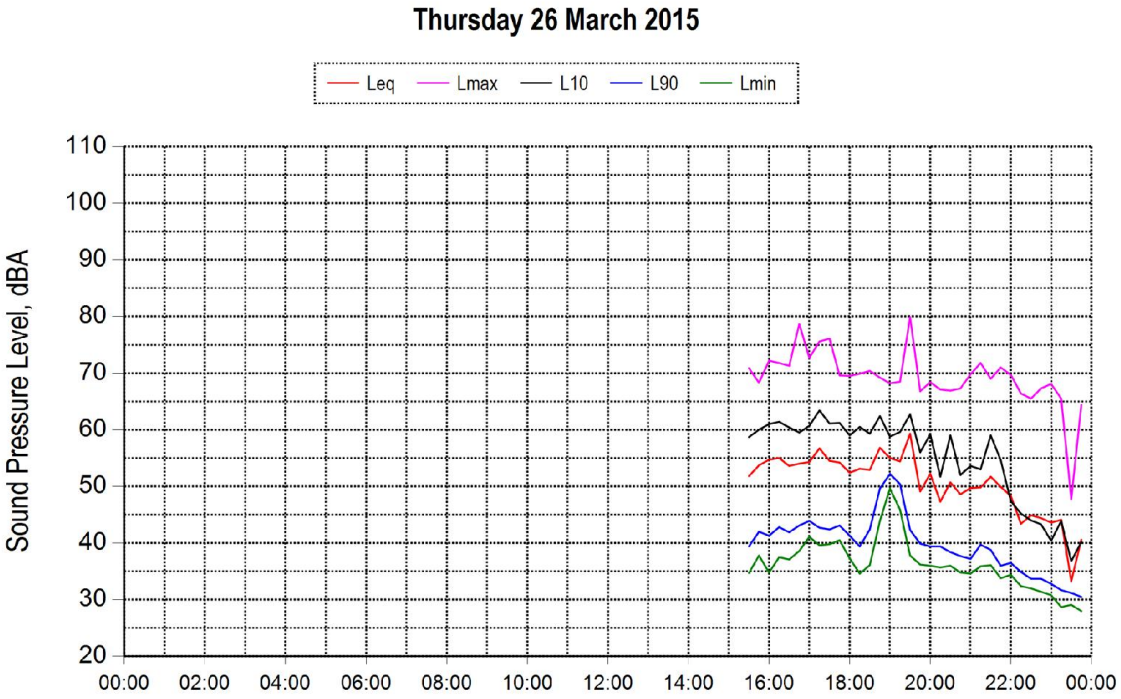
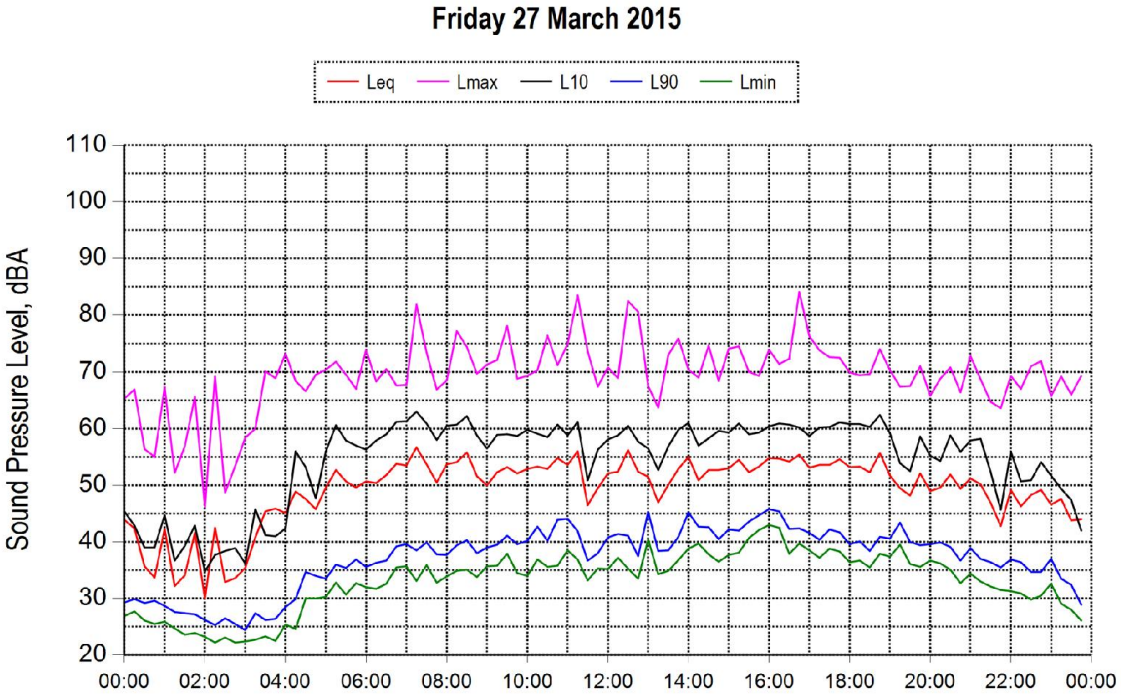


54 Ridgehaven Road, Silverdale





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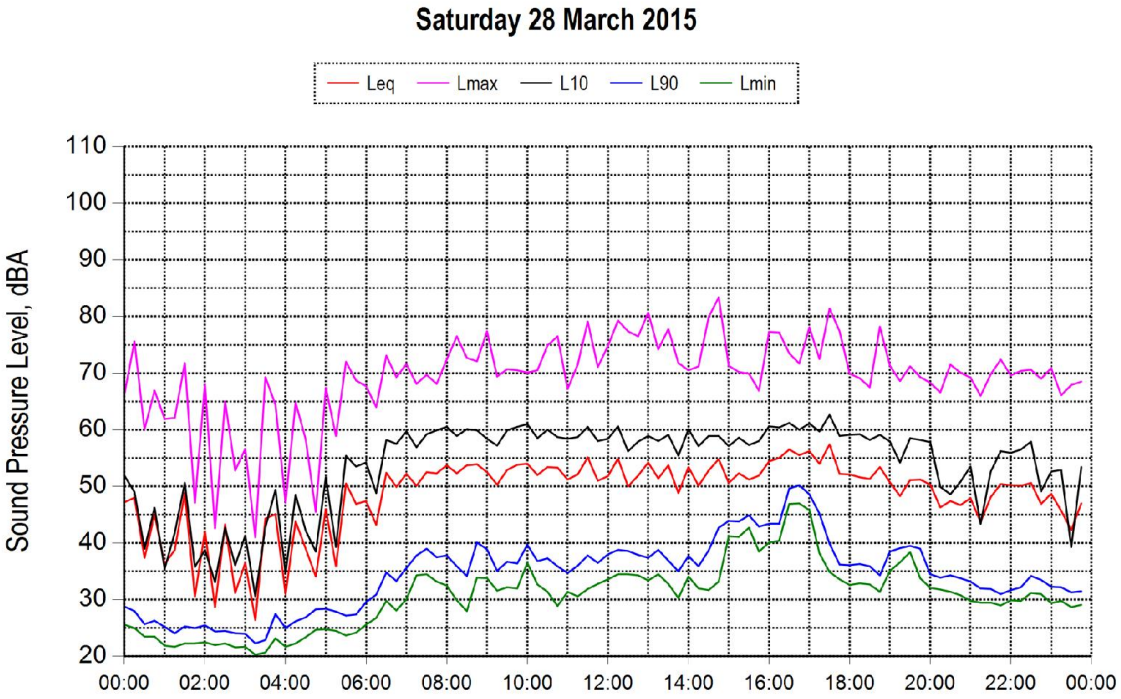

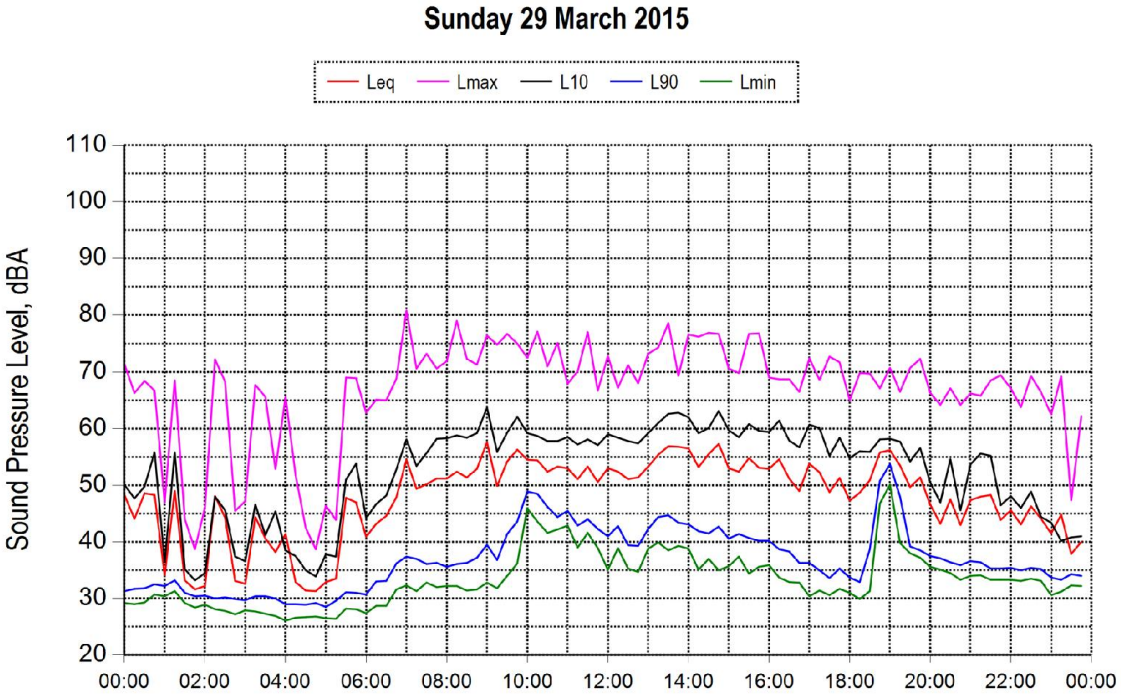

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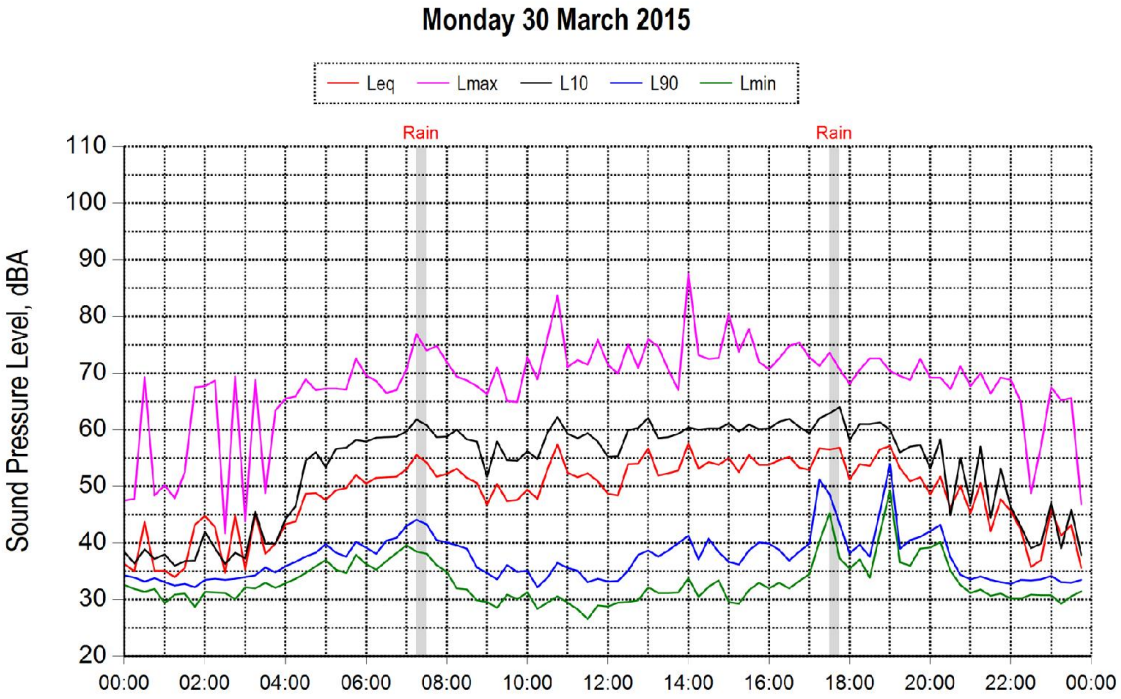

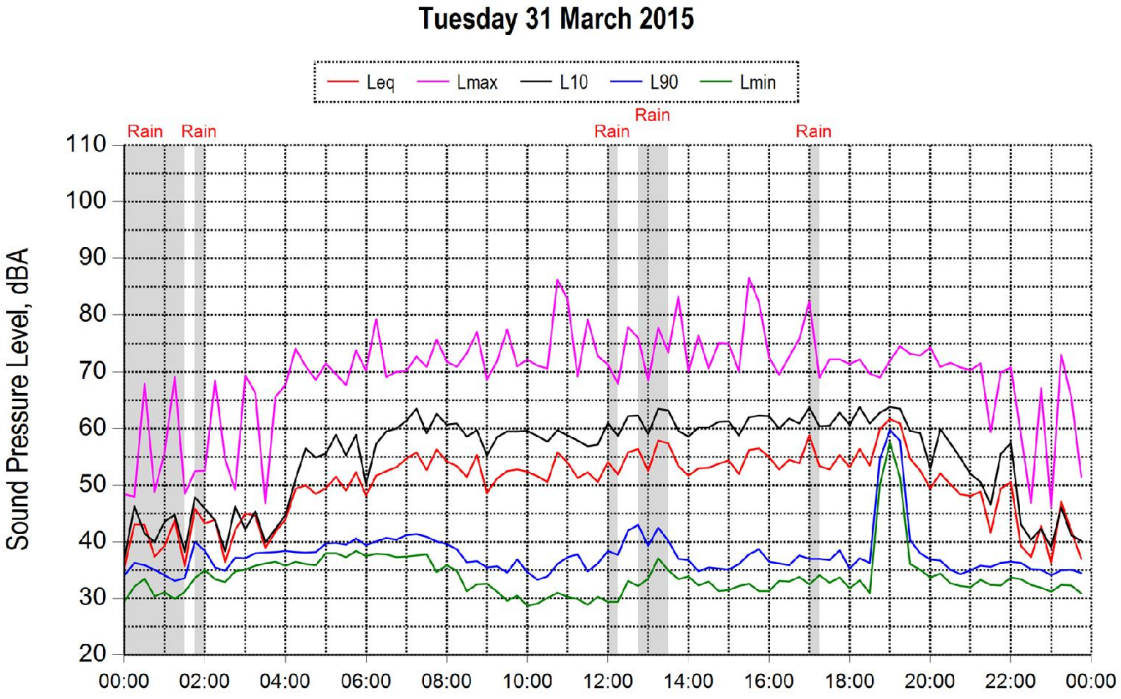

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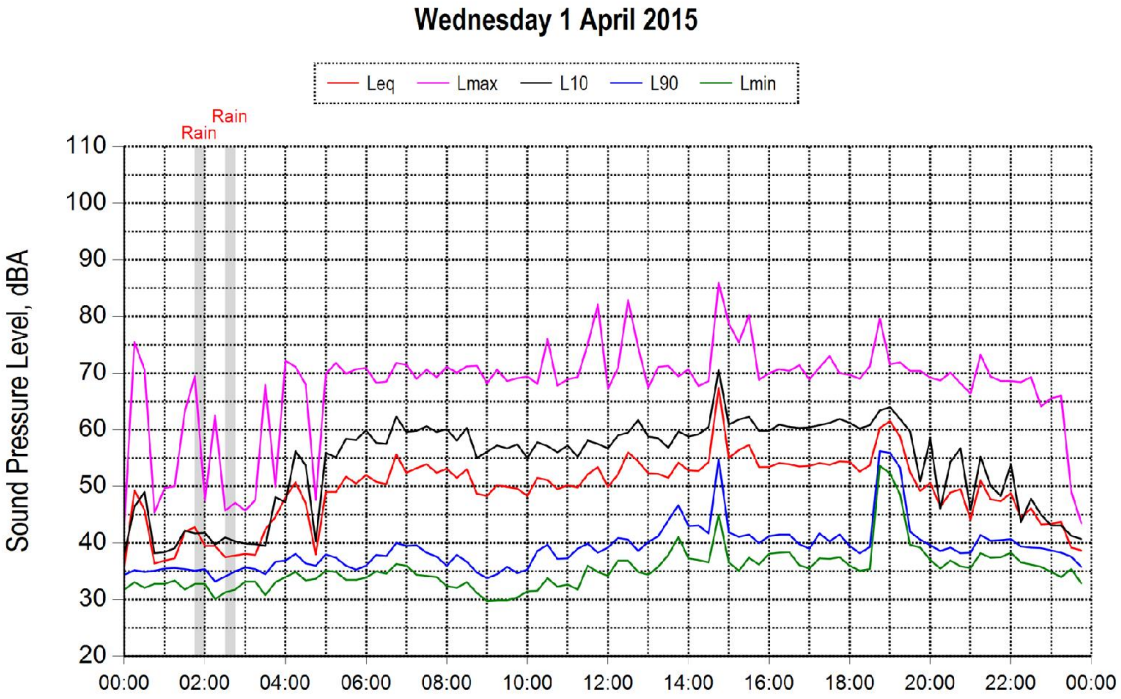
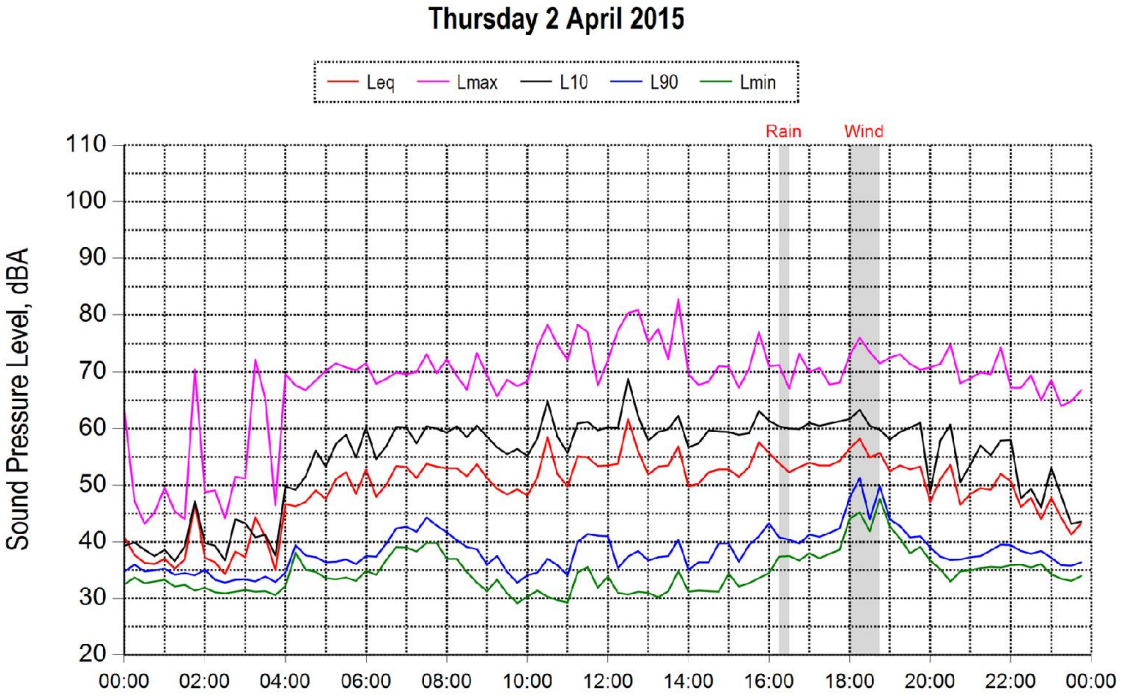
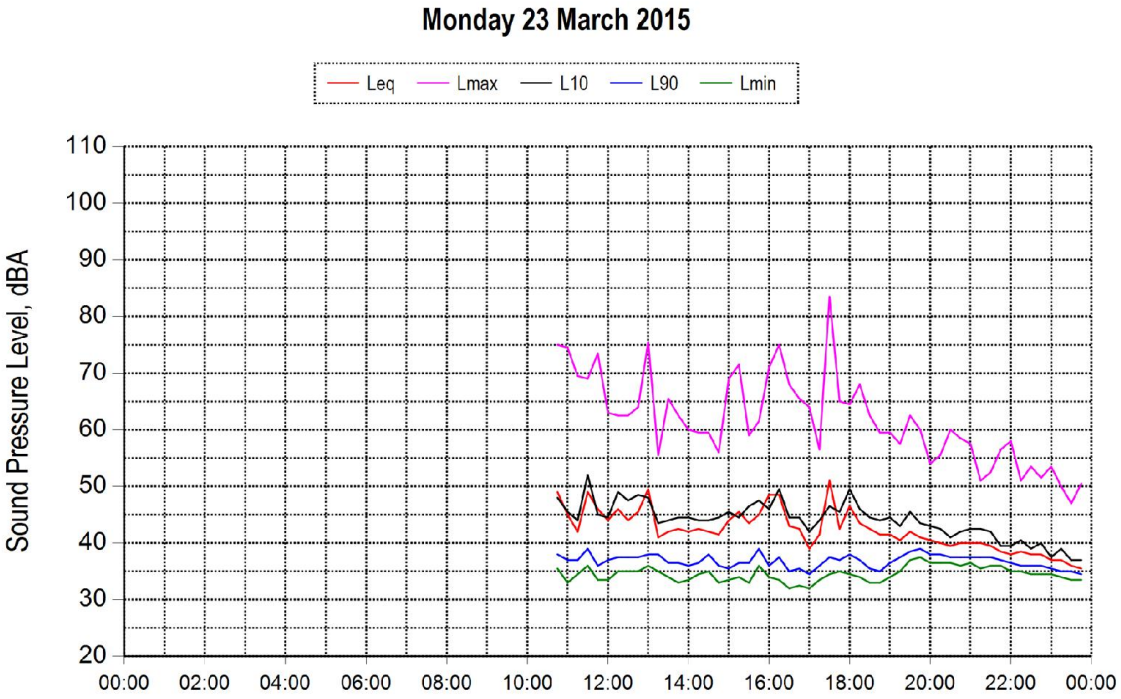
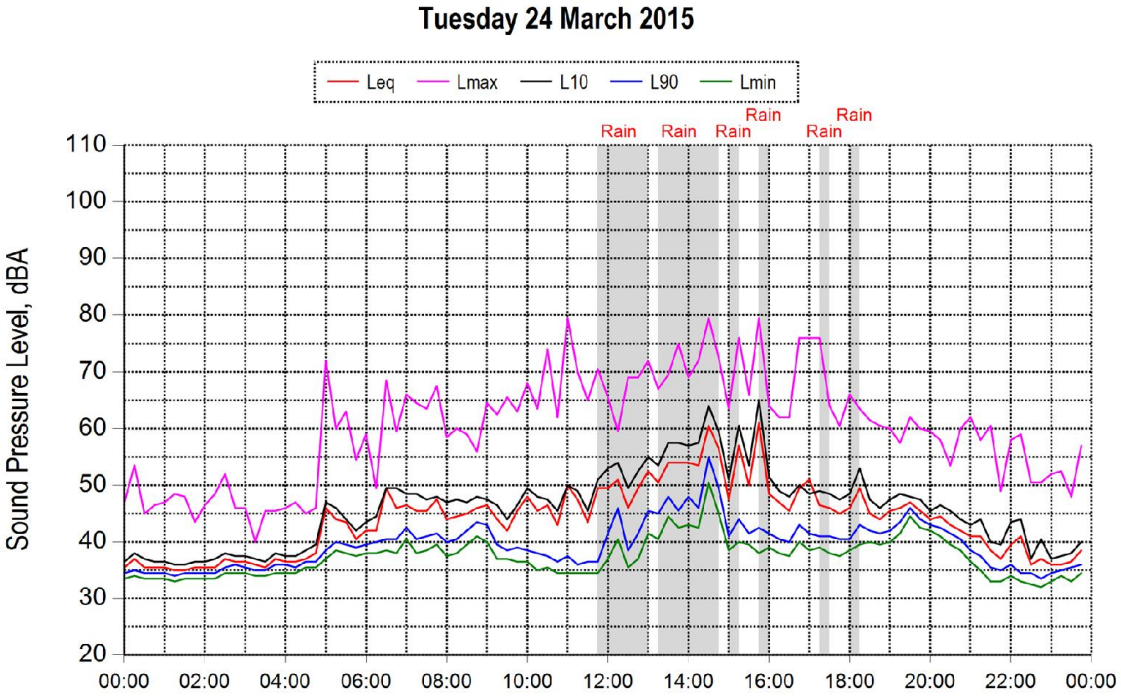




114 Mount Vernon Road, Mount Vernon





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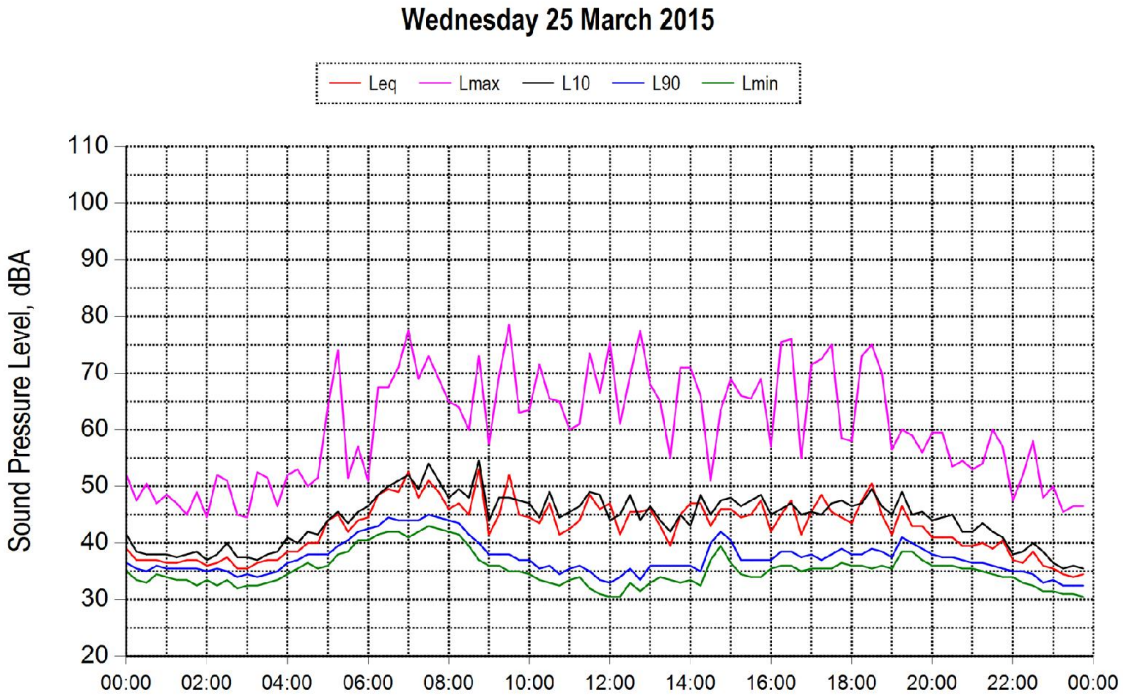

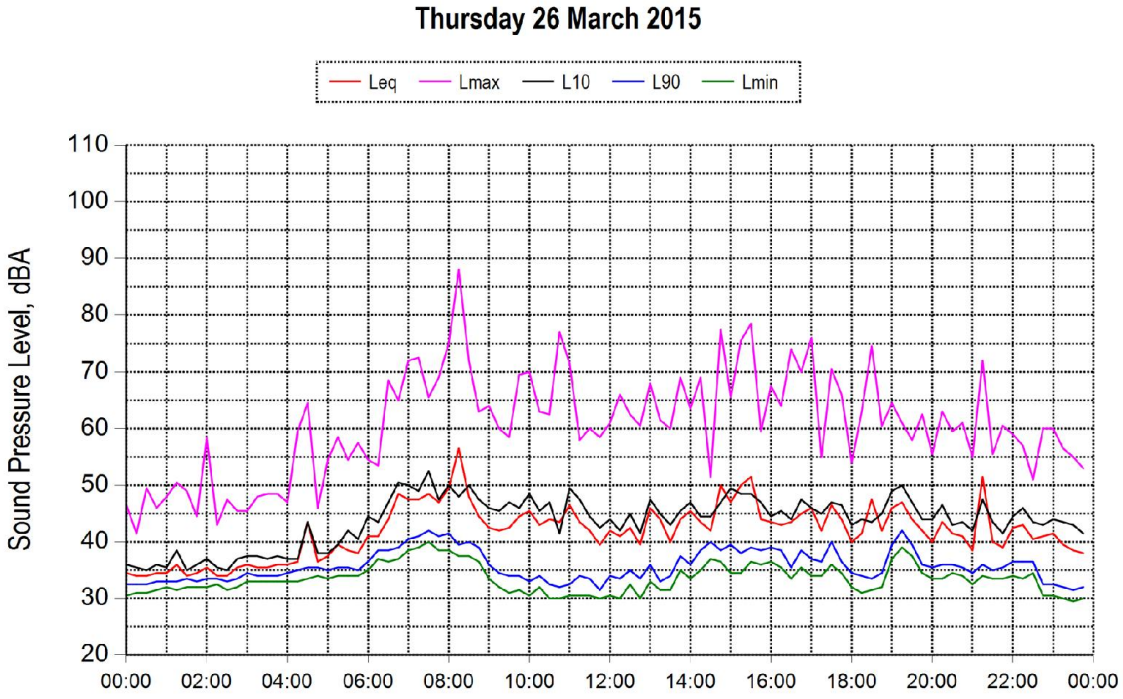

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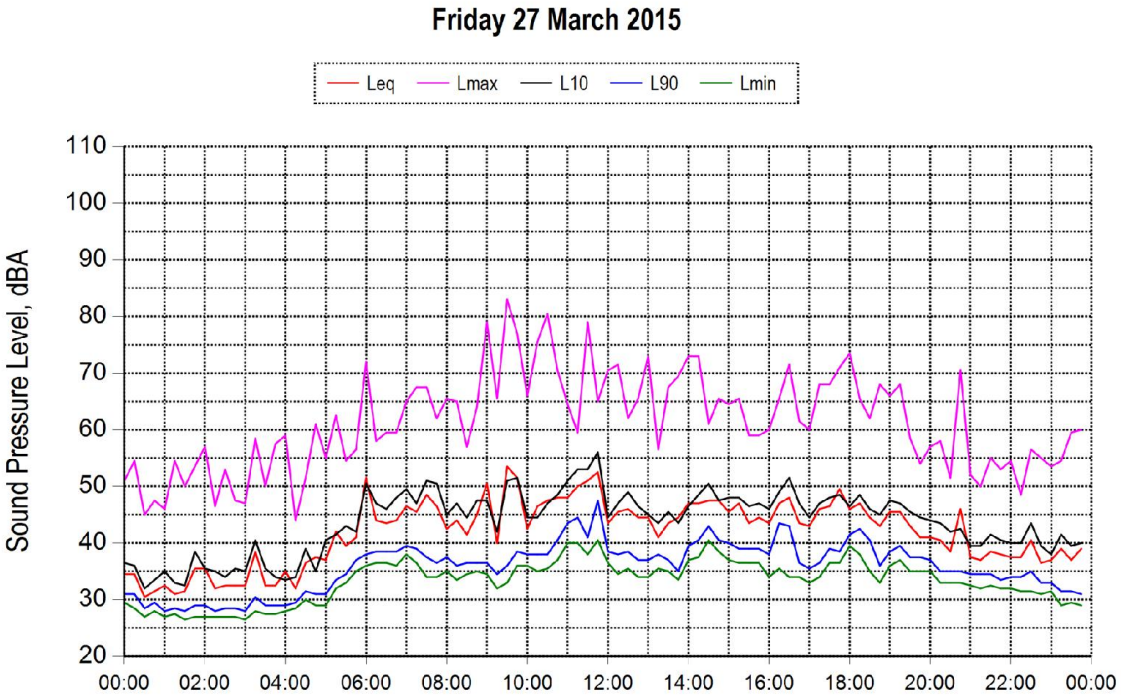

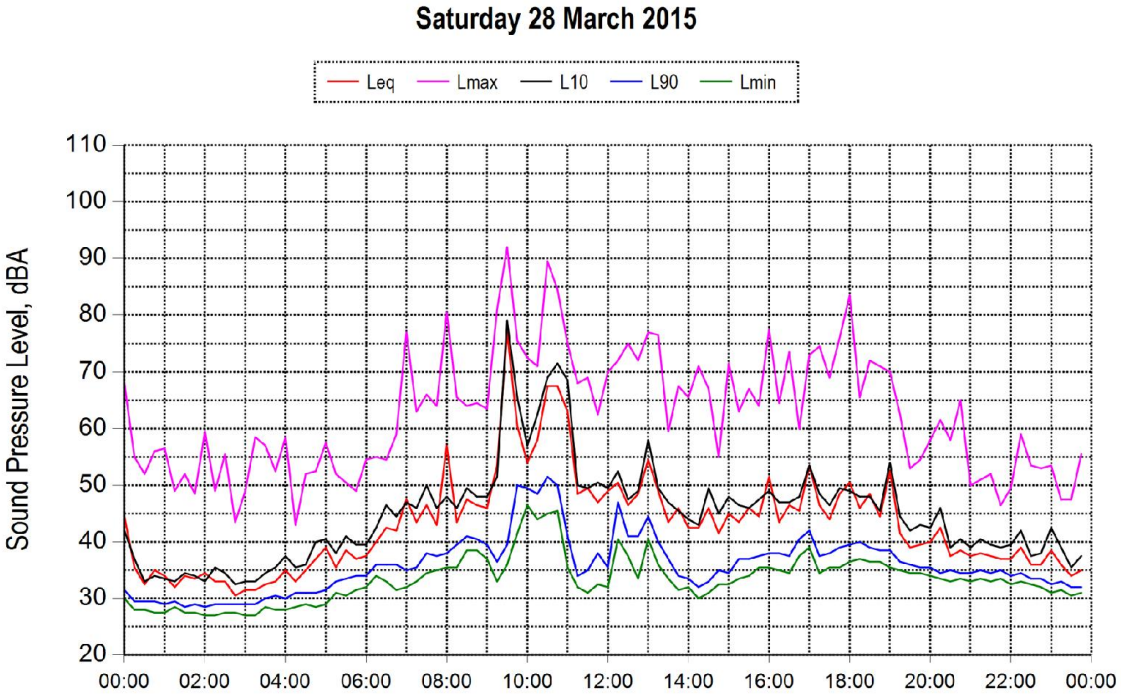

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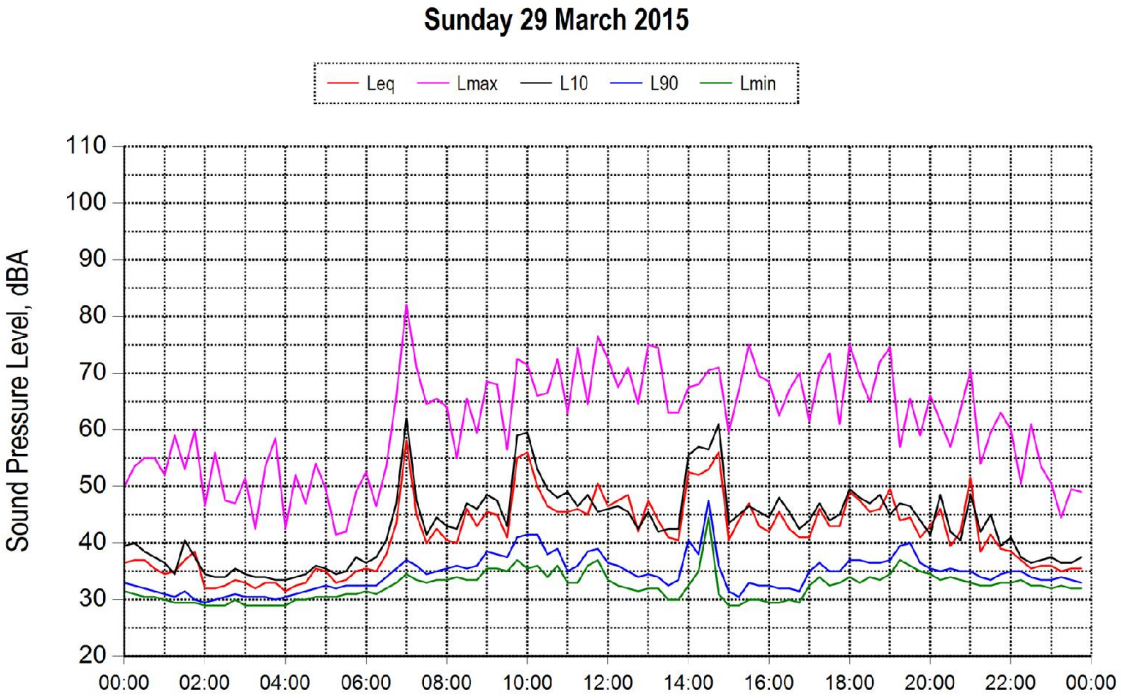

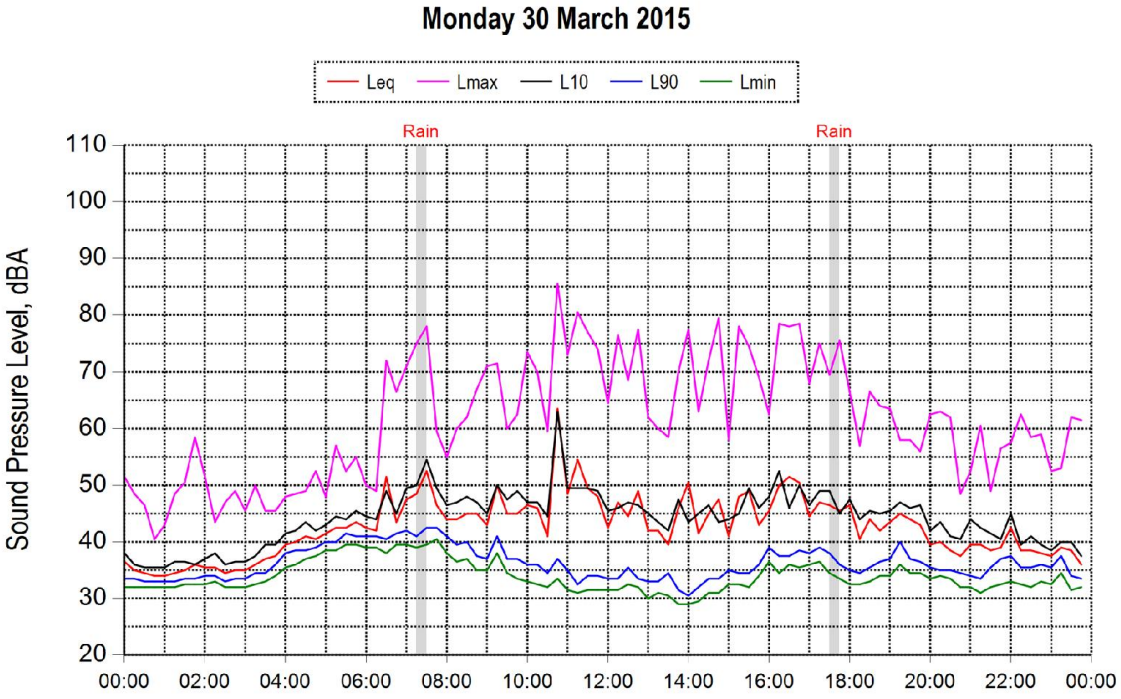

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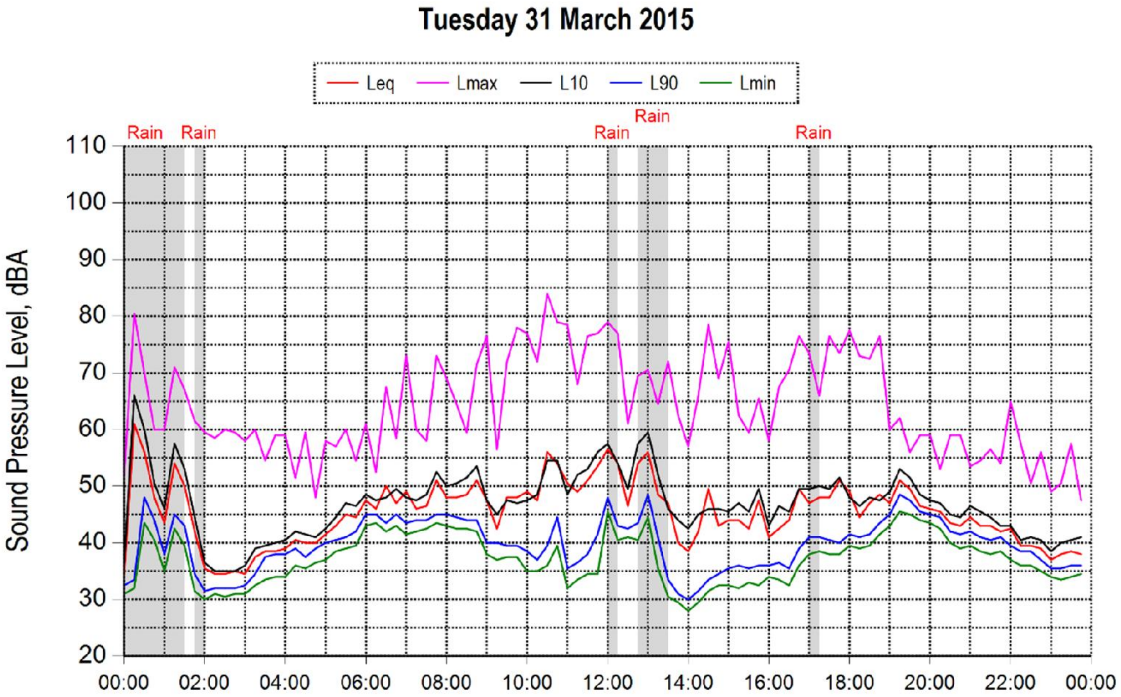

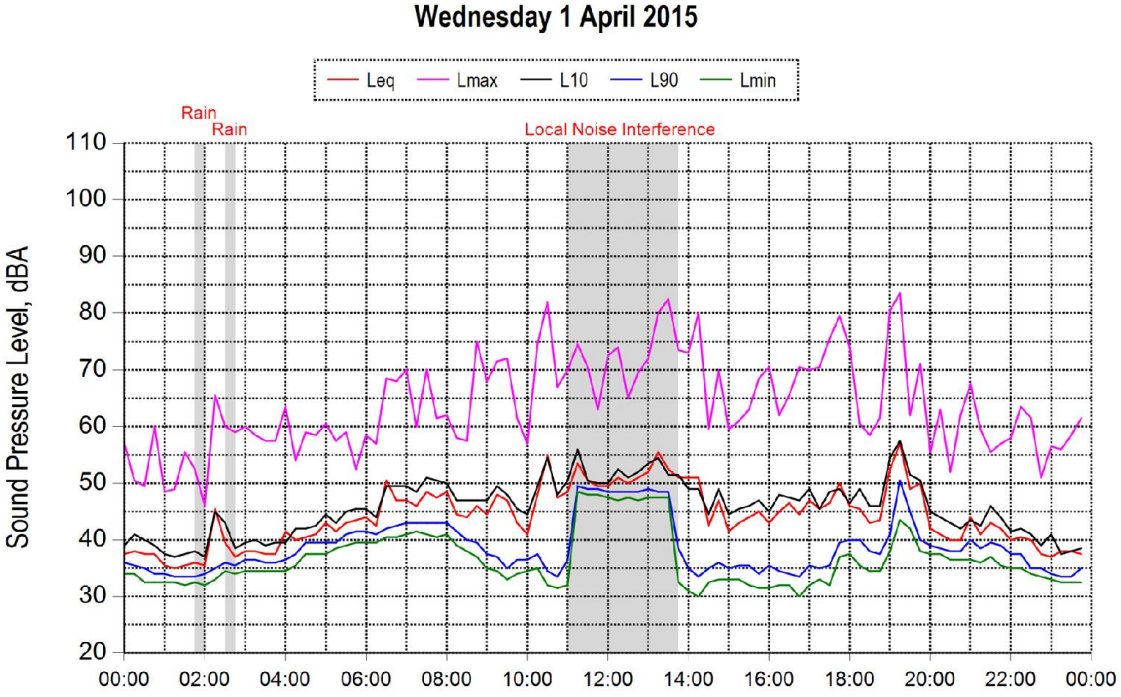

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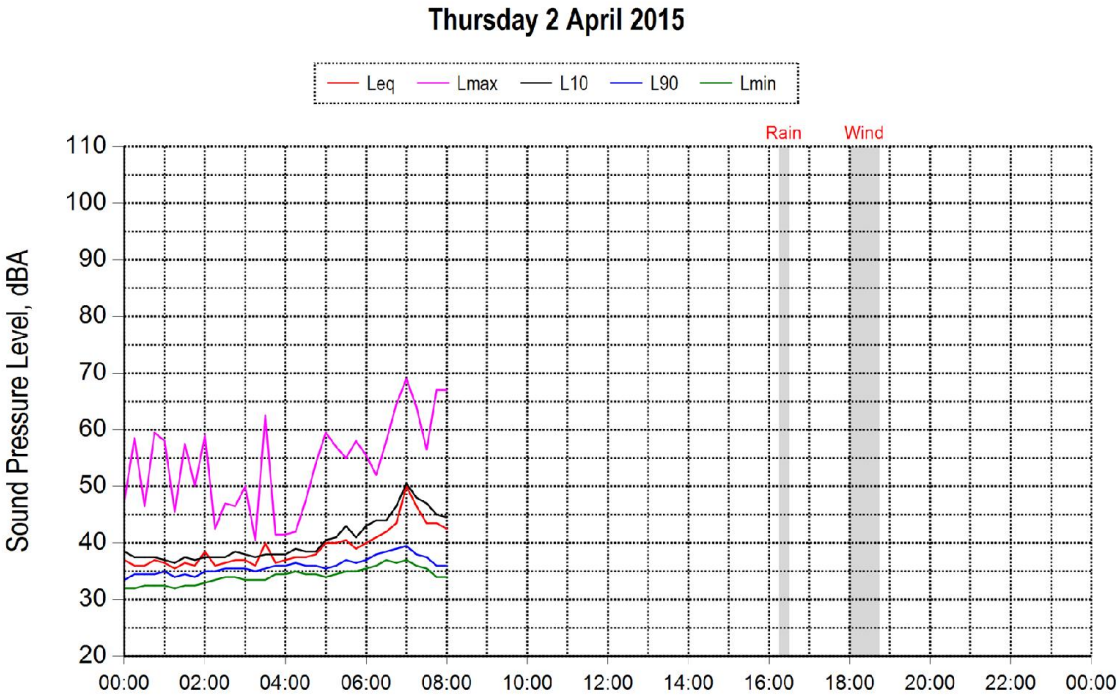

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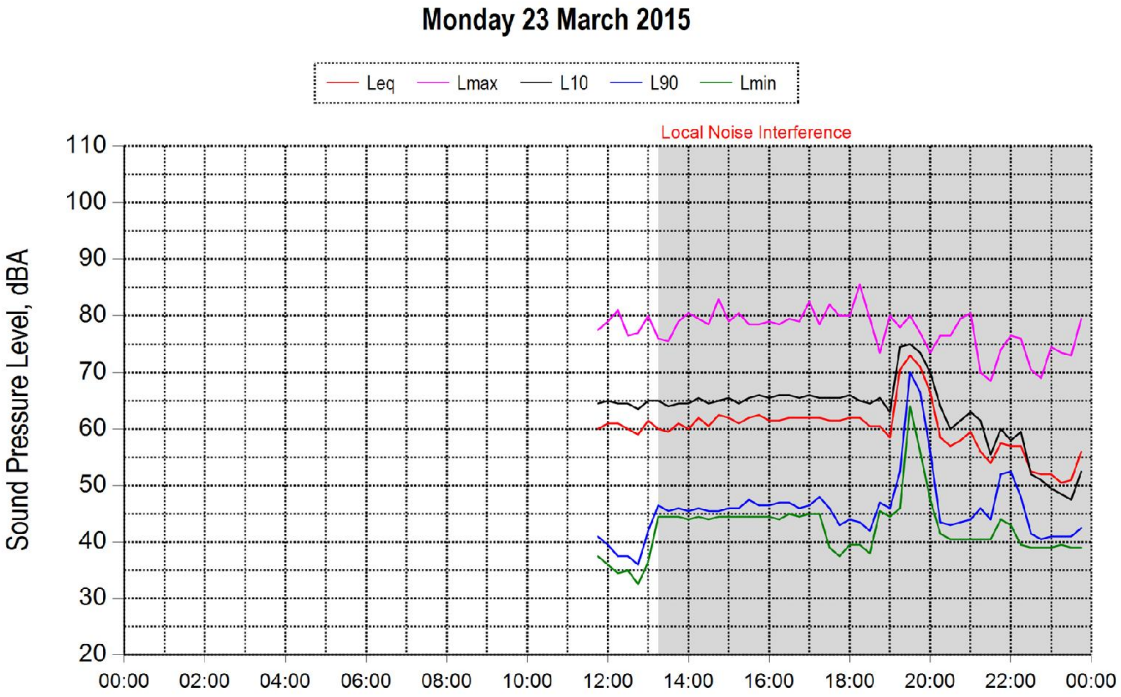

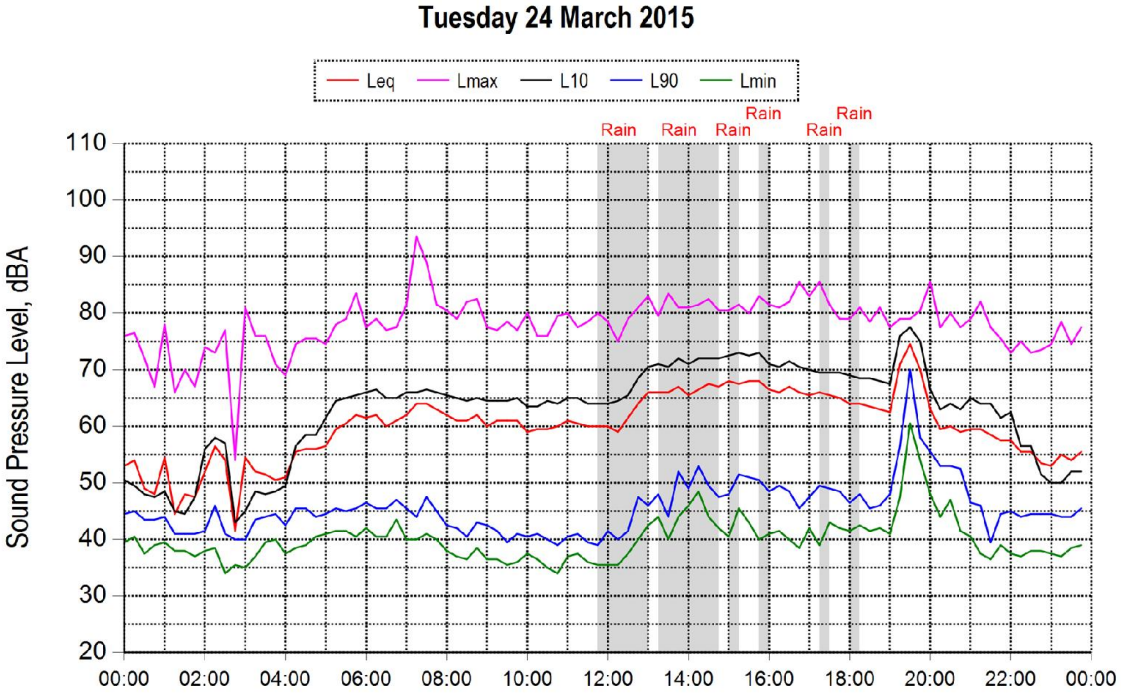

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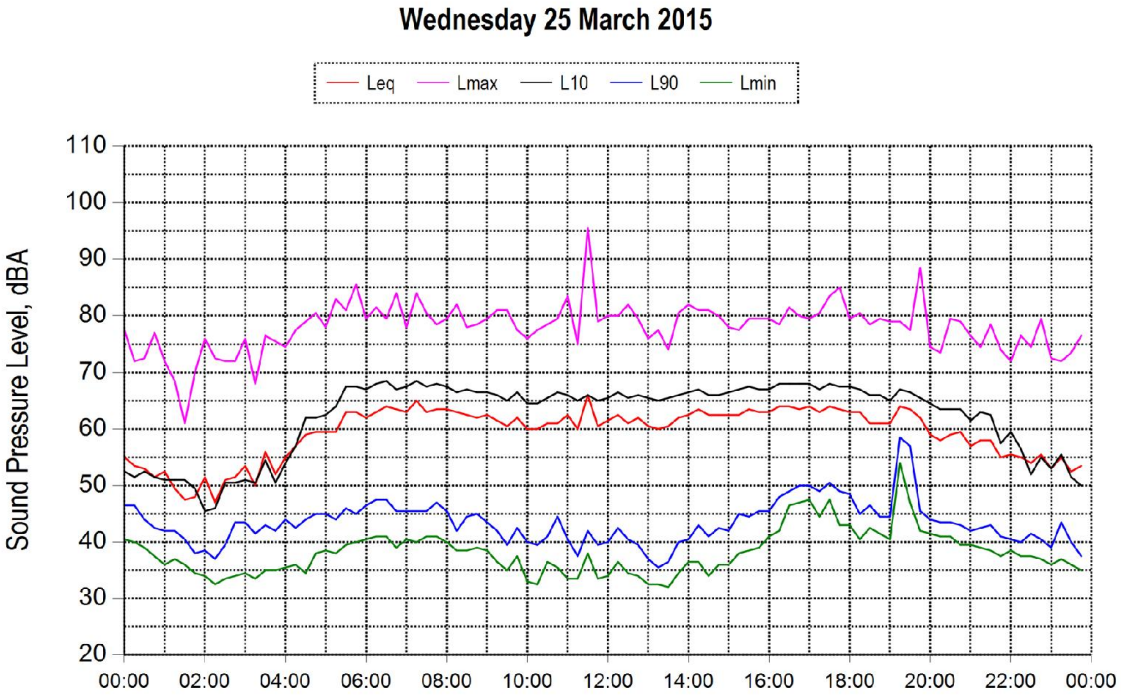

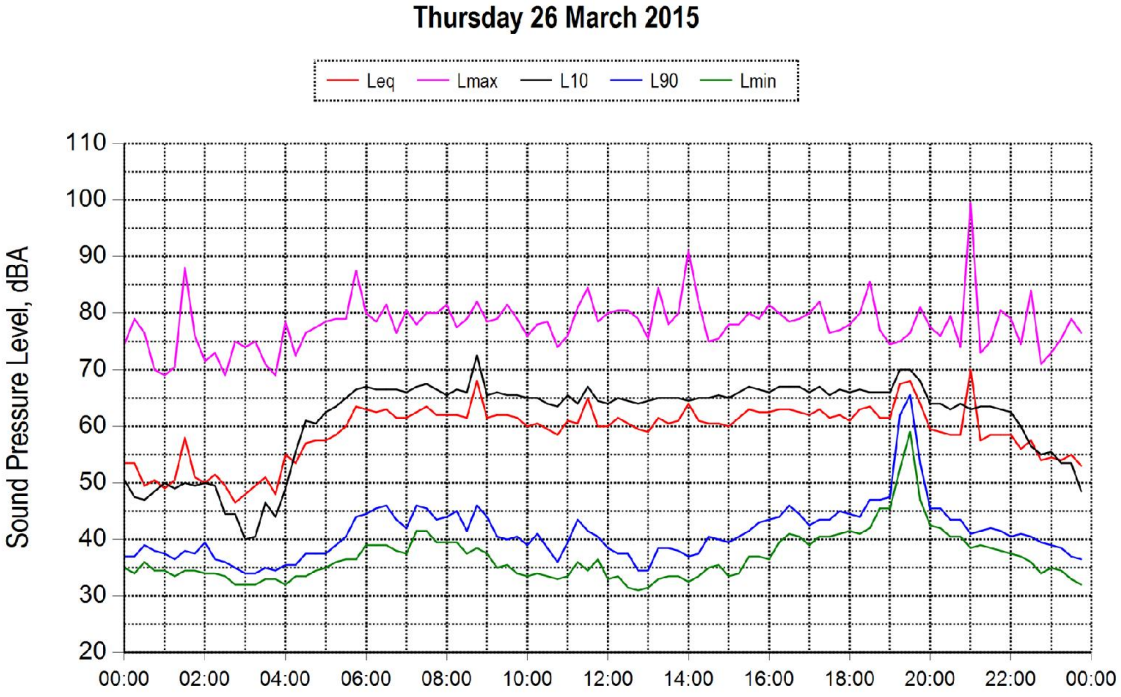

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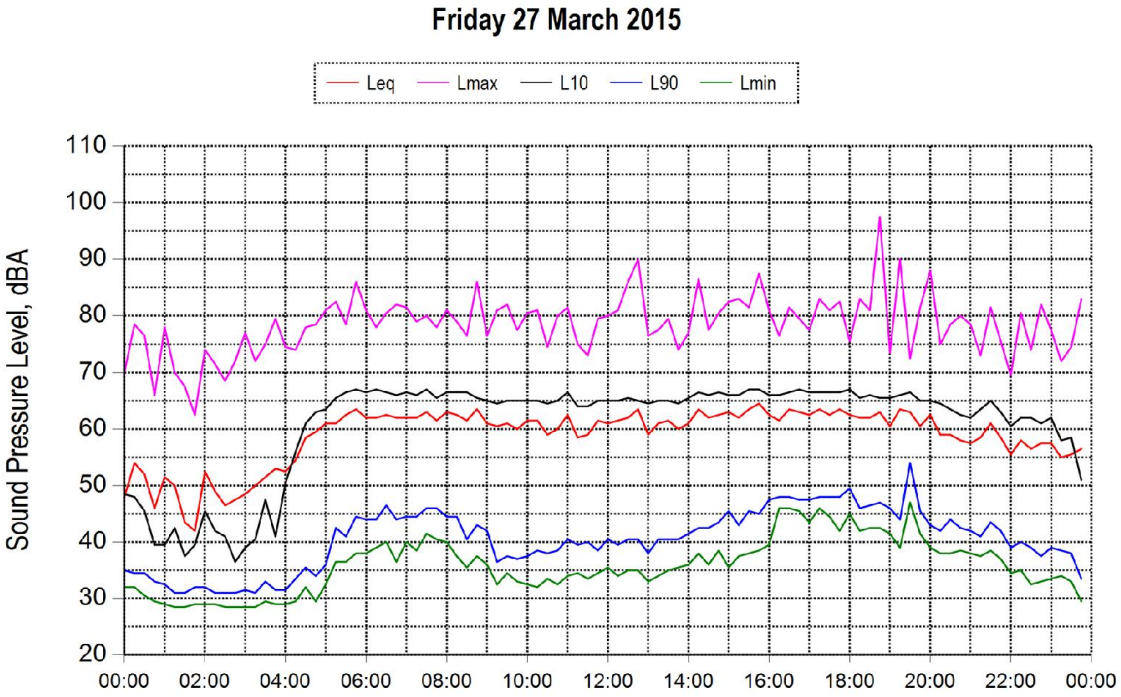

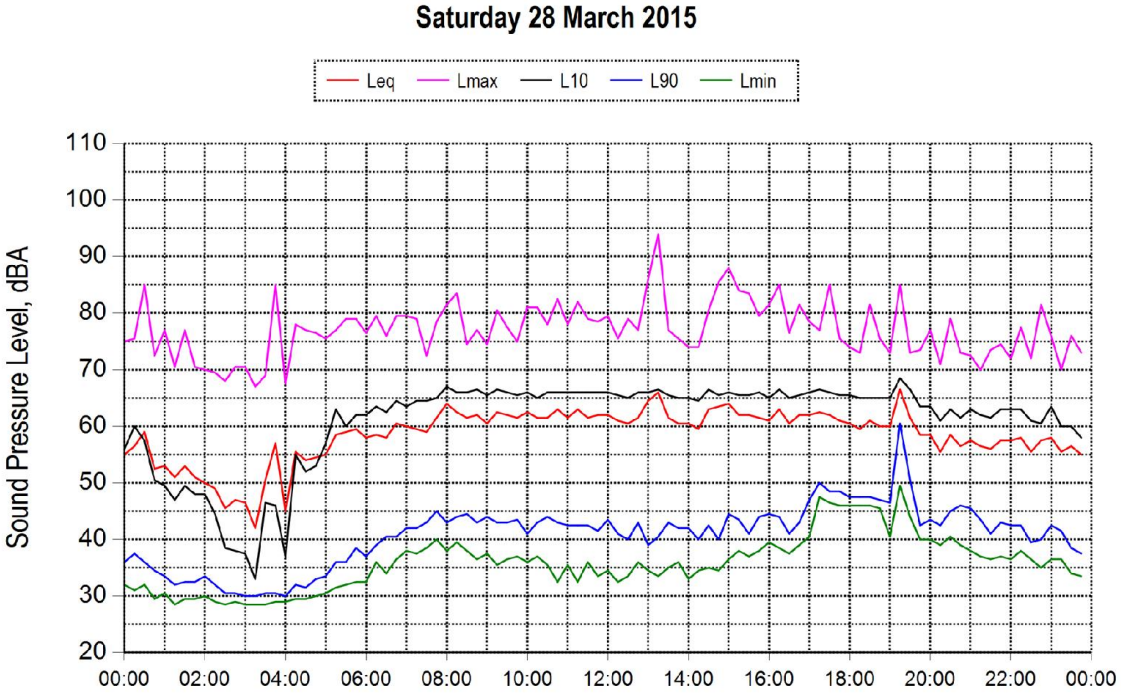

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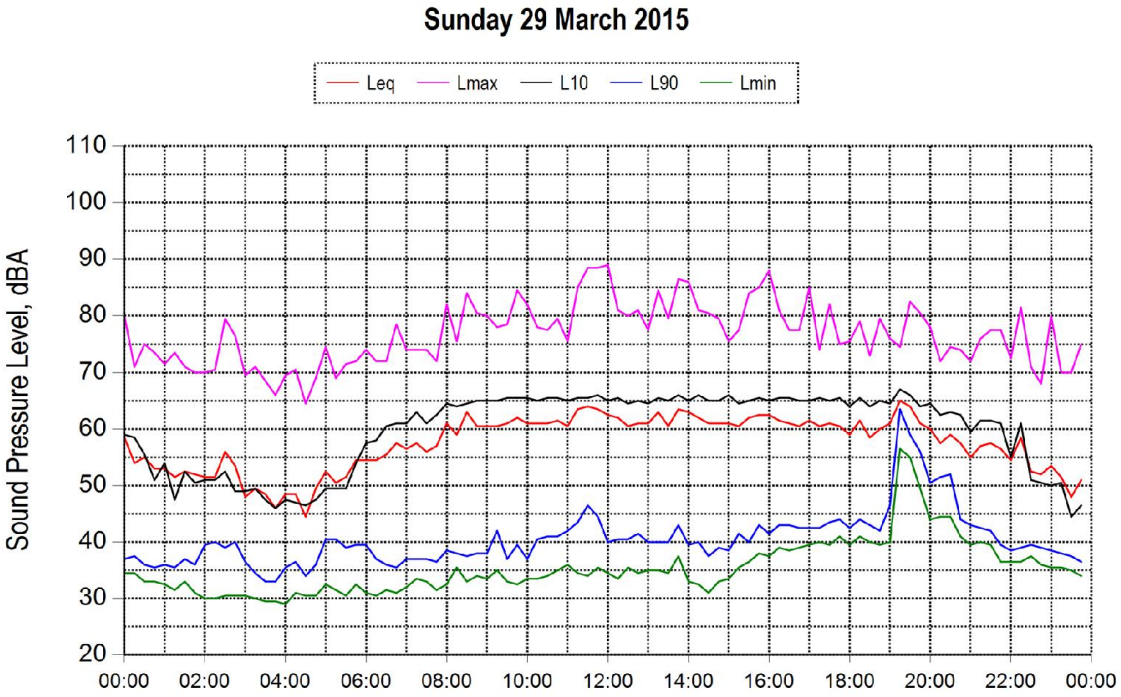

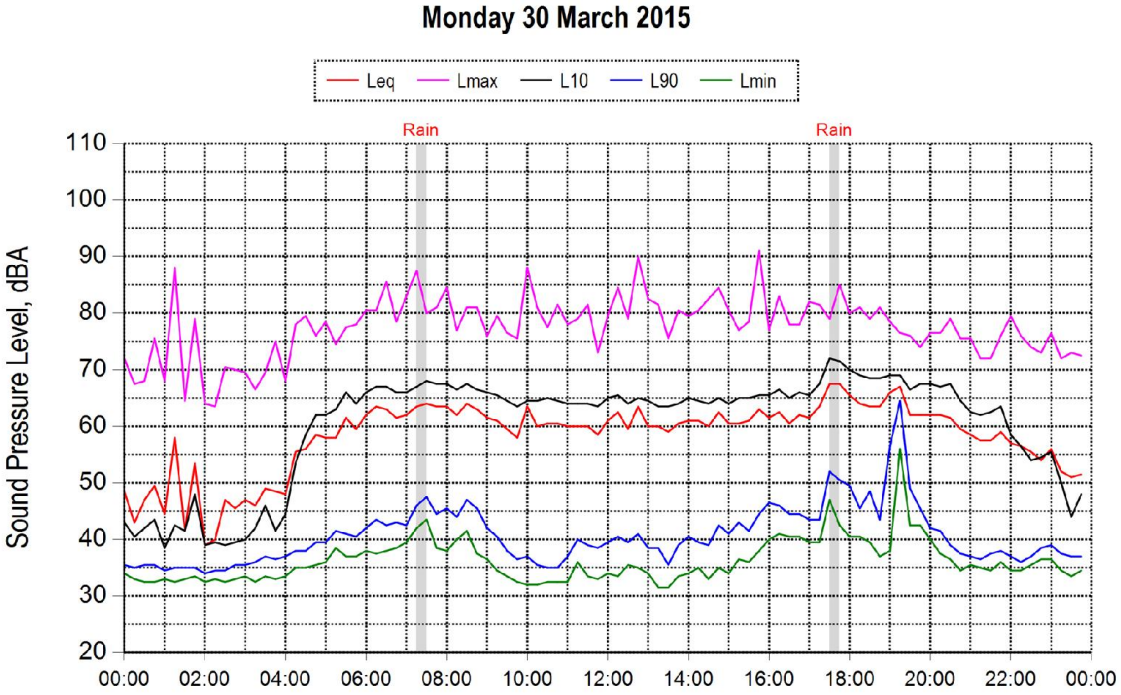

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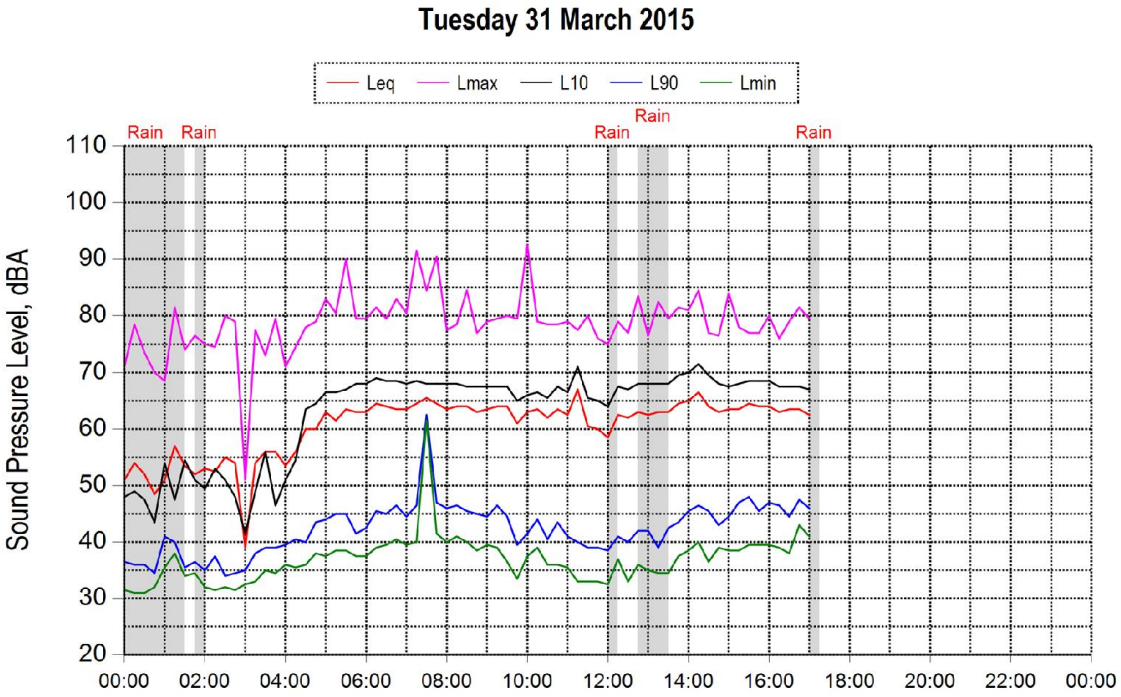

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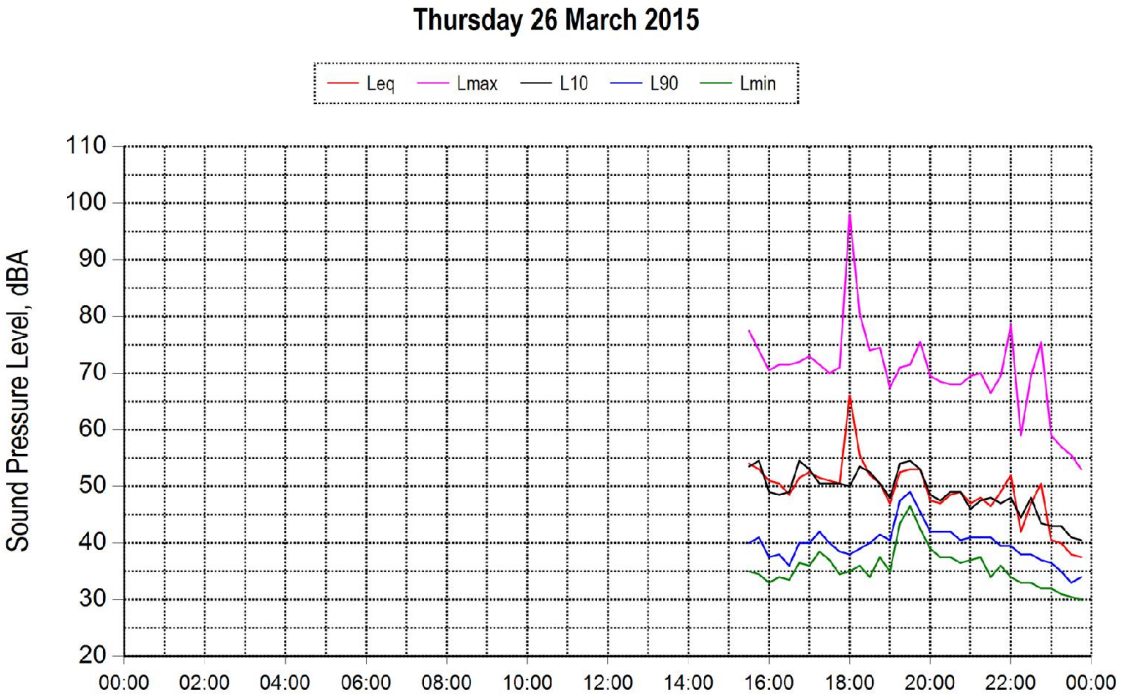

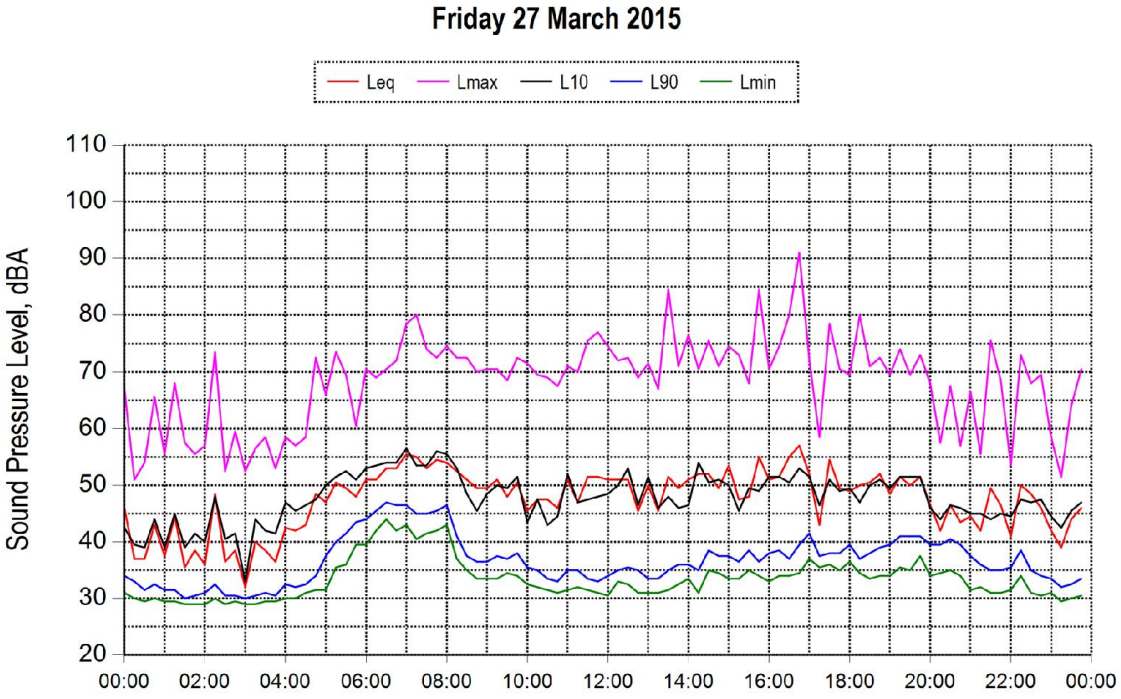

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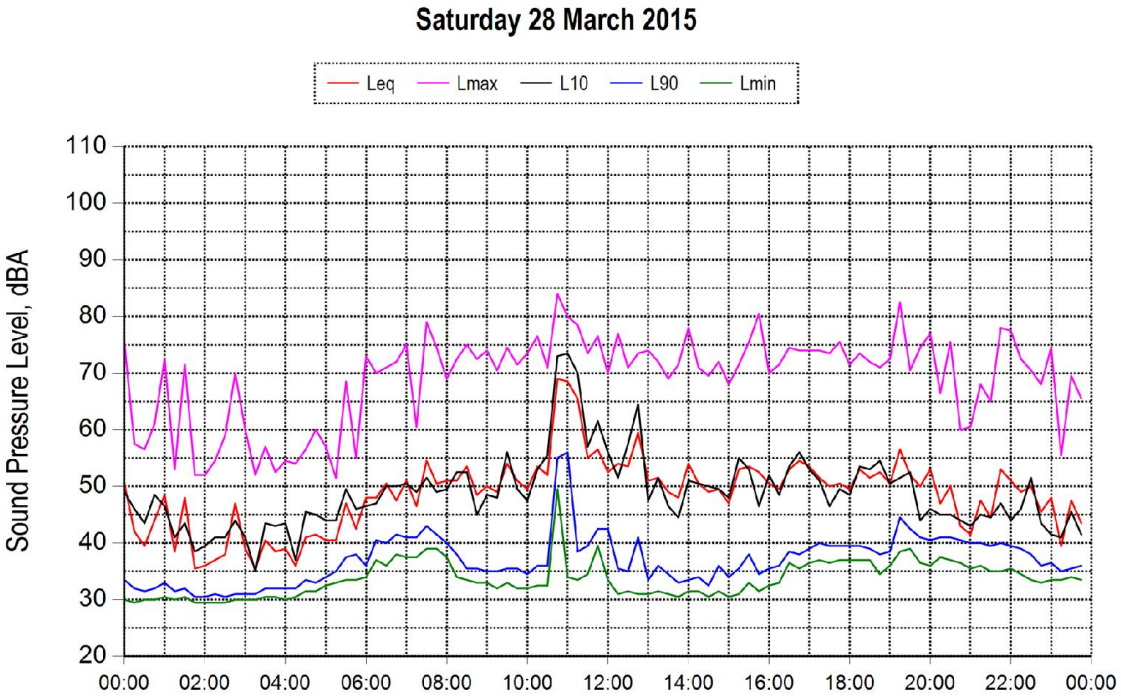

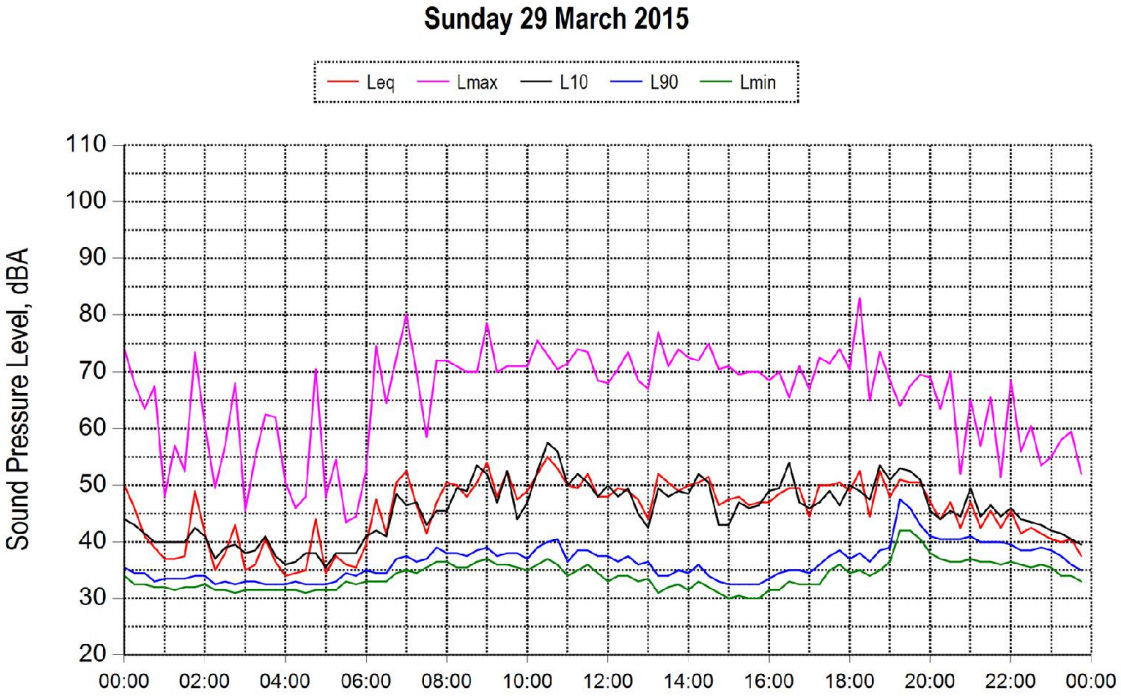

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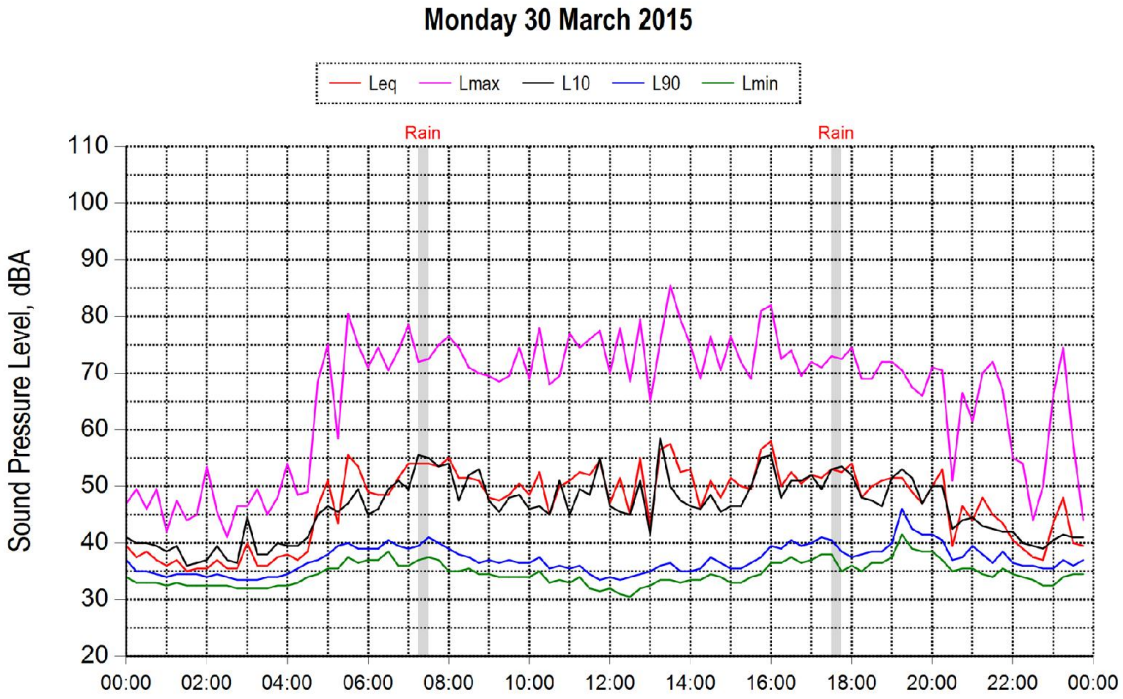

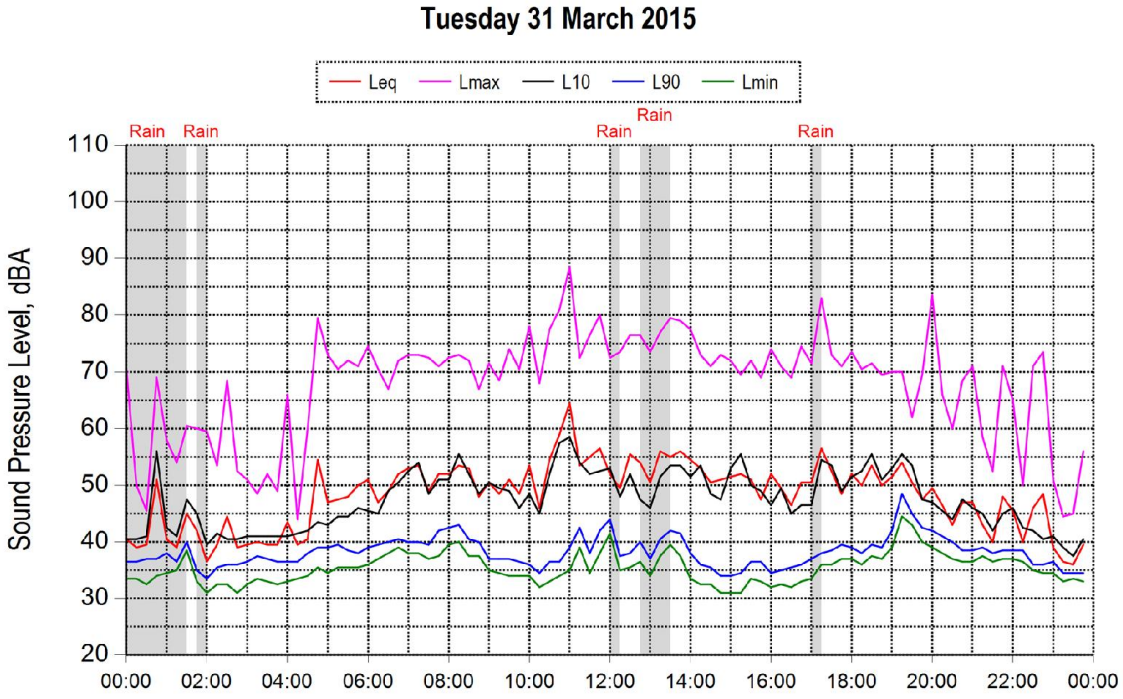

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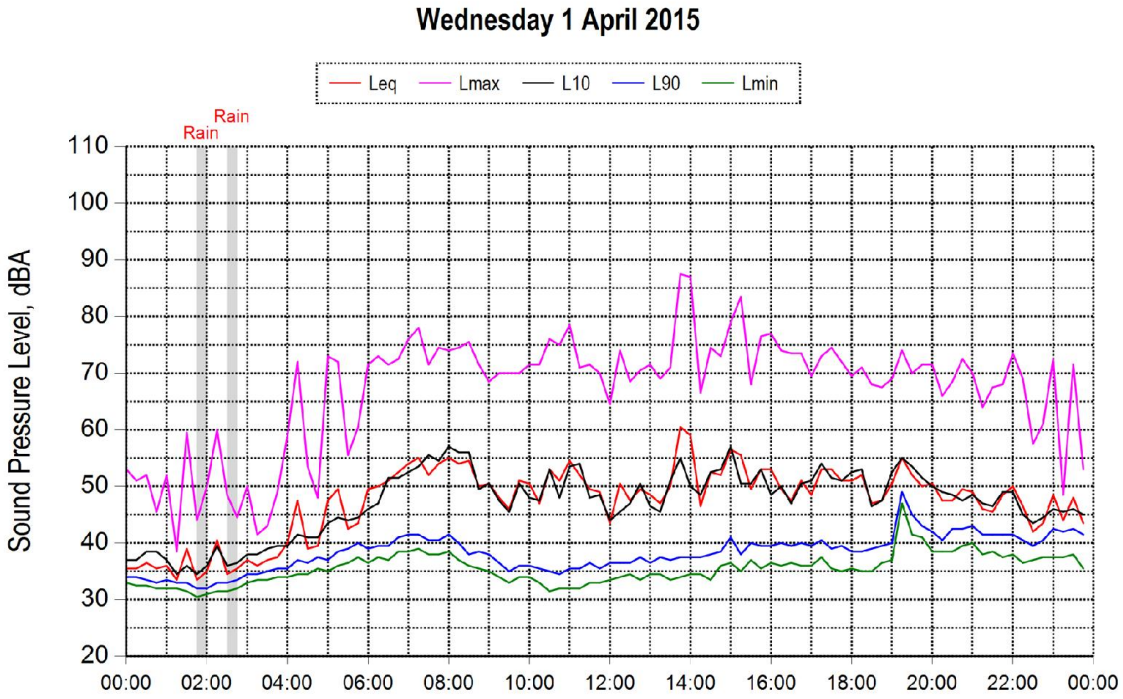

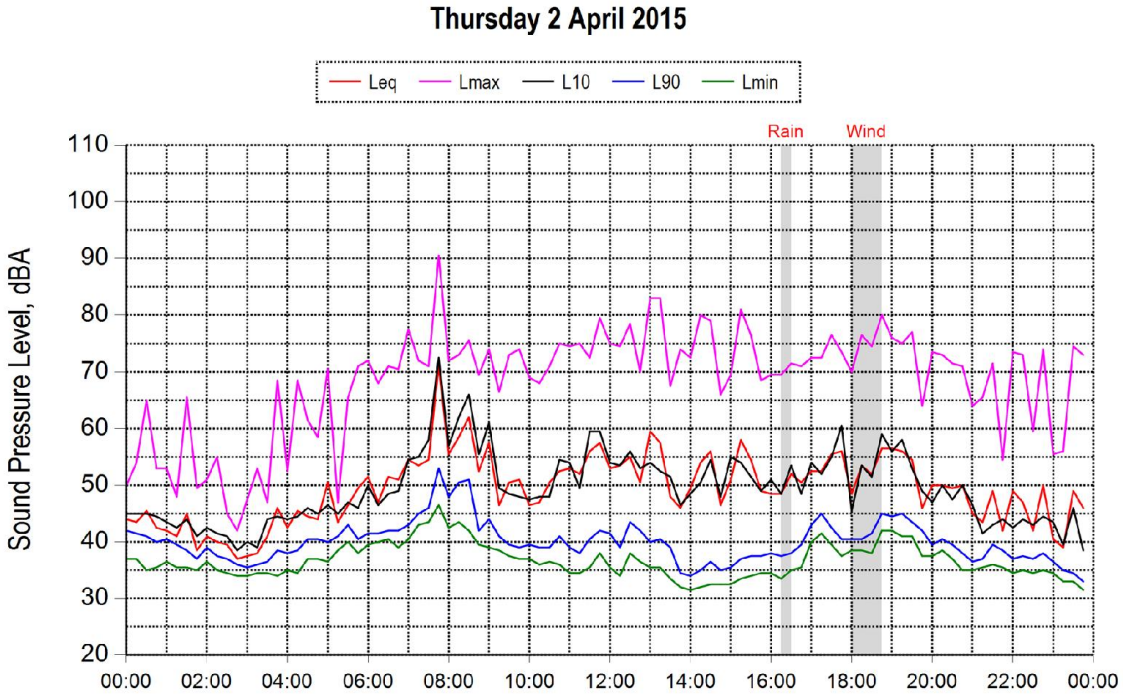

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WESTERN SYDNEY AIRPORT



DRAFT ENVIRONMENTAL IMPACT STATEMENT

VOLUME 4
TECHNICAL REPORTS

Appendix F

VOLUME 4

Appendix F1
Local air quality and greenhouse gas



Pacific Environment Limited

Consulting • Technologies • Monitoring • Toxicology



Report

WESTERN SYDNEY AIRPORT EIS – LOCAL AIR QUALITY AND GREENHOUSE GAS ASSESSMENT

DEPARTMENT OF INFRASTRUCTURE AND REGIONAL DEVELOPMENT

Job ID. 9417B

14 October 2015

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EXECUTIVE SUMMARY

Pacific Environment has been engaged by GHD to prepare an Air Quality and Greenhouse Gas Assessment for the proposed Western Sydney Airport ('the airport') as part of an Environmental Impact Statement (EIS) required under the *Environment Protection and Biodiversity Conservation Act 1999*. This report has quantified the potential local air quality impacts and greenhouse gas emissions that may arise due to the operation of Stage 1 airport development and longer term airport development as well as the Stage 1 construction phase.

For the purposes of this assessment the local air quality study is defined as being within a 5 km radius of the airport site. The regional air quality impacts are addressed separately in *Western Sydney Airport EIS – Regional Air Quality Assessment* **(Environ, 2015)**.

This assessment has followed the procedures outlined in the NSW Environment Protection Authority (EPA) document titled *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW* (**NSW EPA, 2005**).

DESCRIPTION OF OPERATIONS

The airport would service both domestic and international air traffic, with development staged in response to passenger demand. The initial development of the airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million domestic and international passengers per year.

In the longer term, approximately 40 years after the airport has been constructed and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and rail transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a curfew-free basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could also be permitted on the site.

OPERATIONS ASSESSMENT METHODOLOGY

The contribution of airport operations to local air pollution was calculated using the United States (US) Federal Aviation Administration (FAA) Emissions and Dispersion Modelling System (EDMS) (Version 5.1.4, June 2013). EDMS performs dispersion analyses using the USEPA's AERMOD **(USEPA, 2004a)** dispersion model. AERMOD has been accepted in Australia for use in a variety of regulatory applications, including several other recent airport assessments such as those for Sydney (Kingsford Smith) Airport (KSA) and Adelaide Airport.

The air quality metrics currently included in EDMS for dispersion analysis are carbon monoxide (CO), total hydrocarbons (THC), non-methane hydrocarbons (NMHC), volatile organic compounds (VOC), total organic gases (TOG), oxides of nitrogen (NO_X), oxides of sulfur (SO_X) and (primary) particulate matter less than 10 micrometres and 2.5 micrometres in aerodynamic diameter (PM_{10} and $PM_{2.5}$ respectively).

Two scenarios were investigated:

- Stage 1 development; and
- Longer term development.

STAGE 1 OPERATIONAL IMPACTS

For the Stage 1 development, the following pollutants were assessed: NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2, air toxics, odour from exhaust emissions and from the waste water treatment plant.

There were no predicted exceedances of the NSW EPA criteria or NEPM goals at the residential receptors investigated in this air quality assessment for Stage 1 operations.

With the exception of roadways external to the airport site, aircraft movements were the largest source of PM_{10}, $PM_{2.5}$, NO_X and SO_2 within the study area. The operation of Auxiliary Power Units (APUs) and ground support equipment (GSE) also had an influence on the predicted pollutant concentrations. Aircraft and stationary sources, in particular evaporative loss from the jet fuel tanks, were shown to be a significant contributor to VOCs emissions and corresponding predicted ground level concentrations.

The highest off-site concentrations of the pollutants evaluated were generally predicted to occur at the receptors located to the north and northeast of the airport. This is anticipated to be a function of the location of the runway, prevalence of south-westerly winds and the proximity of these receptors to airport activities.

The external road infrastructure was shown to be a significant contributor to predicted off-site ground level concentrations, particularly for those receptors located in close proximity to existing or proposed new roadways.

There were almost no predicted exceedances of the NSW EPA criteria or NEPM goals at the residential or on-site receptors investigated in this air quality assessment for the proposed Stage 1 operations. The exception is the 99.9th percentile 1-hour maximum for formaldehyde with an exceedance shown at the on-site receptor R24 when assessed against the NSW EPA assessment criterion.

Predicted off-site odour concentrations were below odour detection limits for both aircraft exhaust emissions and odours from the waste water treatment plant.

LONGER TERM OPERATIONAL IMPACTS

A key assumption integral to the assessment of the longer term development is that no improvement in aircraft emissions, either due to improvements in fuel or engine emissions was able to be incorporated into the modelling. This is based on the inability to predict the effect of future policies or technological developments which are expected to occur and which are likely to result in improvements in levels of combustion emissions and pollutants. This assumption embeds a high degree of conservatism into the assessment process of this longer term scenario.

Given the uncertainty about emissions from a future aircraft fleet, combined with an expected improvement in aircraft emissions over time, the longer term development was evaluated only for the air quality metrics, namely: NO_2, PM_{10}, and $PM_{2.5}$.

The results indicate that exceedances of the 1-hour average NO_2 criterion of 246 µg/m^3 may be experienced at 11 residential receptors. These exceedances are predicted to occur for between one and four hours per year.

With the exception of roadways external to the airport site, aircraft movements were again predicted to be by far the largest source of PM_{10}, $PM_{2.5}$, NO_X and SO_2 within the study area, with operation of APUs and GSE also having an influence on predicted off-site impacts. Aircraft and stationary sources, in particular evaporative loss from the jet fuel tanks, were shown to be a significant contributor to VOCs emissions and corresponding predicted ground level concentrations.

The results of the dispersion modelling indicate that, under the conservative emission assumptions adopted, exceedances of the 1-hour average NO_2 AEPR ambient objective of 320 µg/m^3 may be experienced at seven residential receptors. These exceedances are predicted to occur for between one and two hours per year.

Predicted (cumulative) 24-hour PM_{10} concentrations are anticipated to be above the NSW EPA impact assessment criterion of 50 µg/m^3 on occasion at one on-site receptor (R24). Receptor R24 is located within the airport site to evaluate impacts on airport staff and passengers.

Predicted (cumulative) $PM_{2.5}$ concentrations are anticipated to be above the NEPM advisory reporting goals of 25 µg/m^3 and 8 µg/m^3, for the 24-hour and annual averaging periods respectively, at a number of receptors. The annual goal is predicted to be exceeded at four residential receptors. This is also not unexpected given that the existing background concentrations of this parameter already contribute to around 90% of the goal.

CONSTRUCTION IMPACTS

Due to the transient, variable nature of construction activities, it is difficult to accurately quantify air quality impacts from construction activities. Any effects of construction on airborne particle concentrations would generally be temporary and relatively short-lived. Moreover, mitigation should be straightforward, as most of the necessary mitigation measures are routinely employed on other construction sites. However, in view of the length of the construction period, a quantitative assessment of impacts was completed for the following:

- bulk earthworks (particulate matter (PM) impacts only);
- construction infrastructure;
- working crew (PM impacts);
- concrete batching plant (PM impacts); and
- asphalt plant (odour impacts).

A risk based approach was used to identify key construction air quality risks and to recommend appropriate mitigation measures based on the methodology described by the Institute of Air Quality Management (IAQM) **(IAQM, I2014)**. Most of the recommended measures are routinely employed as 'good practice' on other construction sites. At the airport site, particular attention should be paid to controlling PM generated by vehicles traveling on unsealed surfaces and transporting materials onto the road network (track-out) due to the overall level of risk and the potential close proximity of potential track-out PM emissions to sensitive receptors.

AIR QUALITY MANAGEMENT AND MITIGATION

The largest contributor of on-site emissions is anticipated to be associated with aircraft taking off and landing, for both the proposed Stage 1 and longer term development scenarios. However, the regulation of aircraft engine emissions is beyond the remit of Western Sydney Airport developer or operator. Moreover, potential exceedances of air quality criteria (notably the 1-hour NO_2 and 24-hour / annual $PM_{2.5}$) are predicted to occur due to activities associated with ground power units. Mitigation of such activities may include the connection of APUs to the mains power where practicable rather than the current conservative assumption that they are operated by dedicated internal combustion engines.

Community concern over potential health impacts of airport emissions can be addressed through the conduct of ambient air quality monitoring within or in the vicinity of the airport. Such monitoring will provide scientifically robust data to demonstrate that any changes in local air quality associated with the WSA development are within regulatory guidelines.

The dispersion modelling identified that NO_x emissions contributed 91% of the emissions from the airport and therefore mitigation and management measures focus on reducing NO_x emissions. International

literature was assessed for mitigation and management measures detailing relevant methods of reducing NO_x emissions during operations at airports. A number of mitigation measures have been adopted by other airports internationally and are suggested for managing air quality impacts from the airport. It is acknowledged some of the measures are up to the individual airline and out of the control of the terminal operator. Nevertheless, these measures are useful as a guideline for potential NO_x reduction.

FUEL DUMPING

Currently, fuel dumping events are very rare and only occur during emergency situations where alternative methods of safely landing are not feasible. Any potential local effects of fuel dumping at the airport site will be limited due to the inability of many aircraft to perform fuel dumps, the quick vaporisation and dispersion of aircraft (jet) fuel, the strict guidelines on fuel dumping altitudes and locations, and the anticipated reduction in fuel dumping events and volumes in the future. For these reasons, fuel dumping is not considered likely to have a significant impact on local air quality.

GREENHOUSE GASES

An assessment was conducted which estimates the GHG emissions from the construction, Stage 1 and longer term development phases of the proposed airport.

Direct (scope 1) and indirect (scope 2) GHG emissions from the Stage 1 development of the airport have been estimated to comprise 0.13 Mt CO_2-e/annum, with the majority of emissions associated with purchased electricity. The Stage 1 development Scope 1 & 2 GHG emission estimates represent approximately 0.11% of Australia's projected 2030 transport-related GHG emission inventory. For this reason, it can be concluded the GHG emissions from the airport will not be material in terms of the national inventory, however a number of mitigation measures have been suggested to reduce these emissions.

CONTENTS

1 INTRODUCTION 11
1.1 Background 11
1.2 Scope of work 12
1.3 Overview of airport construction and operations 12
1.4 Structure of this report 13
2 RELEVANT LEGISLATION AND STANDARDS 14
2.1 Background 14
2.2 Gaseous Pollutants and Particulate Matter Performance Criteria 14
2.3 Odour Performance Criteria 19
2.4 Fuel Standards relevant to Airports 19
2.5 Greenhouse Gases 20
2.5.1 International Framework 20
2.5.2 Australian Context 22
3 APPROACH AND METHODOLOGY 24
3.1 Operations 24
3.1.1 Overview 24
3.1.2 Modelling overview 24
3.2 Sensitive receptors 29
3.3 Cumulative impacts 31
3.4 Model post-processing 31
3.4.1 Modelling of NO_X chemistry 31
3.4.2 SO_2 estimation 32
3.4.3 VOC speciation 32
3.5 Odour 32
3.5.1 Odour from aircraft exhaust 32
3.5.2 Odour from on-site waste water treatment plant 33
3.6 Construction 34
3.6.1 Overview 34
3.6.2 Construction dust 35
3.6.3 Concrete batching plant 36
3.6.4 Asphalt batching plant 36
3.6.1 Diesel particulate matter emissions 37
3.7 Greenhouse gases 37
3.7.1 Assessment approach 37
4 EXISTING ENVIRONMENT 41
4.1 Meteorology 41
4.1.1 Wind speed and wind direction 41
4.1.2 Temperature, rainfall and humidity 46
4.1.3 Vertical profile 48
4.2 Ambient air quality 49
4.2.1 Nitrogen dioxide 50
4.2.2 Ozone 52
4.2.3 Particulate matter 53
4.2.4 Carbon monoxide 58
4.2.5 Sulphur dioxide 59
4.2.6 Air toxics 62
4.2.1 Odour 62
4.3 Adopted background concentrations 63
5 OPERATIONAL IMPACT ASSESSMENT 64
5.1 Emissions 64
5.1.1 Stage 1 development 64

5.1.1 Longer term development 68
5.2 Dispersion modelling results 70
5.2.1 Overview 70
5.2.2 Stage 1 development 70
5.2.1 Longer term development 82
5.3 Summary of dispersion model results 85
5.4 Mitigation and management measures 86
5.4.1 Measures for the Stage 1 development 86
5.4.2 Measures for the longer term development 87
6 FUEL DUMPING 90
7 CONSTRUCTION IMPACT ASSESSMENT 92
7.1 Dispersion modelling results 92
7.1.1 Overview 92
7.1.2 Bulk earthworks 92
7.1.3 Aviation infrastructure 93
7.1.4 Asphalt plant 95
7.2 Mitigation and management 96
7.3 Significance of risks 99
8 GREENHOUSE GAS ASSESSMENT 101
8.1 Introduction 101
8.2 Assessment Results 101
8.2.1 Operations 101
8.2.2 Construction Emission Estimates 104
8.2.3 Context 104
8.3 Greenhouse Gas and Energy Reduction Measures 105
9 SUMMARY AND CONCLUSIONS 107
9.1 Stage 1 Operational Impacts 107
9.2 Longer Term Operational impacts 107
9.3 Air quality mitigation and management 108
9.4 Construction impacts 108
9.5 Fuel dumping 109
9.6 Greenhouse gases 109
10 REFERENCES 110
APPENDIX A TERMS AND ABBREVIATIONS A-1
APPENDIX B CRITERIA AIR POLLUTANTS: HEALTH EFFECTS AND SOURCES B-1
APPENDIX C CHARACTERISATION OF EMISSION SOURCES IN EDMS C-1
APPENDIX D DISPERSION MODEL INPUTS D-1
APPENDIX E SENSITIVE RECEPTORS E-1
APPENDIX F TABULATED RESULTS AND CONTOUR PLOTS DURING OPERATIONS F-1
APPENDIX G TABULATED RESULTS AND CONTOUR PLOTS DURING CONSTRUCTION G-1
APPENDIX H IMPACTS FROM DIESEL EMISSIONS H-1

List of Figures

Figure 3-1: Location of sensitive receptors 30

Figure 3.2: Overview of Scopes and Emissions across a Reporting Entity 39

Figure 4-1 Monthly average wind speed at Badgerys Creek (2010-2014) 42

Figure 4-2: Annual and seasonal wind roses for Badgerys Creek (2010) 43

Figure 4-3: Annual and seasonal wind roses for Badgerys Creek (2011) 43

Figure 4-4: Annual and seasonal wind roses for Badgerys Creek (2012) 44

Figure 4-5: Annual and seasonal wind roses for Badgerys Creek (2013) 44

Figure 4-6: Annual and seasonal wind roses for Badgerys Creek (2014) 45

Figure 4-7 Annual and monthly average rainfall, temperature and relative humidity at Badgerys Creek (2010-2014) 47

Figure 4-8: Vertical profile of wind speed at Sydney (Kingsford Smith) Airport 2010 – 2014 48

Figure 4-9: Air quality monitoring stations in proximity to the study area 50

Figure 4-10: Monthly mean NO_2 concentrations at Bringelly 51

Figure 4-11: Polar plot of normalised NO_2 concentration at Bringelly 52

Figure 4-12: Monthly mean O_3 concentrations at Bringelly 53

Figure 4-13: Monthly mean PM_{10} concentrations at Bringelly 54

Figure 4-14: Polar plot of normalised PM_{10} concentration at Bringelly 55

Figure 4-15: Monthly mean $PM_{2.5}$ concentrations at Liverpool 56

Figure 4-16: Monthly mean $PM_{2.5}$ concentrations at Richmond 57

Figure 4-17: Monthly mean CO concentrations at Macarthur 59

Figure 4-18: Monthly mean SO_2 concentrations at Bringelly 61

Figure 4-19: Polar plot of normalised SO_2 concentration at Bringelly 61

Figure 5-1: Total estimated emissions for criteria pollutants during Stage 1 development 64

Figure 5-2: Estimated airport and external roads emissions as a percentage of total modelled for criteria pollutants during Stage 1 development 65

Figure 5-3: Estimated aircraft emissions by operational mode for Stage 1 development 67

Figure 5-4: Total estimated emissions for criteria pollutants for longer term development 68

Figure 5-5: Estimated airport and external roads emissions as a percentage of total modelled for criteria pollutants during longer term development 69

Figure 5-6: Contributions to PM_{10} concentrations at R30 73

Figure 5-7: Contributions to $PM_{2.5}$ concentrations at R4 75

Figure 8.1: Percentage Estimated Scope 1 & 2 GHG Emissions from Stage 1 development 102

Figure 8.2: Percentage Estimated Scope 1 & 2 GHG Emissions from longer term development 103

1 INTRODUCTION

Pacific Environment has been engaged by GHD to prepare a local air quality and greenhouse gas assessment for the proposed Western Sydney Airport ('the airport') as part of an Environmental Impact Statement (EIS), required under *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). This report has quantified the potential local air quality impacts and greenhouse gas emissions that may arise due to the operation of the proposed Stage 1 airport development and longer term development as well as the Stage 1 construction phase.

This assessment has followed the procedures outlined in the NSW Environment Protection Authority (EPA) document titled *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW* (**NSW EPA, 2005**) (Approved Methods).

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (**Department of Infrastructure and Transport, 2012**) and *A Study of Wilton and RAAF Base Richmond* for civil aviation operations (**Department of Infrastructure and Transport, 2013**) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS.

The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Scope of work

The EIS Guidelines (Department of the Environment 2014) require the following to be addressed as part of the air quality assessment (Section 5g):

- changes to air quality during construction and operation (including consideration of seasonal and meteorological variations that influence local air quality)

This report has been prepared in accordance with the EIS Guidelines.

The scope of work of the local air quality assessment for the airport therefore included the following activities.

- Summarising the legislation, standards and goals that are relevant to air quality at the proposed airport.
- Characterising existing local air quality and meteorology in the vicinity of the airport site.
- Identifying the types and locations of sensitive receptors that are representative of residences and communities in the local area.
- Developing an airport model for estimating the operational emissions and associated ambient concentrations of regulated air pollutants.
- Assessing the operational impacts of the airport on emissions and air quality using a computer dispersion model.
- Developing emission inventories and conducting dispersion modelling for two scenarios:
    - Stage 1 development; and
    - Longer term development.
- Assessing construction impacts on air quality using a computer dispersion model.
- Providing mitigation and management measures to address identified issues.

1.3 Overview of airport construction and operations

The site for the Western Sydney Airport covers an area of approximately 1,700 hectares located at Badgerys Creek in Western Sydney. The airport site is located within the Liverpool local government area, around 50 kilometres west of Sydney's Central Business District and 15 to 20 kilometres from major population centres such as Liverpool, Fairfield, Campbelltown and Penrith.

The Northern Road transects the western end of the airport site and Elizabeth Drive borders the site to the north. Badgerys Creek flows in a north-easterly direction and forms the south eastern boundary of the airport site. The airport site is located on undulating topography that has been extensively cleared with the exception of stands of remnant vegetation located predominantly along Badgerys Creek and the south western portion of the site.

The runways would be on an approximate 50/230 degree (magnetic) orientation, referred to as 05/23. The terminal complex including aircraft gates would be located approximately midway along the runway and in the middle of the site and ultimately between the two runways.

Aircraft maintenance and cargo areas would be located at the south-western end of the site. The sewage treatment plant and main access road would be at the north-eastern end of the site. The jet fuel storage area would be along the north-western site boundary. These and other details of the proposal including concept plans are provided in Volume 1, Section 5.1 of the main EIS volume.

The proposed airport is expected to be developed over a number of stages.

The construction of the Stage 1 development involves bulk earthworks for the airport site and the aviation infrastructure for the development. In summary, the works would involve:

- bulk earthworks;
- aviation infrastructure and support facilities, including the use of on-site asphalt and concrete batching plants;
- network infrastructure including utilities; and
- ground transport infrastructure.

A detailed description of quantities of materials, proposed hours of operation, equipment types and numbers is provided in the Construction Planning Report **(GHD, 2015a)** which was used as the basis for the modelling completed for this aspect of the proposed development.

Given the uncertainty of the timing of the longer term development, the construction impacts for this aspect have not been quantitatively assessed. Construction impacts for the Stage 1 development are therefore the focus of this assessment.

1.4 Structure of this report

The remainder of this report is structured as follows.

- Chapter 2 – outlines the relevant legislation and guidelines for the assessment as well as the modelling methodology and key modelling assumptions used
- Chapter 3 – describes the methodology used to assess the operational, construction and greenhouse gas (GHG) impacts.
- Chapter 4 – summarises the existing environmental conditions in and around the airport site at Badgerys Creek
- Chapter 5 – presents the key stages and results of the airport operational assessment
- Chapter 6 – presents a qualitative assessment of fuel dumping on the local area
- Chapter 7 – presents the key stages and results of the construction assessment
- Chapter 8 – presents the key stages and results of the GHG assessment
- Chapter 9 – summary and conclusions.

2 RELEVANT LEGISLATION AND STANDARDS

2.1 Background

The proposed airport has the potential to generate emissions in the form of nitrogen dioxide (NO_2), particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO), sulphur dioxide (SO_2), air toxics, odour and greenhouse gases (GHGs). These emissions have the ability to impact human health, amenity and contribute to climate change.

In an effort to reduce emissions, Australia's air navigation service provider, Airservices Australia, has implemented a range of measures to improve fuel efficiency such as flexible flight tracks, improved air traffic control sequencing, continuous descent approaches and better management of aircraft on the ground **(DIRD, 2014a)**.

Airservices Australia is also working with the Asia and Pacific Initiative to Reduce Emissions (ASPIRE), that includes air navigation service providers from the United States, New Zealand, Japan, Singapore and Thailand. One of the key goals of ASPIRE is to reduce aviation's environmental footprint. During 2014, Airservices focussed on improving the Oceanic and en-route phase of flight with network and surface movement optimisation, reduced airborne holding and runway efficiency **(ASPIRE, 2014)**.

The introduction of newer, more fuel efficient aircraft into their fleets such as the A380, A320neo, B787 and B737-800 aircraft is also being undertaken by airlines in Australia. For example, the phasing out of the B737 in favour of the B737-800 is now common to many domestic routes. The B737-800 is approximately 20% more fuel efficient than the earlier B737 models. Other actions by airlines include the refinement of operational procedures to minimise fuel use, including the reduction in weight of cabin items and the reduction of engine ground running time **(DIRD, 2014a)**.

There are also a number of also measures being undertaken by Australian airports that primarily focus on reducing GHG emissions and include green star rated commercial developments on airports, energy and water audits, recycling and the creation of biodiversity zones **(DIRD, 2014a)**.

2.2 Gaseous Pollutants and Particulate Matter Performance Criteria

Legislation, guidelines and standards governing air pollutant emissions and ambient air quality have been introduced at the Commonwealth and State levels in Australia. The legislation that is relevant to the airport is summarised in **Table 2-1**.

Air quality must be assessed in relation to criteria for the specific pollutants that are set out in the legislation summarised in **Table 2-1**. Regulated air pollutants are divided into 'criteria' pollutants and 'air toxics'. Criteria pollutants tend to be ubiquitous and emitted in relatively large quantities, and their health effects have been studied in some detail. Air toxics are gaseous or particulate organic pollutants that are present in the air in low concentrations with characteristics. The health effects and main sources of pollutants investigated in this assessment are summarised in **Appendix B**.

The *Airports (Environment Protection) Regulations 1997* (Cth) (AEPR) provide assessment criteria for some pollutants, but the guidelines for assessing air quality impacts are contained in the Approved Methods which takes pollutant criteria and averaging periods from several sources, notably the Commonwealth *National Environment Protection (Ambient Air Quality) Measure* (NEPM-AAQ).

The assessment criteria from the AEPR and Approved Methods are listed in **Table 2-2**. The AEPR includes ambient objectives for NO_2, CO, SO_2, lead, ozone (O_3), total suspended particulates (TSP) and sulphates. One criteria pollutant from the Approved Methods, hydrogen fluoride (HF), has been excluded from this Table as HF relates to sensitive vegetation rather than human health, and HF is not a pollutant that is relevant to airport operations. Three other pollutants/metrics in the AEPR and the Approved Methods have not been assessed here: O_3, TSP and lead. Ozone, because of its secondary and regional nature, cannot practicably be considered in a local air quality assessment. Ozone has

been addressed in a separate EIS technical study pertaining to regional air quality **(Environ, 2015)**. Sulphates have also not been assessed as impacts are associated with regional air quality rather than local air quality. For the types of particulate matter (PM) sources at an airport (mainly combustion-related), it can be assumed that TSP is equivalent to PM_{10}, and therefore the standard for PM_{10} is the controlling one. Following its removal as a petrol additive, lead is no longer considered to be an air quality problem except in relation to specific industrial activities such as smelting.

The NEPM-AAQ was extended in 2003 to include advisory reporting standards for PM with an aerodynamic diameter of less than 2.5 µm ($PM_{2.5}$). This is designed for the evaluation of overall population exposure rather than the impacts of a specific facility, and there is no requirement to evaluate $PM_{2.5}$ in the Approved Methods.

On 29 April 2014, National Environment Protection Council (NEPC) proposed to vary the NEPM-AAQ for particles reflecting the latest scientific understanding on health risks arising from particle pollution. The proposed variation seeks to establish a more stringent reporting standard for particle pollution ($PM_{2.5}$ and PM_{10}). As the more stringent standard has not yet been incorporated in the NEPM-AAQ, $PM_{2.5}$ has been assessed in this report against the existing advisory reporting standard.

A number of further steps towards improving the regulation of air pollution in Australia have recently been taken. In particular, the National Environment Protection Council published a review of the NEPM-AAQ which recommended updating the standards for PM_{10}, $PM_{2.5}$, NO_2, O_3, and SO_2 (**NEPC, 2011a**), and a methodology for the setting of air quality standards (**NEPC, 2011b**). The Council of Australian Governments identified air quality as an issue of national priority (**COAG, 2012**), and agreed to implement a strategic approach to air quality management in the form of a National Plan for Clean Air (NPCA). The Australian Environment Ministers subsequently agreed to develop a National Clean Air Agreement that will focus on actions to reduce air pollution and improve air quality through cooperative action between industry and government. The Agreement will build on previous initiatives to tackle air pollution in Australia. A meeting of the Australian Environment Ministers was held in Melbourne on 15 July 2015, with one of the topics of discussion being a variation of the NEPM-AAQ.

In 2014 NEPC released an Impact Statement and draft variation to the NEPM-AAQ in relation to the standards for airborne particles. The Impact Statement evaluated the environmental, social and economic costs and benefits of meeting a range of different standards for airborne particles.

NSW EPA, which has managed the NEPM variation, has subsequently requested NSW Cabinet approval for the following changes to the PM standards:

- The introduction of an annual mean PM_{10} standard of 25 µg/m^3. There is currently no annual mean standard in the NEPM. However, for the assessment of projects and developments in NSW this could replace the current criterion in the Approved Methods of 30 µg/m^3
- The conversion of the advisory reporting standards for $PM_{2.5}$ to formal standards
- The introduction of the following long-term (10 year) targets:
    - An annual average PM_{10} target of 20µg/m^3
    - An annual average $PM_{2.5}$ target of 7µg/m^3
    - A 24 hour $PM_{2.5}$ target of 20µg/m^3.

Following the meeting of the Australian Environment Ministers, a statement was issued in which the Ministers signalled their support for varying the NEPM-AAQ to implement these strengthened reporting standards for PM. Ministers agreed in-principle to formalise the $PM_{2.5}$ standards of 8 µg/m^3 (annual) and 25 µg/m^3 (24-hour), with a move to 7 µg/m^3 and 20 µg/m^3 respectively over the longer term. The Ministers also agreed to finalise their consideration of the annual and 24-hour standards for PM_{10} by the end of 2015.

It should be noted that the NEPM is a national monitoring and reporting protocol. The NEPM standards are applicable to urban background monitoring sites which are broadly representative of population exposure. The use of any NEPM air quality criteria in relation to the assessment of projects and

developments is outside the scope of the NEPM itself, and is decided by the jurisdictions. The criteria for air quality assessments for projects/developments in NSW are contained in the Approved Methods. However, should the Approved Methods be revised it is possible that they will take into account the new NEPM standards, but they may not necessarily take exactly the same form."

In recognition of the potential health problems arising from the exposure to air toxics, Australia has set 'investigation levels' for five pollutants in ambient air. These investigation levels are given in **Table 2-3.**

Table 2-1: Emissions and air quality legislation

Legislating body	Legislation/measures	Summary
Ambient air quality		
Australian Government	*Airports Act (1996)*	Promotes the sound development of civil aviation in Australia. It contains an obligation on airport lessee companies to develop a master plan every 5 years including a detailed environmental strategy which is required to address amongst other things continuous improvement in the environmental consequences of activities at the airport; progressive reduction in extant pollution at the airport and development and adoption of a comprehensive environmental management system for the airport that maintains consistency with relevant Australian and international standards. The Act also contains a number of offences related to pollution at airports. An Airport Plan is required to authorise the construction and operation of Stage 1 of the proposed Western Sydney Airport, address the longer term operation of the proposed airport, and provide planning and land use controls for the proposed airport.
	Airports (Environment Protection) Regulations 1997	Imposes a general duty to prevent or minimise environmental pollution once an airport lease is granted. Promotes improved environmental management practices at airports. Includes provisions setting out definitions, acceptable limits and objectives for air quality, as well as monitoring and reporting requirements.
	Air Navigation (Aircraft Engine Emissions) Regulations /Chicago Convention Annex 16	The regulations make it an offence to fly certain aircraft if they do not meet relevant emissions standards including the standards set out in Annex 16 to the Chicago Convention
	National Environment Protection (Ambient Air Quality) Measure (NEPM-AAQ)	Sets the national health-based air quality standards for six air pollutants (CO, NO_2, SO_2, Pb, O_3, PM_{10} and includes advisory reporting standards for $PM_{2.5}$.
	*National Environment Protection (Air Toxics) Measure (*Air Toxics NEPM)	Sets a nationally consistent approach to monitoring (by reference to 'investigation levels') for five air toxics: benzene, formaldehyde, toluene, xylenes and benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons). These are not compliance standards but are for use in assessing the significance of the monitored levels of air toxics with respect to the protection of human health.
NSW Government	*Protection of the Environment Operations Act 1997 (*POEO Act), and the *Protection of the Environment Operations Amendment Regulation 2010*	The POEO Act provides a range of controls with regard to air quality including a requirement to maintain plant and equipment in a proper and efficient condition and to operate plant and equipment in a proper and efficient manner. This includes the means of processing, handling, moving, storage and disposal of materials.
Emissions of air quality criteria pollutants		
Australian Government	*National Environment Protection (National Pollutant Inventory) Measure*	The primary goals are to: (a) collect a broad base of information on emissions and transfers of substances and (b) disseminate information to all sectors of the community.
NSW Government	*Protection of the Environment Operations Act (2007* POEO Act *and Protection of the Environment Operations (Clean Air) Regulation (2010)*(Clean Air Regulation)	The object of the POEO Act is to achieve the protection, restoration and enhancement of the quality of the NSW environment having regard to the need to maintain ecologically sustainable development. The Clean Air Regulations prescribe standards for certain groups of plant and premises to regulate industry's air emissions and impose requirements on the control, storage and transport of volatile organic liquids.
	Approved Methods for the Modelling and Assessment of Air Pollutants in NSW	This policy document lists the statutory methods that are to be used to model and assess emissions of air pollutants from stationary sources in NSW. It is referred to in Part 5: Air impurities from emitted activities and plant of the Clean Air Regulation. It also prescribes the air pollutants and averaging periods that an airport's emissions are to be assessed against.
Emissions of greenhouse gases		
Australian Government	*National Greenhouse and Energy Reporting Act 2007*	The airport lessee company will be required to register and report its operational GHG emissions attributable to the activities over which it has operational control as it is expected that its emissions will exceed relevant thresholds. This may also apply to the construction contractor and other contractors or users of the airport (e.g. airlines).
Ozone-depleting substances		
Australian Government	*Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* and the *Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995*	This Act and Regulations impose controls on the manufacture, import, export and management of substances that deplete ozone in the atmosphere including CFCs 11, 12, 113, 114 and halons 1211, 1301 and 2402.
NSW Government	*Ozone Protection Act 1989*	This Act regulates or prohibits the manufacture, sale, distribution, conveyance, storage, possession and use of ozone-depleting substances in NSW.

Table 2-2: Air quality criteria applicable to the airport

Pollutant		Criterion[a]	Averaging period	Source[b]
Carbon monoxide (CO)		87 ppm or 100 mg/m³	15 minutes	NSW EPA
		25 ppm or 30 mg/m³	1 hour	NSW EPA
		9 ppm or 10 mg/m³	8 hours	NSW EPA, AEPR [b]
Nitrogen dioxide (NO_2)		16 pphm or 320 µg/m³	1 hour	AEPR
		12 pphm or 246 µg/m³	1 hour	NSW EPA
		3 pphm or 62 µg/m³	1 year	NSW EPA
Total suspended particulate matter (TSP)		90 µg/m³	1 year	NSW EPA, AEPR
Particulate matter<10 µm (PM_{10})		50 µg/m³	24 hours[c]	NSW EPA
		30 µg/m³	1 year	NSW EPA
Particulate matter <2.5 µm ($PM_{2.5}$)		25 µg/m³	24 hours	NEPM-AAQ advisory reporting standard
		8 µg/m³	1 year	
Deposited dust	Incremental	2 g/m²/month	Annual	NERDDC
	Cumulative	4 g/m²/month	Annual	
Lead (Pb)		1.5 ppm	3 months	AEPR
		0.5 µg/m³	1 year	NSW EPA
Photochemical oxidants (as ozone (O_3))		0.10 ppm or 210 µg/m³	1 hour	NSW EPA[d], AEPR
		0.08 ppm or 170 µg/m³	4 hours	NSW EPA[e], AEPR
Sulfur dioxide (SO_2)		25 pphm or 710 µg/m³	10 minutes	NSW EPA[f], AEPR
		20 pphm or 570 µg/m³	1 hour	NSW EPA, AEPR
		8 pphm or 228 µg/m³	1 day	NSW EPA
		2 pphm or 60 µg/m³	1 year	NSW EPA, AEPR
Benzene		0.009 ppm or 29 µg/m³	99.9th 1-hour max	NSW EPA
Toluene		0.09 ppm or 360 µg/m³	99.9th 1-hour max	NSW EPA
Xylene		0.004 ppm or 180 µg/m³	99.9th 1-hour max	NSW EPA
Formaldehyde		0.18 ppm or 20 µg/m³	99.9th 1-hour max	NSW EPA
Benzo[a]pyrene		0.4 µg/m³	99.9th 1-hour max	NSW EPA

(a) ppm = parts per million; pphm = parts per hundred million; µg/m³ = micrograms per cubic metre; mg/m³ = milligrams per cubic metre

(b) NSW EPA = NSW EPA 'Approved Methods'; AEPR = *Airports (Environment Protection) Regulations 1997*

(c) Up to 5 exceedances allowed per year in NEPM-AAQ

(d) Given as 214 µg/m³ in Approved Methods

(e) Given as 171 µg/m³ in Approved Methods

(f) Given as 712 µg/m³ in Approved Methods

Table 2-3: Advisory standard air toxic investigation levels applicable to the airport

Pollutant	Criterion[a]		Averaging period	Source
Benzene	0.003	ppm	1 year[d]	Air Toxics NEPM, investigation levels
PAHs[b] (as B[a]P)[c]	0.3	ng/m³	1 year[d]	
Formaldehyde	0.04	ppm	24 hours	
Toluene	1.0	ppm	24 hours	
	0.1	ppm	1 year[d]	
Xylenes	0.25	ppm	24 hours	
	0.20	ppm	1 year[d]	

(a) ng/m³ – nanograms per cubic metre

(b) PAH – polycyclic aromatic hydrocarbons

(c) B[a]P – benzo[a]pyrene, the most widely studied PAH and used as an indicator compound

(d) Arithmetic mean of concentrations of 24-hour monitoring results

2.3 Odour Performance Criteria

The Approved Methods also include ground-level concentration (glc) criteria for complex mixtures of odorous air pollutants, taking account of population density in a given area. **Table 2-4** lists the odour criteria to be exceeded not more than one per cent of the time, for different population densities.

The differences between odour criteria are based on considerations of risk of odour impact rather than differences in odour acceptability between urban and rural areas. For a given odour concentration, there will be a wide range of responses in the exposed population. In a densely populated area there will therefore be a greater risk that some individuals within the community will find the odour unacceptable than in a sparsely populated area.

The project location falls within the Sydney contiguous urban area, and thus an odour criterion of 2 OU is anticipated to apply.

Table 2-4: Odour Performance Criteria for the Assessment of Odour

Population of affected community	Criterion for complex mixtures of odorous air pollutants 99th percentile (OU)
≤ ~2	7
~10	6
~30	5
~125	4
~500	3
Urban (2000) and/or schools and hospitals	2

2.4 Fuel Standards relevant to Airports

The Fuel Quality Standards Act 2000 provides a legislative framework for setting national fuel quality and fuel quality information standards for Australia. It also regulates the quality of fuel supplied in Australia by requiring compliance with standards made under the Act. The Act aims to minimize the levels of pollutants and emissions arising from the use of fuel that may cause environmental and health problems, facilitate the adoption of better engine technology and emission control technology and allow the more effective operation of engines. Fuel that does not meet the requirements of the standards must obtain approval to vary the standard by the Minister. The Minister will consider the protection of the environment, the protection of occupational and public health and safety, the interests of consumers and the impact on economic and regional development when deciding whether or not to grant approval to vary a fuel standard.

Under the National Fuel Quality Standards Act 2000, the Australian Government announced a phase-out of leaded petrol in Australia. On 1 January 2002, that phase-out was completed. The sale of leaded petrol in Australia is now prohibited, except in cases specifically authorised by the Minister.

One exception to this relevant to airport operations is the allowance for lead within Aviation Gasoline, or Avgas. Avgas is used in small piston engine powered aircraft within the General Aviation community. Predominately activities such as private pilots, flight training, flying clubs and crop spraying. Piston engines operate using the same basic principles as spark ignition engines of cars, but they have a much higher performance requirement.

There are two main Avgas grades available in Australia - 100 and 100LL low lead. The former is permitted to contain lead up to 1.12 g/litre of fuel and the latter 0.56 g/litre. This is compared with 0.005 g/litre for all conventional grades of petrol.

Notwithstanding the above, the proportion of small piston aircraft servicing the WSA is anticipated to be low (less than 5% of total aircraft). The resultant lead emission inventory associated with Avgas use at

the airport is not considered significant and this air quality metric has not been considered further within the assessment.

2.5 Greenhouse Gases

2.5.1 International Framework

2.5.1.1 Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) is a panel established in 1988 by the World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) to provide independent scientific advice on climate change. The panel was originally asked to prepare a report, based on available scientific information, on all aspects relevant to climate change and its impacts and to formulate realistic response strategies. This first assessment report of the IPCC served as the basis for negotiating the United Nations Framework Convention on Climate Change (UNFCCC).

The IPCC also produce a variety of guidance documents and recommended methodologies for GHG emissions inventories, including:

- 2006 IPCC Guidelines for National GHG Inventories; and
- Good Practice Guidance and Uncertainty Management in National GHG Inventories (2000).

Since the UNFCCC entered into force in 1994, the IPCC remains the pivotal source for scientific and technical information relevant to GHG emissions and climate change science.

The IPCC operates under the following mandate: *"to provide the decision-makers and others interested in climate change with an objective source of information about climate change. The IPCC does not conduct any research nor does it monitor climate-related data or parameters. Its role is to assess on a comprehensive, objective, open and transparent basis the latest scientific, technical and socio-economic literature produced worldwide, relevant to the understanding of the risk of human-induced climate change, its observed and projected impacts and options for adaptation and mitigation. IPCC reports should be neutral with respect to policy, although they need to deal objectively with policy relevant scientific, technical and socio economic factors. They should be of high scientific and technical standards, and aim to reflect a range of views, expertise and wide geographical coverage"* (**CCC, 2011**).

The stated aims of the IPCC are to assess scientific information relevant to:

- human-induced climate change;
- the impacts of human-induced climate change; and
- options for adaptation and mitigation.

IPCC reports are widely cited within international literature, and are generally regarded as authoritative.

2.5.1.2 United Nations Framework Convention on Climate Change

The UNFCCC sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognises that the climate system is a shared resource, the stability of which can be affected by industrial and other emissions of CO_2 and other GHGs. The convention has near-universal membership, with 172 countries (parties) having ratified the treaty, the Kyoto Protocol.

Under the UNFCCC, governments:

- gather and share information on GHG emissions, national policies and best practices;
- launch national strategies for addressing GHG emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries; and
- cooperate in preparing for adaptation to the impacts of climate change.

2.5.1.3 Kyoto Protocol

The Kyoto Protocol entered into force on 16 February 2005. The Kyoto Protocol built upon the UNFCCC by committing to individual, legally binding targets to limit or reduce GHG emissions. Annex I Parties are countries that were members of the Organisation for Economic Co-operation and Development (OECD) in 1992, plus countries with economies in transition such as Russia. The GHGs included in the Kyoto Protocol were:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs); and
- sulfur hexafluoride (SF_6).

The emission reduction targets were calculated based on a party's domestic GHG emission inventories (which included land use change and forestry clearing, transportation and stationary energy sectors). Domestic inventories required approval by the Kyoto Enforcement Branch. The Kyoto Protocol required developed countries to meet national targets for GHG emissions over a five year period between 2008 and 2012.

To achieve their targets, Annex I Parties had to implement domestic policies and measures. The Kyoto Protocol provided an indicative list of policies and measures that might help mitigate climate change and promote sustainable development.

Under the Kyoto Protocol, developed countries could use a number of flexible mechanisms to assist in meeting their targets. These market-based mechanisms include:

- Joint Implementation – where developed countries invest in GHG emission reduction projects in other developed countries; and
- Clean Development Mechanism – where developed countries invest in GHG emission reduction projects in developing countries.

Annex I countries that failed to meet their emissions reduction targets during the 2008-2012 period were liable for a 30% penalty (additional to the level of exceedance).

A second commitment period was agreed on in 2012 that spans from 2013 to 2020, whereby 37 countries, including Australia, were bound to emissions targets (**DFAT, 2015**). Country representatives are meeting in Paris in 2015 to work on a new protocol to replace the Kyoto Protocol.

2.5.1.4 International Agreement Post-Kyoto

An international framework for mitigating the impacts of climate change post the Kyoto period was discussed at the 15th United Nations Conference of Parties (COP-15), Copenhagen, in December 2009. It concluded with an agreement that the global temperature rise should be capped through significant emission reductions by all countries; however no legally binding agreement was ratified. The *Copenhagen Accord* was drafted and supported by the majority of countries, and outlined the following (**UNFCCC, 2009**).

- The global average temperature increase should be held below 2°C.

- Emissions targets for developed countries and actions to reduce emissions by developing countries should be specified.
- An international framework for measurement, reporting and verification of GHG emissions will be developed.
- Financial assistance will be provided for developing countries to reduce emissions and adapt to climate change.

Nations went to Copenhagen with national emission reduction targets, both unconditional and dependent on global emission reduction commitments. On 27 January 2010, Australia officially presented its full target range to the *Copenhagen Accord*. The *Accord* is not legally binding to the extent of the Kyoto Protocol and the specification of national emissions reduction commitments for the period 2012-2020 will be subject to further negotiation.

At the 16th United Nations COP in Cancún, November - December 2010, the *Cancún Agreements* were developed. While not legally binding, the *Agreements* anchor the mitigation pledges made by both developed and developing countries in the *Copenhagen Accord* under the UNFCCC. This is seen as an important step in securing a new global treaty to replace the Kyoto Protocol. Other outcomes from the COP-15 include the establishment of a new Green Climate Fund to support developing countries with climate change adaption, as well as technology sharing mechanisms.

Further discussions in Lima (2014) planned for the development of a successor Protocol document that will be implemented from 2020. This document has been named the Durban Platform for Enhanced Action that mandates "a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties" (**DFAT 2015**).

2.5.2 Australian Context

2.5.2.1 Australia's GHG Inventory

According to the Department of Environment (DoE), Australia's GHG emissions increased by 2.4% between 1990 and 2012. The energy sector was the largest source of GHG emissions in 2012 having contributed 76% (413.4Mt CO_2-e) of total net emissions (excluding the Land Use, Land Use Change and Forestry (LULUCF) sector) and increased 44.2% between 1990 and 2012. Within the energy sector, 'transport' emissions accounted for 16.6% of total net emissions (excluding LULUCF) in 2012 and increased by 49.7% between 1990 and 2012. The proposed airport is considered a part of the 'transport' subsector of the energy sector emissions.

The relatively small change in Australia's GHG emissions from 1990 to 2012 is largely attributable to a significant reduction in GHG emissions associated with land use change, which has decreased by over 88% between 1990 and 2012 (**DoE, 2014**).

2.5.2.2 National Inventory

Australia's National Inventory Report 2012 from the DoE shows that 2012 emissions were 102.4% of the 1990 baseline (**Table 2-5**). Having come in below the target by 5.6%, Australia has 131 million tonnes of CO_2-e that can be transferred over to Australia's new Kyoto target to cut emissions by 5% below 2000 levels by 2020.

Table 2-5: Australian's Net GHG Emissions 1990 to 2012 by Sector

Sector and Subsector	Emissions (Mt CO_2-e)		Percentage Change
	1990	2012	1990 to 2012
All Energy (Combustion + Fugitive)	286.7	413.4	44.2%
Stationary Energy	194.6	283.2	45.5%
Transport	60.3	90.2	49.7%
Fugitive Emissions from Fuel	31.9	39.9	25.2%
Industrial Processes	24.7	31.2	26.5%
Agriculture	86.5	87.4	1.0%
Waste	17	11.7	-31.4%
Land Use, Land Use Change and Forestry	130.5	15.2	-88.4%
Australia's Net Emissions	545.5	558.8	2.4%

Source: (**DoE, 2014**).

2.5.2.3 National Greenhouse and Energy Reporting Framework

The *National Greenhouse and Energy Reporting Act 2007* (Cth) (the NGER Act) establishes a mandatory obligation on corporations which exceed defined thresholds to report GHG emissions, energy consumption, energy production and other related information.

Corporate and facility reporting thresholds for GHG emissions and energy consumption or energy production are provided in **Table 2-6**. Emissions are measured in terms of tonnes of CO_2-e. Emissions are normalised to their equivalent Global Warming Potential (GWP) of CO_2.

Table 2-6: NGER reporting thresholds

Corporate Threshold		Facility Threshold	
GHG Emissions (Scope 1&2) (kt CO_2-e)	**Energy Usage (TJ)**	**GHG Emissions (Scope 1&2) (kt CO_2-e)**	**Energy Usage (TJ)**
50	200	25	100

Source: **DCCEE, 2007**

If a corporation has operational control over facilities whose GHG emissions or energy use in a given reporting year:

- individually exceed the relevant facilities threshold; or
- when combined with other facilities under the corporation's operational control, exceed the relevant corporate thresholds, that corporation must report its GHG emissions or energy use (as the case may be) for that year under the NGER Act.

This may include the airport lessee-company, construction or other contractors, and airlines, for example. A preliminary assessment of GHG emissions and energy use for Stage 1 of the airport is set out in chapter 8 of this report.

It is anticipated that during construction, there will be multiple parties with operational control over different aspects of the site development. For this reason, while it is anticipated that there is likely to be some reporting requirement under the NGER scheme, this is likely to be apportioned across the NGER reporting corresponding to several corporations. Once operational, the airport is anticipated to have combined Scope 1 and Scope 2 emissions greater than 25,000 tonnes CO_2-e in a financial year (see **Section 8.2.1**). Because of this, the reporting of emissions is expected to be required under the NGER scheme.

3 APPROACH AND METHODOLOGY

3.1 Operations

3.1.1 Overview

This Chapter describes the modelling of emissions and air pollution associated with the airport using the EDMS model. EDMS is a combined emissions and dispersion model which permits the factors affecting emissions and air quality to be considered in some detail.

Two scenarios were investigated:

- **Stage 1 development** - The initial stage in the development of the airport, including a single runway and handling approximately 10 million passengers annually. The EIS assumes 10 million passengers is reached in 2030 for assessment purposes.
- **Longer term development** - A future stage in the development of the proposed airport, where the airport is assumed to comprise parallel runways and handling approximately 82 million passengers annually. The EIS assumes this occurs in 2063 for assessment purposes.

The methodology for this assessment is comprehensive, and rather than presenting all the technical elements in the body of the report, these have been provided in **Appendix C** and **Appendix D**. The following Sections provide a brief description of the inputs for the air quality modelling. **Table 3-1** provides a summary of the data sources used for the air quality scenario assessment.

Table 3-1: Summary of data sources for the air quality assessment

Activity	Data source
Aircraft	Synthetic schedule developed based on worst case day and projected ATMs
GSE	GSE operations based on aircraft schedule
APUs	APU operations based on aircraft schedule
Parking facilities	Projected traffic numbers
External roadways	Projected traffic numbers
Terminal traffic	Projected traffic numbers
Stationary sources	
Boilers	Fuel throughput
Engine tests	SACL (2012)
Fuel tanks	SACL (2012)
Generators	Fuel throughput
Solvent	SACL (2012)
Surface coating/painting	SACL (2012)
Training Fires	SACL (2012)

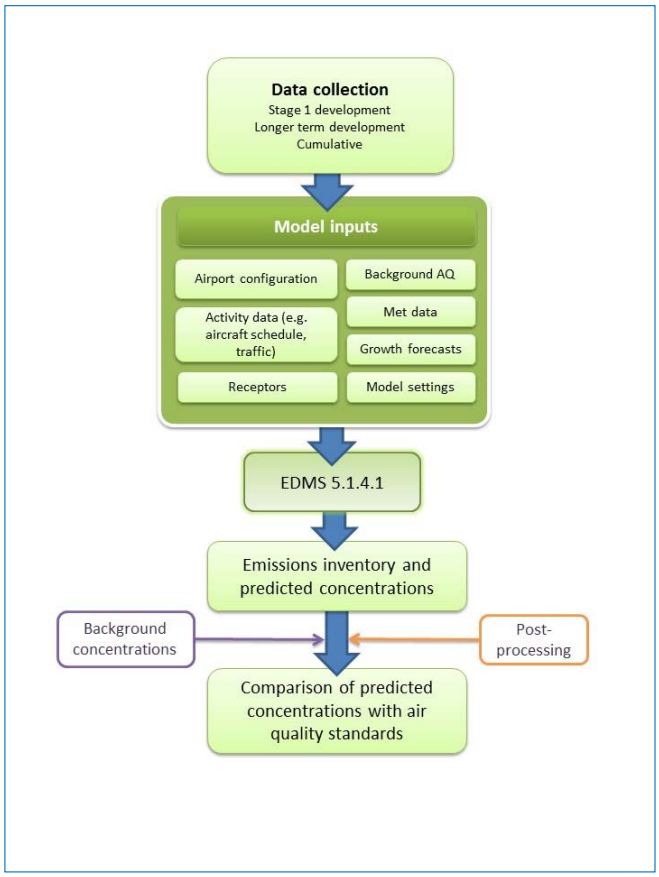
3.1.2 Modelling overview

3.1.2.1 Selection of computer model

The contribution of operations at the airport to emissions and resultant local air quality were calculated using the US Federal Aviation Administration (FAA) Emissions and Dispersion Modelling System (EDMS)

(Version 5.1.4 from June 2013). EDMS has been used for several recent airport assessments in Australia including Sydney (Kingsford Smith) Airport (KSA) and Adelaide Airport. The overall modelling approach is summarised in **Appendix C.**

Summary of air quality assessment methodology



Emissions inventories and dispersion model predictions for the two scenarios (Stage 1 and longer term development) were obtained using EDMS based on activity data and growth projections provided by GHD for all emission sources. These include aircraft fleet types, engine tests, vehicle emissions, and stationary sources such as fuel tanks.

For dispersion modelling, detailed spatial information on aircraft movements, spatial information on the other emission sources (e.g. engine testing, APUs, etc.), the airport layout, and meteorological data were employed within EDMS to determine the airport's contribution to concentrations of criteria pollutants at discrete receptor locations and across the model domain. The results from the dispersion modelling were then used in combination with the data on existing air quality (used to define background concentrations) to determine the likely impact of operations at the airport.

The operational air quality assessment takes into consideration the Approved Methods, along with other relevant legislation and guidelines (see **Section 2**).

3.1.2.2 Dispersion modelling

The EDMS dispersion analysis undertaken in this assessment uses the USEPA's AERMOD **(USEPA, 2004a)** dispersion model. AERMOD has USEPA preferred model status, and has been accepted in Australia for use in a variety of regulatory applications. The air quality metrics currently included in EDMS for

dispersion analysis are CO, THC, NMHC, VOC, TOG, NO_X, SO_X, (primary) $PM_{2.5}$ and (primary) PM_{10} **(CSSI, 2013)**.

AERMOD is designed to handle a variety of source types, including surface and buoyant elevated sources, in a wide variety of settings such as rural and urban as well as flat and complex terrain. AERMOD replaced the Industrial Source Complex (ISC) model for regulatory purposes in the United States in December 2006 as it provides more realistic results compared to the conservative ISC model. Ausplume, a steady-state Gaussian plume dispersion model developed by the Victorian EPA and frequently used in Australia for simple near-field applications, is largely based on the ISC model. Compared with ISC and Ausplume, AERMOD represents an advanced next-generation model which requires additional meteorological and land-use inputs to provide more refined predictions.

All of the inputs necessary for the emissions inventory are also necessary for dispersion modelling. However, the amount of data required to perform a dispersion analysis is significantly greater than the amount required for an emissions inventory alone, as spatial and temporal information is important. Additional requirements in AERMOD include:

- locations of receptors;
- hourly local meteorological data;
- accurate operational profiles to describe how activities, and hence emissions, vary with time;
- an annual schedule of aircraft operations, including gate and runway allocations;
- aircraft performance modelling; and
- aircraft delay and sequencing modelling.

The location of sensitive receptors and site-specific meteorological data was made available for this study. Information on aircraft operations was available for a worst case day only. To develop the schedule for a full year of aircraft movements daily and monthly operational profiles from KSA were adopted. In the absence of highly detailed information, such as aircraft performance and aircraft delay and sequence modelling, default parameters were adopted. A technical description of the dispersion model inputs is provided in **Appendix D**.

3.1.2.3 Emissions inventory

The types of activity which result in atmospheric emissions at airports are identified in the relevant NPI emission estimation technique manual **(DEWHA, 2008)**. These activities (which generate emissions through either combustion or evaporation) are listed in **Table 3-2**.

Table 3-2: Summary of activities generating atmospheric emissions at the airport

NPI Source type		Description
Emissions directly from aircraft	Aircraft main engine	Main engines of aircraft ranging from start-up to shut-down.
	APU	APU located on-board aircraft providing electricity and pre-conditioned air during ground times and bleed air for main engine start.
Aircraft handling emissions	Ground support equipment (GSE)	GSE necessary to handle the aircraft during the turnaround at the stand, including ground power units, air climate units, aircraft tugs, conveyor belts, passenger stairs, fork lifts, tractors, cargo loaders, etc.
	Airside traffic	Service vehicle and machinery traffic, including sweepers, trucks (catering, fuel, sewage), cars, vans, buses etc. that circulate on service roads within the airport perimeter (typically restricted area).
	Aircraft refuelling	Evaporation through aircraft fuel tanks (vents) and from fuel trucks or pipeline systems during fuelling operations.
Stationary/ infrastructure sources	Power/heat generating plant	Facilities that produce energy for the airport infrastructure, namely boiler houses, heating/cooling plants, co-generators.
	Emergency power generator	Diesel or other generators for emergency operations (e.g. for buildings or for runway lights).
	Aircraft maintenance	All activities and facilities for maintenance of aircraft, i.e. washing, cleaning, paint shop, engine test beds, etc.
	Airport maintenance	All maintenance of airport facilities, including cleaning operations.
	Fuel	Fuel storage, distribution and handling.
	Construction and demolition activities	All construction and demolition activities in airport operation and development, including the resurfacing of roads and runways.
	Fire training	Activities for fire training with different fuel (e.g. kerosene, butane, propane, wood).
	Waste water treatment	All activities and facilities for the collection, storage and treatment of waste water on-site.
Landside traffic	Vehicle traffic	Cars, vans, trucks, buses, motorbikes etc. associated with the airport on access roads, drop-off areas and on- or off-site parking lots. Emissions include tailpipe and evaporative releases).

EDMS incorporates a comprehensive database of emission factors for aircraft engines, GSE, APUs, vehicles and stationary sources. The emission factors are taken from a range of sources, including the International Civil Aviation Organisation (ICAO), the FAA and the USEPA. The pollutants currently included in the EDMS emission calculations are:

- Carbon dioxide (CO_2)
- CO
- NO_x
- SO_x
- $PM_{2.5}$
- PM_{10}
- Total hydrocarbons (THC)
- Non-methane hydrocarbons (NMHC)
- Volatile organic compounds (VOC)
- Total organic gases (TOG)
- 394 speciated organic gases (including benzene, toluene, xylenes and formaldehyde)

CO_2 is calculated only for aircraft, and THC is calculated only for aircraft and APUs. EDMS includes information that is not included in the public ICAO database, such as PM emission factors. It also contains more up-to-date emission factors than those given in the NPI manuals.

The emission categories which are used in EDMS, along with their relevance to the airport are summarised in **Table 3-3**. Any default values in EDMS were replaced with these site-specific values where possible. More detailed descriptions of the different elements of the emissions calculation method are provided in **Appendix C**.

Table 3-3: EDMS categories and relevance to the airport

EDMS category		Relevant
Aircraft main engines and APUs		Yes
Ground support equipment		Yes
Parking facilities		Yes
Roads		Yes
Buildings		Yes
Stationary sources	Engine tests	Yes
	Boilers	Yes
	Generators	Yes
	Incinerators	No
	Fuel tanks	Yes
	Surface coating/painting	Yes
	Solvents	Yes
	De-icing area	No
	Sand/salt piles	No
Training fires		Yes

In May 2015, the EDMS model was replaced with the Aviation Environmental Design Tool (AEDT) as the FAA's preferred model. At the time of writing, the full release version of the model was not available and therefore was not considered for this assessment. Nevertheless, the emissions data for EDMS and AEDT both reference the ICAO database and therefore the aircraft based emissions are expected to be the same. Key differences between EDMS and the AEDT models include the transition of roadway emissions from the US EPA's MOBILE emission estimation tool to Motor Vehicle Emissions Simulator (MOVES) in 2013. This upgrade is of no consequence for this assessment as roadways and parking emissions have been based on the Australian traffic emission data developed by **PIARC (2012)**.

3.1.2.4 Airport layout

The airport layout for each development scenario assessed is provided in **Appendix C**.

Aircraft movements are calculated in EDMS using the schedule, gate locations, runway locations and the taxi paths between the gates and runways. Whilst EDMS allows each gate to be specified individually, this would have been impractical in this study given this detail is not yet available. Gates were therefore allocated in groups. More than 30 different taxiway sections were entered utilising the proposed runways, and these were used in different sequences to define a total of 72 taxi paths once the airport is fully operational as part of the longer term development.

3.1.2.1 Roadways

In EDMS it is assumed that roadways generate emissions due to on-road vehicle operations and vehicle idling and travelling within and outside of the airport site. These have been termed 'terminal traffic' and 'external roadways', respectively.

The terminal traffic comprises traffic that will be travelling to and from the airport and accounts for movements such as the use of the parking facilities and the drop off and collection of passengers.

The traffic emissions from the external roadways include all roads outside of the airport study boundary, extending as far north as the M4 and as far east as the M7. Future emissions from the proposed M12 roadways were also included.

A detailed description of the roadway emission calculations for each development scenario assessed is provided in **Appendix C**.

3.2 Sensitive receptors

It is standard practice in air quality assessments to estimate pollutant concentrations at discrete locations which are considered to be broadly representative of exposure in the area of interest. The concentrations at these locations are then compared with the relevant air quality assessment criteria. The locations are known as 'receptors'. As a general rule, receptors should reflect locations where the general public is likely to have access on a regular basis. In addition, it is important that any sensitive locations are identified. These include where people are likely to work or reside as well as schools, day care centres, hospitals, etc., as defined in the Approved Methods.

The airport site is located in an area where there is a high density of sensitive receptors. To assess each individual receptor is not practicable given the extent of the project. For this reason, a series of receptors have been selected, representative of residential suburbs and individual residences in close proximity to the proposed development. In addition, a number of community receptors that comprise schools, churches, shopping centres and recreational areas were also identified within the local area. On-site receptors were nominated within the airport site boundary to evaluate the potential exposures of airport staff and passengers at the facility, noting that airport terminal staff are likely to have a much longer exposure. The on-site receptors have been assessed during operations only as during construction the respective uses will not yet exist.

For the EIS, a total of 152 sensitive receptors were identified. The approach taken for this assessment was to identify a sub-set of receptors to represent individual residences and clusters of residences located within approximately 5km of the airport site. This subset includes 18 residential receptors, two on-site receptors and 75 community receptors which are listed in **Appendix E** for reference. The locations of the receptors are shown in **Figure 3-1**.

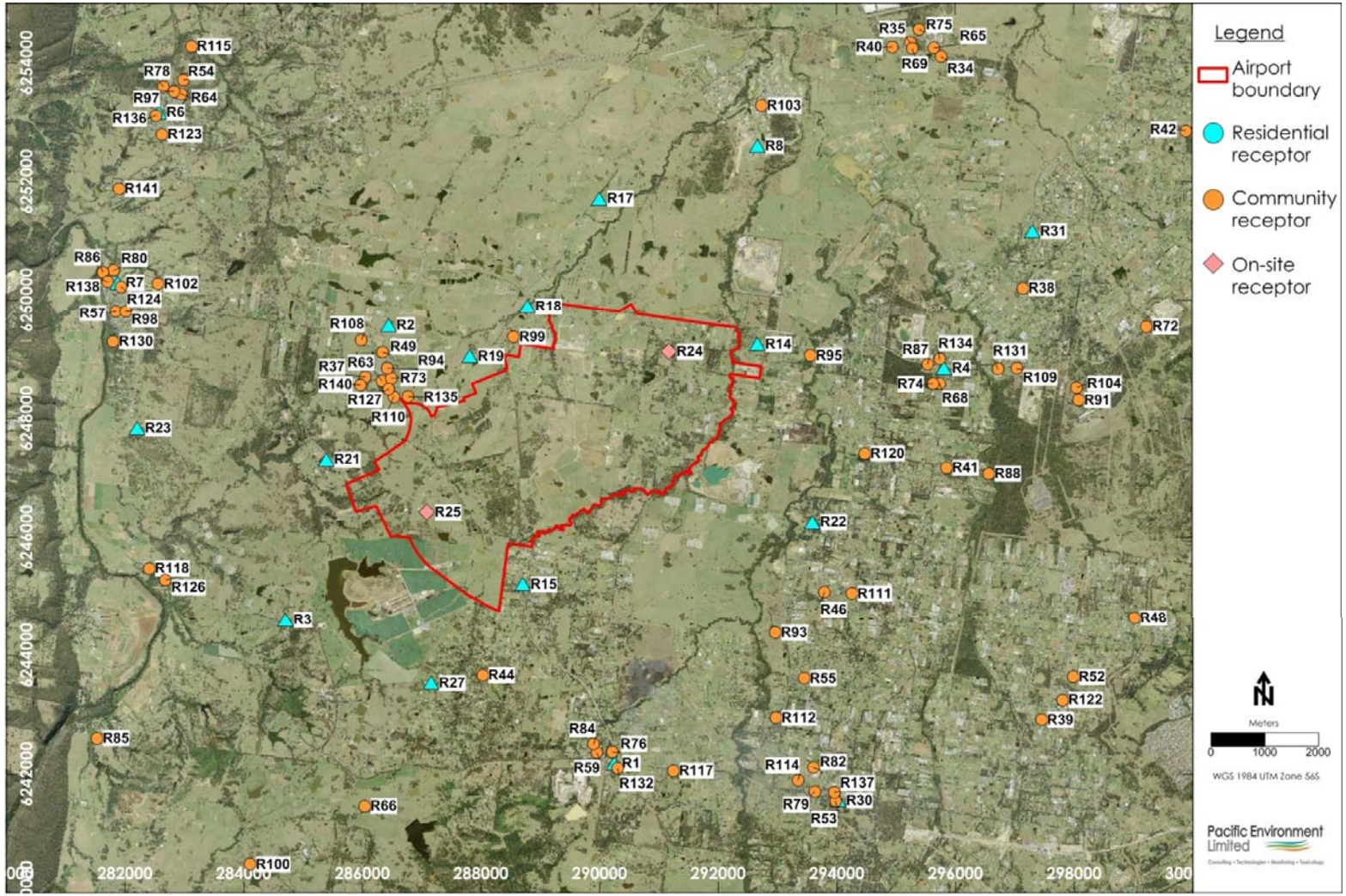


Figure 3-1: Location of sensitive receptors

3.3 Cumulative impacts

There is potential for cumulative impacts to occur during the operation of the airport. Cumulative impacts, for the purpose of this assessment, are defined as 'existing' (background) air quality, combined with the airport activities within the airport site (incremental) for each development stage. For the Stage 1 development, cumulative impacts would be the emissions from the airport operating with the single runway and the external roadways combined with background pollutant measurements that represent other sources. For the longer term development, this would also be the case except that the airport emissions would comprise emissions from the airport running with both runways at full capacity.

Within the Western Sydney air shed, there are a number of other industrial emitters in the area with the potential to affect local air quality and these include:

- major roadways (e.g. M4, M7);
- Camden Airport;
- Bankstown Airport;
- Elizabeth Drive landfill facility;
- Boral Bricks Bringelly;
- Erskine Park Quarry;
- Western Sydney Service Centre (metal manufacturing); and
- Western Sydney Employment Area (WSEA).

With the exception of the major roadways, the above listed sources are all located at a sufficient distance from the airport site that potential cumulative impacts at the local scale are considered negligible. Furthermore, the adopted background air quality values will effectively account for potential emissions from these sources.

To address the potential cumulative impacts of the airport in combination with the major roadways, emissions from both sources have been included in the modelling. Sources that are specifically included in dispersion modelling are detailed in **Appendix D**.

It is also noted that there is potential for cumulative emissions from the operation of Stage 1 of the airport in combination with the construction activities pertaining to the longer term development. It is anticipated that the dust emissions generated during construction of the second runway would be effectively managed. This assumption is supported by the fact that there are significant safety issues associated with dust generation in the vicinity of an operational airport that would be of much greater risk (and thus receive much greater management) than conventional nuisance dust issues from other construction activities. The additional combustion emissions from onsite equipment during longer term development construction activities are also assumed to be insignificant in comparison to the emissions from the airport in isolation and on that basis, have not been considered further.

3.4 Model post-processing

3.4.1 Modelling of NO_X chemistry

One of the most common atmospheric chemistry issues is the estimation of NO_2 from modelled NO_x concentrations. The amount of NO_2 in the exhaust stream as it is released from combustion sources is typically in the order of 5-10% of total NO_x (expressed as NO_2 equivalents), but can be much higher for some sources, such as modern diesel vehicles equipped with catalytically regenerating particle filters. However, following release, the NO_2 proportion also changes through complex photochemical reactions of atmospheric ozone and NO_x.

Several approaches are available for estimating the transformation of NO to NO_2 that occurs after the exhaust gases are discharged. For this project, the 'ozone limiting method' (OLM) was used. The

OLM is based on the assumption that approximately 10% of the NO_x emissions are generated as NO_2 **(Alberta Environment, 2003)**. The majority of the NO_X emission is in the form of NO, which reacts with ambient levels of ozone to form additional NO_2. If the ozone concentration is greater than 90% of the predicted NO_x concentration, all the NO_x is assumed to be converted to NO_2, otherwise NO_2 concentrations are calculated using the equation below, which assumes total conversion of the ozone and adds the 10% of the NOx that was emitted as NO_2:

$$NO_2 = O_3 + 0.1 \times NO_X$$

The predicted NO_2 concentration is then added to the background NO_2 concentration.

For this assessment, a modified version of the OLM Level 2 assessment methodology equation was adopted to reflect the NSW EPA requirement outlined in a recent submission by NSW EPA for the NorthConnex EIS **(AECOM, 2012)**. The modified equation is as follows:

$$[NO_2]_{total} = \{0.16 \times [NO_X]\} + MIN\ \{(0.84) \times [NO_X]\ or\ (46/48) \times [O_3]_{background}\} + [NO_2]_{background}$$

To apply the OLM, hourly background concentrations of ozone and NO_2 in 2014 were obtained for the NSW EPA monitoring station at Bringelly. The NO_2 concentration at each receptor was calculated using the above equation for each hour of the year, and then added to the corresponding hourly background value from the Bringelly site. The maximum hourly NO_2 concentration and annual mean concentration were then determined from the results.

3.4.2 SO_2 estimation

As the vast majority of SO_X emissions are SO_2, it was assumed that all SO_X predicted by EDMS is released as, and remains, SO_2.

3.4.3 VOC speciation

Concentrations of specific air toxics were estimated from the total VOC concentrations predicted by EDMS in combination with speciation profiles for aircraft exhaust from the USEPA SPECIATE programme **(US EPA, 2015b)** (**Table 3-4**).

Table 3-4: Air toxics as % of VOC emissions from aircraft engines (US EPA, 2015b)

Compound	% by weight of VOC emissions
Benzene	1.681
Benzo[a] pyrene	N/A [(a)]
Formaldehyde	12.31
Toluene	0.642
Xylenes	0.448

Note: (a) Benzo[a] pyrene is not specified as an aircraft exhaust emission **(US EPA, 2015b)**.

3.5 Odour

3.5.1 Odour from aircraft exhaust

The assessment of potential odour effects on the local area is not straightforward. A qualitative method is to survey odour nuisances caused by aircraft activities and draw comparisons between aircraft operations and odour complaints. This method has a number of limitations as demonstrated by **BAA (2008)** in its survey of 14,000 residents in the vicinity of Stansted Airport. The survey was conducted between August and November 2005 with residents asked to report any incidents of odour annoyance. During the survey period, only 99 responses were received with the majority

located some distance from the airport. This was considered a critical limitation to the study, with no cause factors related to odour occurrence from airport activities able to be deduced from the survey. Similar studies have also been completed for other major international airports including Hamburg, Amsterdam and Boston.

The current approach to the assessment of odour is to use the quantitative approach described in *Technical framework: Assessment and management of odour from stationary sources in NSW* **(DEC, 2006)**. As there are no instrument-based methods that can measure an odour response in the same way as the human nose, "dynamic olfactometry" is typically used as the basis of odour quantification by regulatory authorities.

Dynamic olfactometry is the measurement of odour by presenting a sample of odorous air to a panel of people with decreasing quantities of clean odour-free air. The panellists then note when the odour becomes detectable. The correlations between the known dilution ratios and the panellists' responses are then used to calculate the number of dilutions of the original sample required to achieve the odour detection threshold. The units for odour measurement using dynamic olfactometry are "odour units" (OU) which are dimensionless and are effectively "dilutions to threshold".

This method was adopted as part of the *Draft Environmental Impact Statement: Second Sydney Airport Proposal* **(PPK Environment and Infrastructure, 1997)**. The odour impacts of the airport were assessed by predicting the ground level total hydrocarbon concentrations and using an odour threshold (1 OU) of 34 mg/m^3. This relationship was based on odour measurements conducted by CSIRO in 1997 at Sydney Airport **(PPK Environment and Infrastructure, 1997)**.

More recent studies include those by **Winther et al (2005)** who established a factor of 57 OU per mg/m^3 of hydrocarbon emission. This approach has been used within other local air quality assessments recently published, such as London Luton Airport **(Air Quality Consultants, 2012)**.

This approach (mass emission of TOC multiplied by 57 to establish the OU emission rate) has been adopted within the current assessment. Hydrocarbon emissions were quantified from aircraft operations in start-up mode in combination with APU and GSE hydrocarbon emissions by EDMS, and scaled accordingly to represent odour emission rates in OU/s.

Due to significant uncertainties in future emission inventories, the predicted odour concentrations for the longer term development have not been assessed.

3.5.2 Odour from on-site waste water treatment plant

There is the potential for odour emissions to be released from the on-site waste water treatment plant (WWTP).

It has been assumed that the WWTP will treat sewage from the airport to produce high quality recycled water. It is understood that the average daily demand for recycled water would be approximately 1.8 ML. As little information is currently available about the type of processing operations and population that would use the WWTP, odour emissions have been based on odour assessments that have been completed for WWTPs to be used for future residential development in the Sydney area, processing 1.5 ML per day **(Pacific Environment, 2015)**, assuming equivalent odour emissions.

To characterise the potential odour impacts of the proposed development, odour sampling was completed at two similar facilities located at Pitt Town and central Sydney (**Pacific Environment, 2015**). The purpose of the monitoring was to characterise the odour from the existing facility and use the data to derive odour emission rates (OERs) for use in the dispersion modelling. The odour emissions used in this assessment are provided in **Table 3-5**. A factor of 2.3 was added to the predictions to account for the peak to mean ratio as prescribed in the *Approved Methods*.

Due to significant uncertainties in future emission inventories, the predicted odour emissions have been assessed for the Stage 1 development only.

Table 3-5: Adopted WWTP odour monitoring inputs

Sample	Odour Concentration (OU)	Specific Odour Emission Rate (OU.m/s)[1]
MBR Tank – Membrane Chamber	1,970	0.68
MBR Tank – Aerobic Chamber	3,620	1.19
MBR Tank –Anoxic Chamber	4,310	1.42
Activated Carbon Filter outlet (treated air)	3,320	n/a

3.6 Construction

3.6.1 Overview

Due to the transient, variable nature of construction activities, it is difficult to accurately quantify air quality impacts from construction activities. Any effects of construction on airborne particle concentrations would generally be temporary and relatively short-lived. Moreover, mitigation should be straightforward, as most of the necessary mitigation measures are routinely employed on construction sites. However, in view of the length of the construction period, a quantitative assessment of impacts has been completed using the same dispersion model used for the operational impact assessment, AERMOD (see **Section 3.1.2.2**). A detailed description of the model configuration and meteorological file is provided in **Appendix D**. Rather than relying on a central database such as EDMS, the emissions have been calculated based on established emission factors.

Construction of the Stage 1 works for the proposed airport would involve two major components namely worksite preparation works and development of aviation infrastructure. It is acknowledged that there are some components of construction that will overlap. So as to provide a conservative assessment, the adopted approach has been to identify the worst case emissions scenario for each of the worksite preparatory works and development of aviation infrastructure and use that as the basis for the assessment. For example, PM emissions during aviation infrastructure include the concurrent emissions from earthworks activities from the working crew, asphalt plant and concrete batch plant.

Dust emissions from each component are as follows:

- Bulk earthworks
  - Dozers
  - Scrapers
  - Loading and unloading of material
  - Hauling on paved and unpaved roads
  - Wind erosion
  - Grading
- Aviation infrastructure
  - Working crew (similar to equipment used during bulk earthworks)
  - Asphalt plant
  - Concrete batching plant

[1] Specific odour emission rate (SOER) is calculated from the sweep gas flow rate and area of flux hood. That is: SOER = odour concentration (ou) x sweep gas flow rate (Nm^3/s) x area (m^2). The SOER is only used when the source is represented as an area source. For the point source (FBT OCU vent), the measured odour concentration is multiplied by the volumetric flow rate to determine an estimated emission rate.

In addition to the above, there would also be diesel particulate matter emissions (comprising $PM_{2.5}$ only) from the onsite equipment and odour emissions from the asphalt plant.

3.6.2 Construction dust

A detailed description of the construction activities is presented in the Construction Planning Report **(GHD, 2015a)**. Construction activities during the site preparation and aviation infrastructure works have been analysed and estimates of dust emissions for the individual activities have been made. Emission factors developed both locally and by the US EPA have been applied to estimate the amount of dust produced by each activity. The emission factors applied are the most reliable and up-to-date for determining dust generation rates. Dust emissions calculated for the site preparation and the airport infrastructure works are presented in **Table 3-6**.

Most activities and emissions are assumed to occur between 6am and 6pm, the exception being pavement materials that will be delivered 24 hour per day and also wind erosion. TSP, PM_{10} and $PM_{2.5}$ emission rates were calculated using emission factors derived from **US EPA (1995)**.

Table 3-6: Estimated dust emissions during construction

Activity	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Bulk earthworks			
Dozers	54,126	17,648	5,683
Loading bulk spoil East (cut)	913	432	65
Loading bulk spoil East (fill)	913	432	65
Loading bulk spoil North (cut)	104	49	7
Loading bulk spoil North (fill)	104	49	7
Loading bulk spoil Northwest (cut)	130	62	9
Loading bulk spoil Northwest (fill)	221	105	16
Loading bulk spoil Southwest (cut)	115	54	8
Loading bulk spoil South (fill)	109	52	8
Hauling unpaved roads East	177,340	54,288	5,429
Hauling unpaved roads North	10,105	3,093	309
Hauling unpaved roads Northwest	21,473	6,573	657
Hauling unpaved roads Northwest	11,115	3,403	340
Scraper loading topsoil for rehabilitation	60,448	31,433	1,813
Scraper transporting topsoil for rehabilitation	31,157	9,538	954
Wind erosion (East)	124,849	62,425	9,364
Wind erosion (North)	846	423	63
Wind erosion (Northwest)	1,383	691	104
Wind erosion (southwest)	4,036	2,018	303
Grading roads	45,623	45,086	4,000
TOTAL	*545,111*	*237,854*	*29,207*
Aviation infrastructure works			
Dozers	23,197	7,564	2,436
Loading subgrade	96	45	7
Unloading subgrade	96	45	7
Unloading unbound gravel	163	77	12

Activity	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Hauling subgrade	37,220	11,394	37,220
Hauling gravel	150,370	46,032	150,370
Wind erosion of subgrade area	28,854	14,427	2,164
Grading roads	13,035	12,882	1,143
TOTAL	*253,029*	*92,465*	*193,357*

3.6.3 Concrete batching plant

During the construction of aviation infrastructure, the concrete batch plant would have the potential to generate PM emissions. The concrete is required over a period of 54 months with an estimated daily average of 424 m^3. Further detail on the concrete batch plant is provided in **GHD (2015)**. As limited information is available on the configuration of the asphalt batch plant, the PM sources and emissions identified are based on a typical concrete batch plant operation in the Sydney region. The estimated dust emissions are presented in **Table 3-7**.

Table 3-7: Estimated PM emissions from concrete batch plant

ACTIVITY	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Movement of delivery trucks onsite	6,641	1,275	308
Movement cement trucks onsite	53,294	10,230	2,475
Vehicle exhaust	-	156	131
Unloading to aggregate storage bins	399	203	52
Residual from de-dusted air loading cement and fly-ash	-	540	30
Wind erosion	88	45	11
Total	*60,421*	*12,448*	*3,007*

3.6.4 Asphalt batching plant

During the construction of aviation infrastructure, the onsite asphalt batch plant would have the potential to release both PM and odour emissions. The asphalt batch plant would produce approximately 712,000 tonnes of asphalt over a 48 month period with a daily average of approximately 1,300 tonnes when operating. Further detail on the asphalt batch plant is provided in **GHD (2015)**. As limited information is available on the configuration of the asphalt batch plant, the odour sources and emissions identified are based on a typical asphalt batch plant operation in the Sydney region. The estimated PM and odour emissions from the asphalt plant are presented in **Table 3-8** and **Table 3-9**, respectively.

Table 3-8: Estimated PM emissions from asphalt batch plant

ACTIVITY	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Wind erosion from raw material stockpiles	175	88	13.14
Loading aggregate to material stockpiles	275	130	19.68
Loading aggregate to conveyors using FEL	275	130	19.68
Conveying / aggregate transfer	275	130	19.68
Oil-fired dryer	5,874	4,094	176.22
Mixer and sorting in mixer	7,476	4,806	224.28
Product load out	275	130	19.68
Delivery trucks	4,165	800	193.43

ACTIVITY	TSP (kg/y)	PM_{10} (kg/y)	$PM_{2.5}$ (kg/y)
Asphalt trucks	26,671	5,119	1238.59
Total	*45,461*	*15,427*	*1,924*

Table 3-9: Estimated odour emissions from asphalt plant

Activity	Assumed Odour Emission
Trucks waiting to be tarped	1080 OU.m³/s
Loading truck with product	11,407 OU.m³/s
Plant stack exhaust	2,167 OU.m³/s

3.6.1 Diesel particulate matter emissions

Diesel particulate matter emissions are required to be assessed as part of the Community Health Assessment **(Pacific Environment, 2015)**. Details of the diesel emissions and predicted concentrations are provided in **Appendix H.**

3.7 Greenhouse gases

3.7.1 Assessment approach

Quantification of GHG emissions (in tonnes of CO_2-equivalent (tCO_2-e)) associated with each GHG source has been made in accordance with the GHG Protocol (**WRI & WBCSD, 2004**), IPCC and Australian Government GHG accounting/classification systems.

The GHG assessment is guided by the *National Greenhouse and Energy Reporting Regulations 2008* (NGER Regulations). These describe the detailed requirements for reporting under the NGER Act.

Calculation is consistent with the *National Greenhouse and Energy Reporting (Measurement) Determination 2008* (the "NGER Measurement Determination").

Technical Guidelines for the Estimation of Greenhouse Gas Emissions by Facilities in Australia (NGER Technical Guidelines) support reporting under the NGER Act. They have been designed to assist corporations in understanding and applying the NGER Measurement Determination.

The NGER Technical Guidelines are reporting year specific, and outline calculation methods and criteria for determining GHG emissions, energy production, energy consumption and potential GHG emissions embodied in natural gas. The latest published NGER Technical Guidelines at the time of writing has been referenced.

It is acknowledged that as the NGER Technical Guidelines are derived from the NGER Measurement Determination, where there is a perceived contradiction between the NGER Technical Guidelines and NGER Measurement Determination, the NGER Measurement Determination takes precedence.

To streamline the quantification process, GHG emissions were calculated within the EDMS model used for the local air quality assessment. Any deviations in the calculation approaches between the NGER Technical Guidelines and the EDMS model are acknowledged and their material impact quantified.

GHG emission calculations are generally of the form:

$$Emission_i = Activity\ data \times EF_i$$

Where:

$Emission_i$	=	Estimated emissions of GHG i	(t CO_2-e)
$Activity\ data$	=	Basis of emission estimate (for example, amount of fuel combusted for energy generation)	(generally in the units of GJ for fuel combustion)
EF_i	=	Emission factor for GHG i	(t CO_2-e/Activity)

The activity data used to determine GHG emissions for this assessment were provided by GHD.

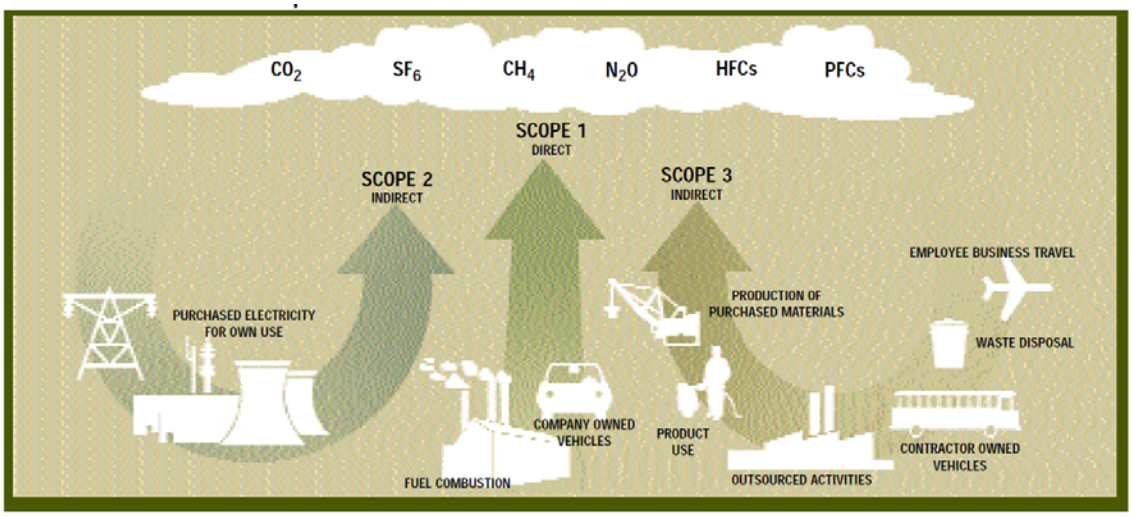
GHG emissions have been estimated based upon the methods outlined in the following documents:

- The World Resources Institute/World Business Council for Sustainable Development GHG Protocol (**WRI & WBCSD, 2004**).
- The National Greenhouse and Energy Reporting (Measurement) Amendment Determination 2015 (No.2) (**DoE, 2015b**) produced from the National Greenhouse and Energy Reporting (Measurement) Determination 2008 (**DCCEE, 2008**).
- Technical Guidelines for the Estimation of Greenhouse Gas Emissions by Facilities in Australia (**DoE, 2014b**).

3.7.1.1 The GHG Protocol

The GHG Protocol (**WRI & WBCSD, 2004**) establishes an international standard for accounting and reporting of GHG emissions. The GHG Protocol has been adopted by the International Organization for Standardization, endorsed by GHG initiatives (such as the Carbon Disclosure Project) and is compatible with existing GHG trading schemes.

Under this protocol, three "scopes" of emissions (scope 1, scope 2 and scope 3) are defined for GHG accounting and reporting purposes. This terminology has been adopted in Australian GHG reporting and measurement methods and has been employed in this assessment. The definitions for scope 1, scope 2 and scope 3 emissions are provided in the following sections, with a visual representation provided in **Figure 3.2**.



Source: WRI & WBCSD 2004

Figure 3.2: Overview of Scopes and Emissions across a Reporting Entity

3.7.1.1.1 Scope 1: Direct Emissions

Direct GHG emissions are defined as emissions that occur from sources owned or controlled by the reporting entity. For the airport, direct GHG emissions primarily result from sources below.

- Airport owned vehicles.
- Airport-owned ground support equipment (GSE).
- Airport-owned auxiliary power units (APU).
- Airport facilities (not including electricity).
- Boilers using natural gas.
- Back-up power generators using diesel oil.
- Fugitive emissions from airport-owned equipment.
- Jet fuel tanks.
- Gasoline and diesel fuel tanks.
- Contractor-owned vehicles used during the construction of the airport.
- Vegetation clearing.
- Emissions from operation of any waste water treatment plant.
- Emissions from fire training.

It is highlighted that it is common practice for tenants such as airline companies to own and operate GSE and APU facilities. For the purposes of this inventory, this report considers all GSE and APU facilities to be within the operational control of the airport. Thus the projected scope 1 emissions for the airport may be conservative compared with the final GHG inventory for the operational airport, once contractual arrangements between the airport and its tenants are finalised. Similarly, the operation of the airport's waste water treatment plant may be the responsibility of a third party, however for the purposes of this exercise have been included within the total GHG inventory for the site.

In addition, it is noted that although the vehicles used throughout construction are not owned and operated by the airport operator, for the purposes of developing a construction phase GHG inventory, these activities have been incorporated.

It was assumed the waste water treatment plant was an 'extended aeration plant'. Data was drawn from Haas & Lant (2009) in order to find an approximate GHG emission. This treatment plant was

assumed to have 100 per cent throughput of potable water (3.5ML/day) and recycled water (1.8ML/day).

3.7.1.1.2 Scope 2: Indirect Emissions

Scope 2 emissions are indirect GHG emissions from the generation of purchased energy by the airport. Scope 2 in relation to the airport covers purchased electricity, defined as electricity that is purchased or otherwise brought into the organisational boundary of the entity. Scope 2 emissions physically occur at the facility that generates the electricity, rather than the facility that uses the electricity. This is why they are often referred to as indirect GHG emissions.

3.7.1.1.3 Scope 3: Other Indirect Emissions

Scope 3 emissions are defined as those emissions that are a consequence of the activities of an entity, but which arise from sources not owned or controlled by that entity. For the airport, other indirect GHG emissions primarily result from sources below.

- Airline-owned aircraft movements.
- Airline-owned jet fuel.
- Private vehicles travelling to and from the airport site.
- Employee business travel.
- Taxis.
- Public transport serving the airport.
- Cargo trucks.
- Off-site waste disposal.

The GHG Protocol allows optional reporting of scope 3 emissions. If an organisation believes that scope 3 emissions are a significant component of the total emissions inventory, these can be reported along with scope 1 and scope 2 emissions. However, the GHG Protocol notes that reporting scope 3 emissions can result in double counting of emissions and can also make comparisons between organisations and/or products difficult (because reporting is voluntary). Double counting needs to be avoided when compiling national (country) inventories under international agreements such as the Kyoto Protocol. The GHG Protocol also recognises that compliance regimes are more likely to focus on the "point of release" of emissions (i.e., direct emissions) and/or indirect emissions from the purchase of electricity.

In this regard, it is noted that the NGER scheme applies only to scope 1 and scope 2 emissions. An estimate of the Scope 3 emissions associated with the combustion of jet fuel from departing aircraft (anticipated to be the principal scope 3 emission source) has also been provided within this report.

4 EXISTING ENVIRONMENT

4.1 Meteorology

Air quality is influenced by meteorological conditions, primarily in the form of interactions with coastal influences, such as sea breezes, and by local conditions driven by topographical features and night time drainage flows. Wind speed, wind direction, temperature and relative humidity all affect the potential dispersion and transport of emissions and are basic input requirements for dispersion modelling. The local meteorology for the airport site has been reviewed and is described in the following sub-sections.

An on-site automatic weather station (AWS) was installed by the Bureau of Meteorology in 1995. Meteorological data measured over the past five years have been used to characterise the prevailing weather conditions at the airport site. As this weather station is located on-site and is compliant with the Australian Standards (AS 2923-1987 Guide for Measurement of Horizontal Wind for Air Quality Applications), it is considered representative of airport site specific meteorology.

As specified in the Approved Methods, five years of data are required to be reviewed so that a representative year of meteorological conditions can be selected. The following sections provide a review of the meteorological data measured at Badgerys Creek AWS between 2010 and 2014.

A detailed study of the meteorological measurements at Badgerys Creek AWS was completed by the Bureau of Meteorology in the *Western Sydney Airport Climatological Review* **(BoM, 2015).**

4.1.1 Wind speed and wind direction

The Badgerys Creek meteorological data have been reviewed for five consecutive years (2010 to 2014). Summary statistics for the wind data - including wind speed and percentage of 'calms' (winds less than 0.5 m/s) - are shown in **Table 4-1.**

Table 4-1: Wind data – summary statistics

Year	Completeness of data set (%)	Average wind speed (m/s)	Calm periods (%)
2010	98.2	2.9	12.5
2011	99.8	2.6	7.5
2012	100.0	2.4	9.0
2013	99.9	2.5	8.6
2014	99.4	2.5	7.4
Average	**n/a**	**2.6**	**9.0**

Figure 4-1 indicates that there is no strong relationship between the time of year and the monthly average wind speed. Generally speaking, the monthly average wind speeds are less during the months of autumn. The 2010 year was the highest average wind speed across the five years investigated at 2.9 m/s. The year with the lowest average wind speed was 2012 at 2.4 m/s.

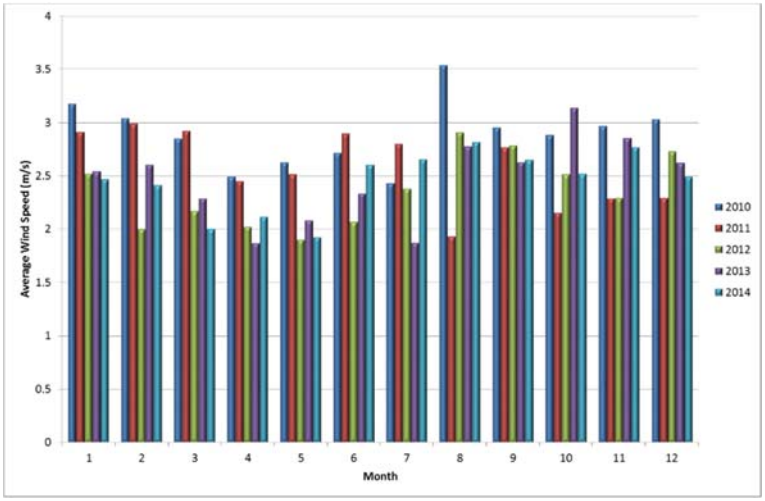


Figure 4-1 Monthly average wind speed at Badgerys Creek (2010-2014)

Wind roses show the frequency of occurrence of winds by direction and strength. The bars correspond to the 16 compass points – north, north-northeast, north-east, etc. The bar at the top of each wind rose diagram represents winds blowing from the north (*i.e.* northerly winds), and so on. The length of the bar represents the frequency of occurrence of winds from that direction, and the widths of the bar sections correspond to wind speed categories, the narrowest representing the lightest winds.

The annual and seasonal wind roses for the years 2010 to 2014 are presented in **Figure 4-2** to **Figure 4-6.** The annual wind distribution patterns across the five years show a similar pattern. On an annual basis, the predominant winds at Badgerys Creek originate from the southwest, followed by the south-southwest and north. Very few winds originate from the north-western quadrant.

The prevailing winds vary across the seasons with the characteristic south-westerly wind less prominent during summer where winds from the north-eastern quadrant become more frequent. During winter, the majority of winds originate from the south-western quadrant. There is a consistent seasonal pattern across all years.

The wind distribution patterns are consistent with the findings described in **BoM (2015)**.

The wind data for 2014 were found to be generally representative of the larger data set in terms of average wind speed, percentage of calms and directional patterns, and were therefore chosen to represent the meteorology of the area within the analysis. This is also the most recent full year of meteorological data available. Further discussion on the selection of the year for dispersion modelling is provided in **Appendix D**.

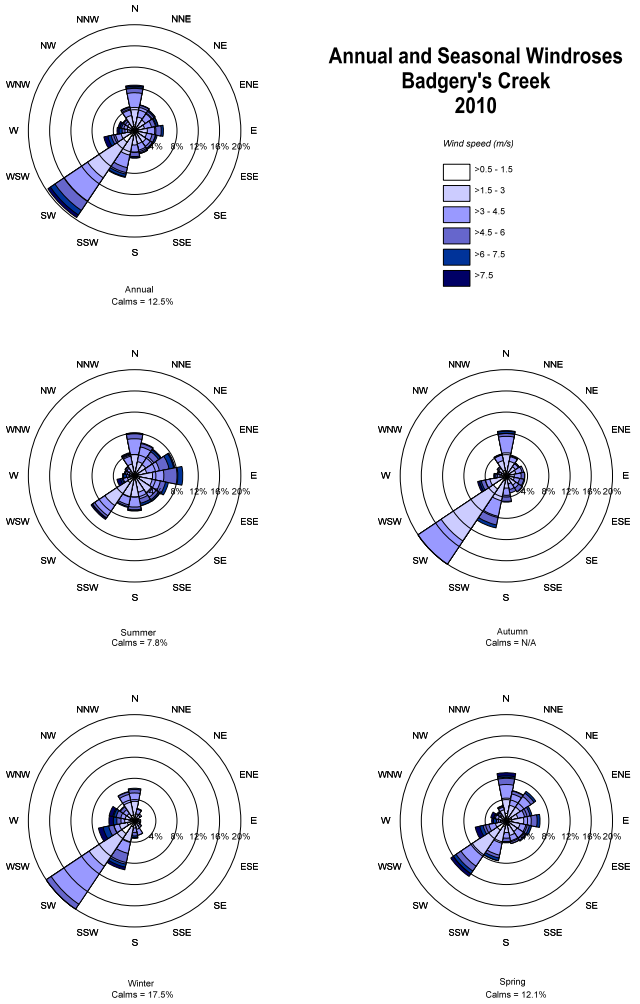


Figure 4-2: Annual and seasonal wind roses for Badgerys Creek (2010)

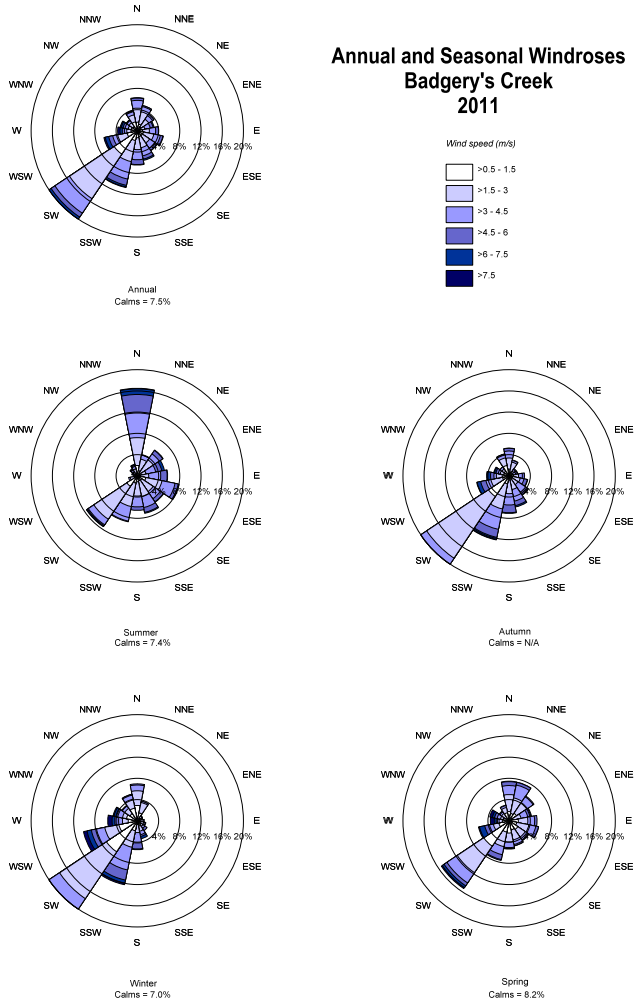


Figure 4-3: Annual and seasonal wind roses for Badgerys Creek (2011)

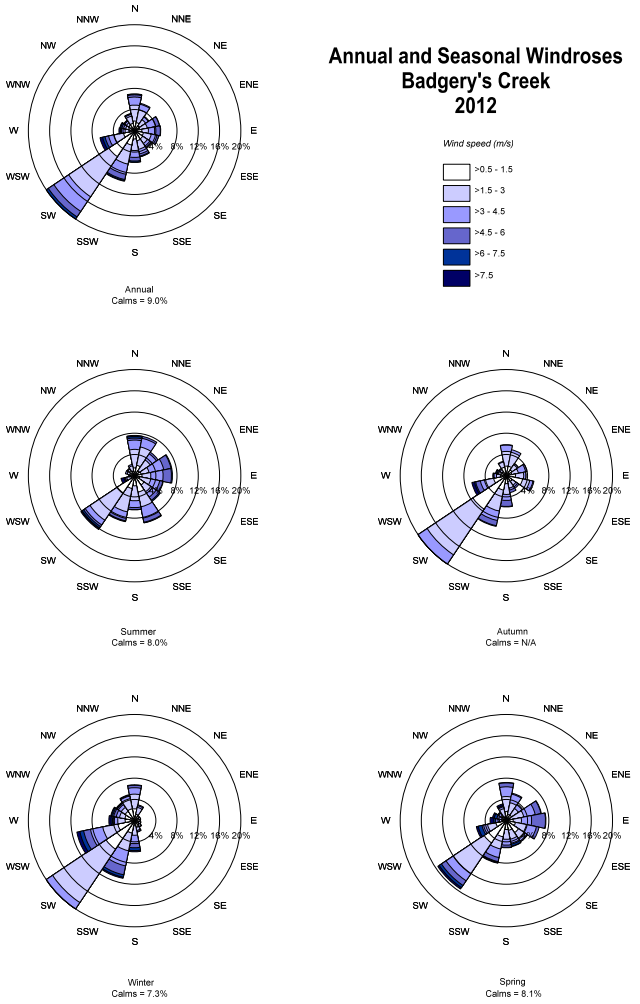


Figure 4-4: Annual and seasonal wind roses for Badgerys Creek (2012)

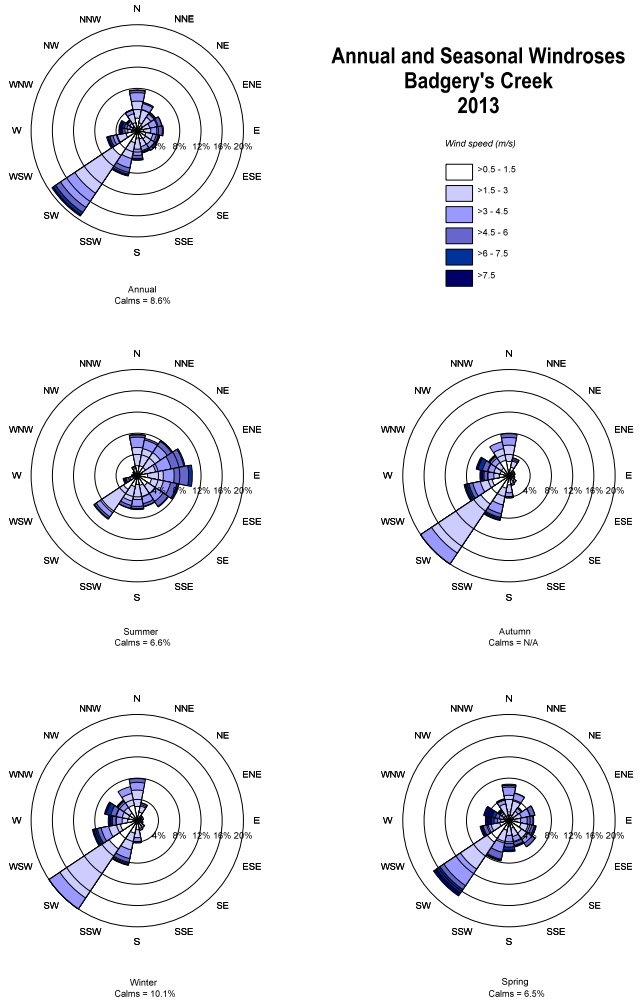


Figure 4-5: Annual and seasonal wind roses for Badgerys Creek (2013)

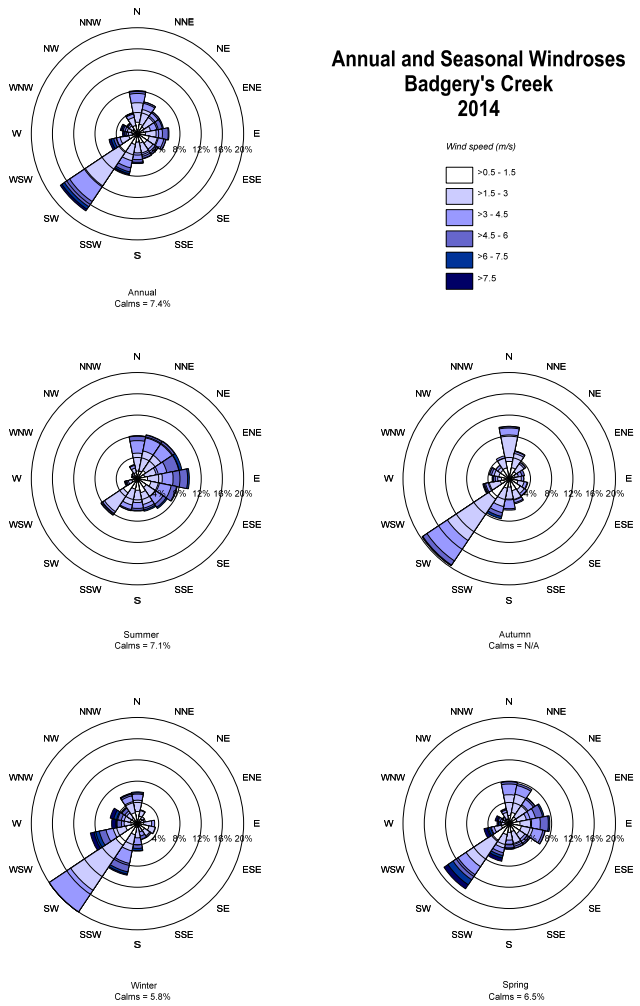


Figure 4-6: Annual and seasonal wind roses for Badgerys Creek (2014)

4.1.2 Temperature, rainfall and humidity

The measurements of temperature, rainfall and humidity at Badgerys Creek between 2010 and 2014 are summarised in **Table 4-2** (**BoM, 2014**). The temperature and humidity data consisted of monthly averages. Also presented are the monthly average maximum and minimum temperatures. The rainfall data consisted of mean monthly values.

Total annual rainfall data measured over the 2010 to 2014 period are shown in **Figure 4-7**. There appears to be a steady fluctuation around the annual average total rainfall (2010-2014) of 814 mm. The wettest year was 2013 with a total of 912 mm of rainfall. The driest year was 2014 with 693 mm of rainfall. The rainfall data collected at Badgerys Creek shown in **Figure 4-7** indicate that February is the wettest month, with an average rainfall of 114 mm. The average monthly rainfall for all years was 73 mm.

Figure 4-7 shows that there is a strong seasonal variation in temperature at Badgerys Creek. The annual average temperature at Badgerys Creek between 2010 and 2014 was 17°C. On average, January was the hottest month (see **Table 4-2** and **Figure 4-7**), with an average monthly temperature of 23°C and maximum of 45°C. June and July were the coldest months for the five year period, with average temperatures of 11°C and 10°C respectively. The minimum temperatures for these months were -2°C and -1°C respectively.

The annual average relative humidity reading at the Badgerys Creek site was 73%. The month with the highest relative humidity on average was June, with an average of 79%. The months with the lowest relative humidity were September and October (see **Table 4-2** and **Figure 4-7**).

The climate variables are consistent with the findings described in **BoM (2015)**.

Table 4-2: Temperature, rainfall and humidity statistics for Badgerys Creek (2010-2014)

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean temperature (°C)	23	22	20	17	13	11	10	12	15	17	20	21	17
Minimum temperature (°C)	10	11	9	5	1	-2	-1	0	1	5	7	8	-2
Maximum temperature (°C)	45	41	35	30	27	21	24	28	33	36	41	40	45
Mean rainfall (mm)	76	114	106	62	37	80	30	42	35	47	101	85	68
Mean relative humidity (%)	71	76	76	77	76	79	76	69	67	67	73	71	73

Source: **BoM (2014)**

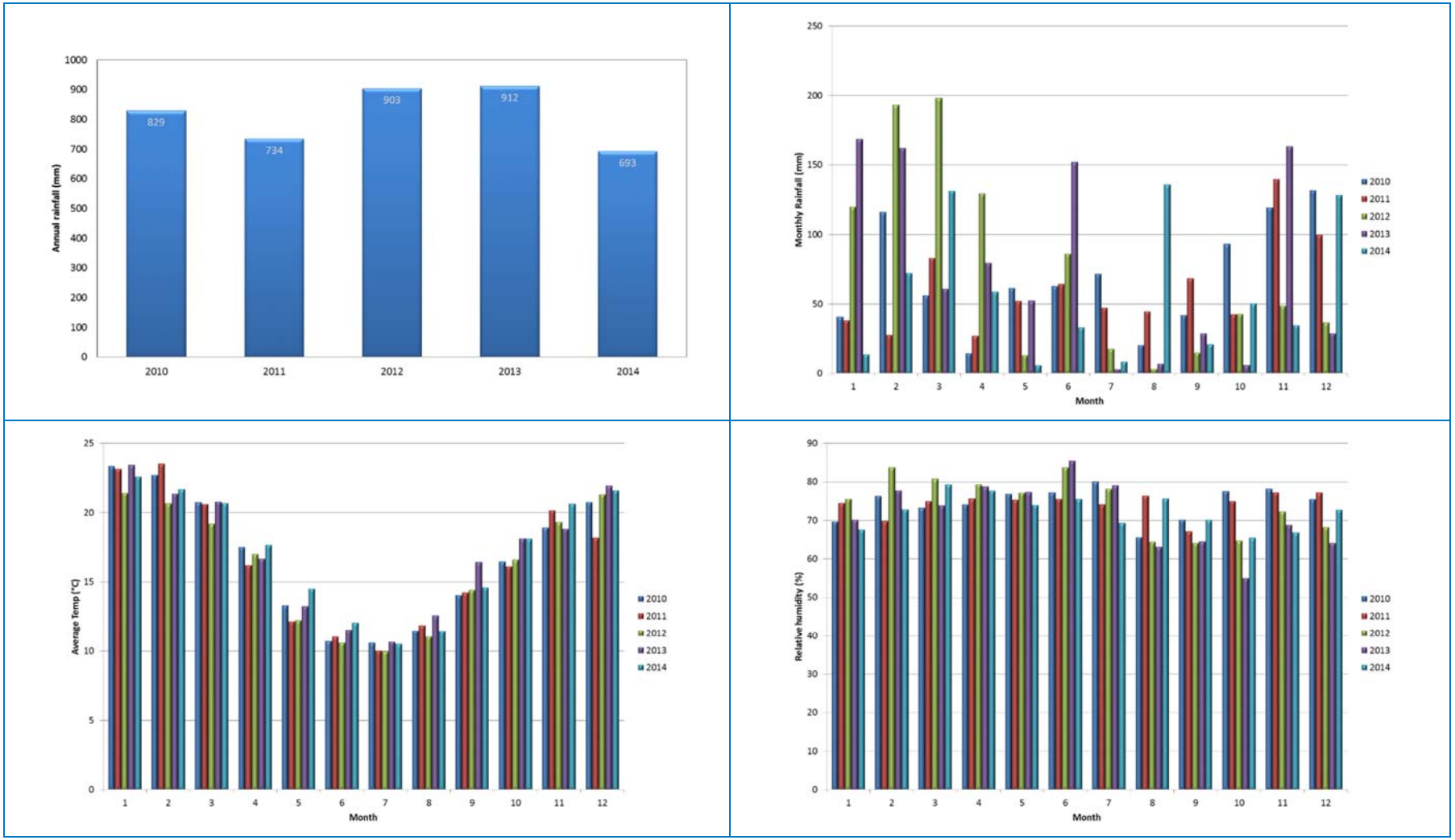


Figure 4-7 Annual and monthly average rainfall, temperature and relative humidity at Badgerys Creek (2010-2014)

4.1.3 Vertical profile

Measurements of the vertical profile of the lower atmosphere are made at Sydney (Kingsford Smith) Airport up to four times each day and are published as part of the NOAA/ESRL Radiosonde database. No other regular measurements of this kind are made within the Sydney region. The measurements are made using a radiosonde that measures wind speed and wind direction, typically up to 7,000 m above ground level. The vertical profile measurements of wind speed between 2010 and 2014 are shown in **Figure 4-8**.

The in-situ measurements of wind speed indicate that generally in the lower few hundred metres of the atmosphere the wind speeds are relatively low, recording up to 8 m/s. Layers of high wind speeds are observed between 800m and 1,000m and again between 3,500m and 4,500m. The highest observed wind speed was 116 m/s.

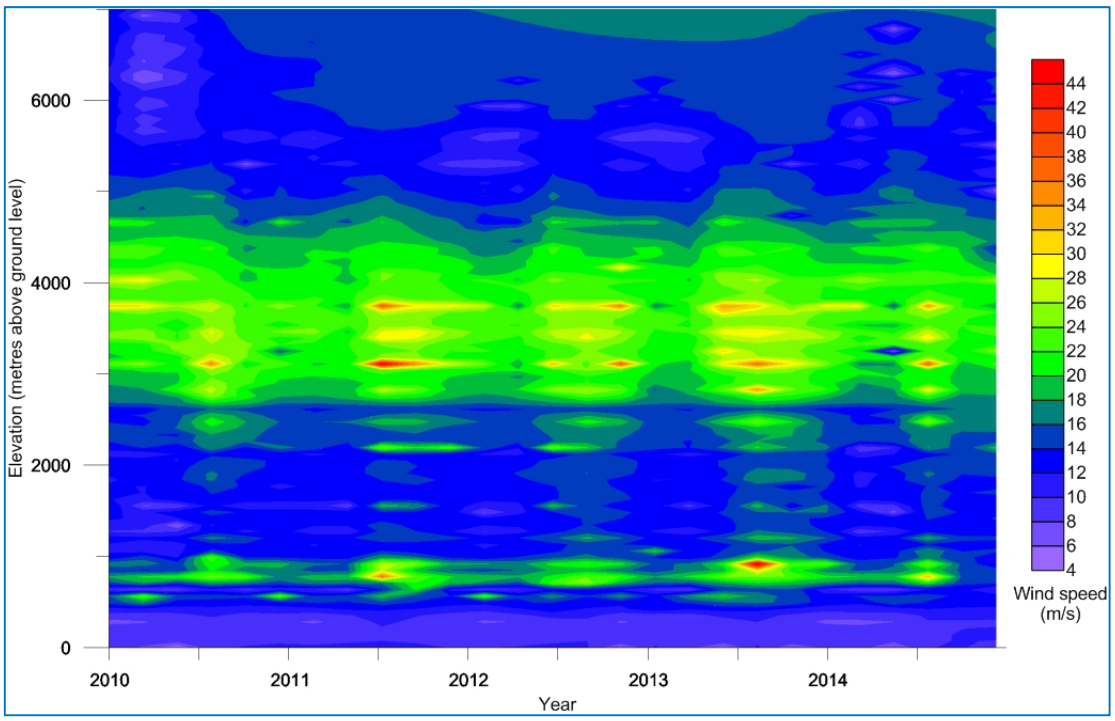


Figure 4-8: Vertical profile of wind speed at Sydney (Kingsford Smith) Airport 2010 – 2014

4.2 Ambient air quality

To assess the potential impacts of the proposal against the relevant air quality criteria in **Section 2**, it is necessary to have information on existing concentrations of these same pollutants for the study area such that the 'cumulative' (ambient conditions plus project incremental emissions) impact may be evaluated.

The NSW Office of Environment and Heritage (OEH) monitoring station at Bringelly was commissioned in 1992 and collects air quality data for air quality parameters including PM_{10}, NO_2 and SO_2. The Bringelly monitoring station is located to the south of the Hawkesbury basin in a semi-rural environment and 3.9 km southeast of the airport site. It is understood through communications with OEH that the SO_2 dataset between January and May 2014 was subject to minor calibration issues.

The Bringelly monitoring station does not measure all air quality parameters investigated as part of this assessment. For this reason, data from OEH air quality monitoring stations located further afield in Western Sydney have also been used. For example, the next closest site is Campbelltown West and is considered a suitable and conservative (as it is located in a more urban area) source for CO measurements and an alternative for the SO_2 data. The only stations in Western Sydney to measure $PM_{2.5}$ are Liverpool and Richmond.

Table 4-3 summarises the available air quality parameters measured at each site. The highlighted cells indicate which sites have been referenced within the assessment of cumulative impacts. **Figure 4-9** shows the location of each of the stations with respect to the airport.

A summary of the available air quality data is provided in the subsequent sections. Generally, air quality for the local area can be described as good, with the exception of isolated high pollution days or extreme events such as dust storms and bushfires. Uncontrolled combustion events such as bushfires will influence regional observations of PM_{10} and $PM_{2.5}$, and to a lesser extent, NO_x.

Table 4-3: Pollutants monitored

Monitoring station	O_3	CO	NO_2/NO_X	PM_{10}	$PM_{2.5}$	SO_2
Bringelly	✓	-	✓	✓	-	✓
Campbelltown West	✓	✓	✓	✓	-	✓
Liverpool	✓	✓	✓	✓	✓	-
Richmond	✓	-	✓	✓	✓	✓

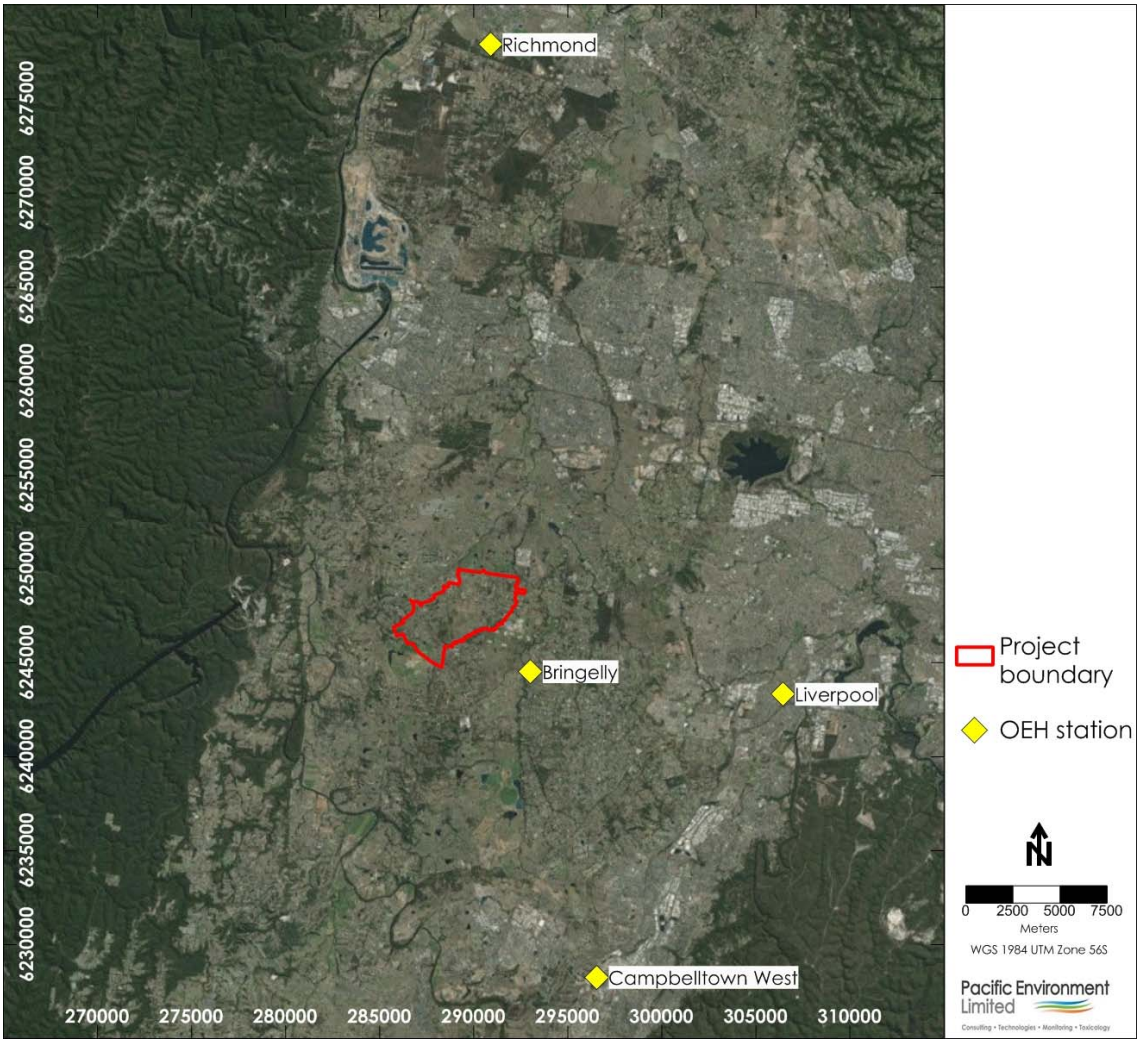


Figure 4-9: Air quality monitoring stations in proximity to the study area

4.2.1 Nitrogen dioxide

The maximum 1-hour, annual average and annual number of exceedances of the relevant criterion for NO_2 for the past ten years of measurements are shown in **Table 4-4**. The monthly mean concentrations are given in **Figure 4-10**.

Information in the table indicates that the NO_2 1-hour maximum concentration ranges between 51 µg/m^3 (2014) and 92 µg/m^3 (2005). The annual average concentrations in 2014 have decreased by 30% from 2004.

Table 4-4: Maximum 1-hour and annual average NO_2 concentrations at Bringelly

Year	1-Hour maximum (µg/m³)	Annual average (µg/m³)	Exceedances of 1-hour standard (days per year)
EPA criterion	**246**	**62**	**n/a**
2005	92	13	No exceedances
2006	82	13	No exceedances
2007	90	12	No exceedances
2008	68	10	No exceedances
2009	70	9	No exceedances
2010	76	12	No exceedances
2011	60	10	No exceedances
2012	78	11	No exceedances
2013	76	10	No exceedances
2014	51	10	No exceedances

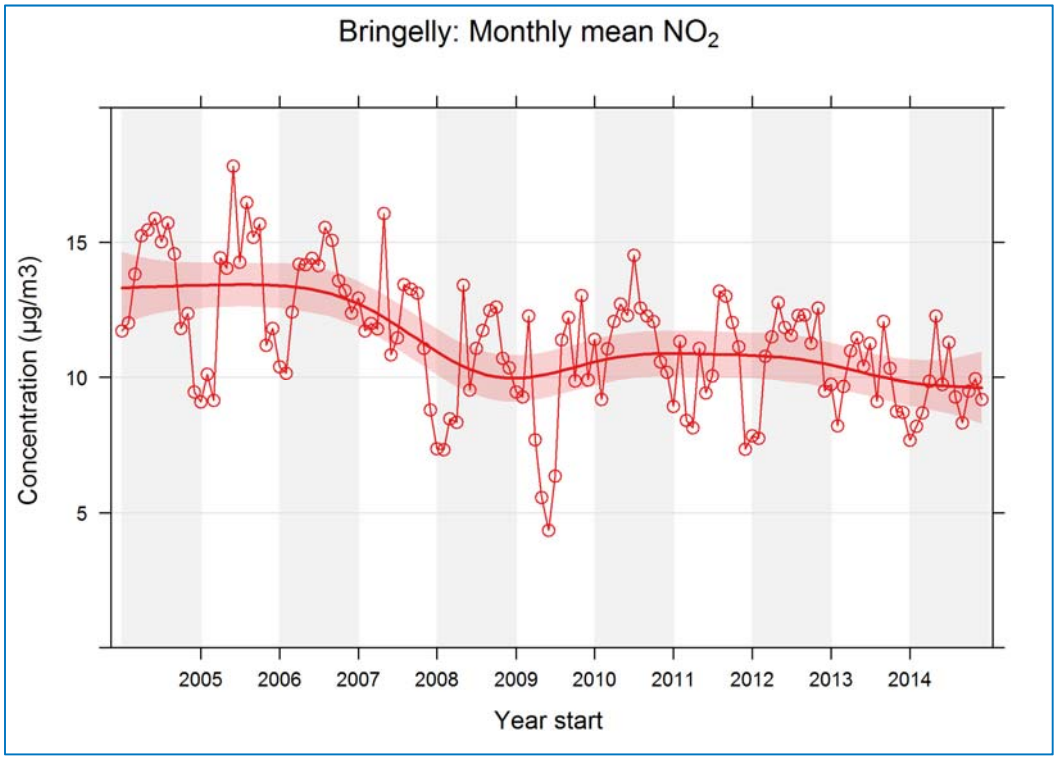


Figure 4-10: Monthly mean NO_2 concentrations at Bringelly

Monthly mean concentrations provide additional data on seasonal patterns in air quality. An example of the seasonal variation in NO_2 concentrations at the Bringelly monitoring site is provided in **Figure 4-10**. The Figure was produced using the 'smooth trend' function in the Openair software, and the shading around the trend line gives the 95% confidence intervals. The time series show a clear downward trend in the NO_2 concentrations most substantially between 2006 and 2009 and then again after 2012. There is a strong seasonal influence on the NO_2 concentrations, peaking during the winter months. This trend is attributed to a combination of more stable atmospheric conditions during this time of year that lead to reduced dispersion and the limited photochemical processes that react with NO_2 during the summer months.

Polar plots have been produced for the Bringelly monitoring data as these data provide a representation of the directional influences of existing emission sources in the vicinity of each monitoring station. Polar plots indicate how pollutant concentrations vary by wind speed and wind direction, with statistical smoothing techniques giving a continuous surface. The monitoring station is located at the centre of each plot. The axes show the directions from which the wind is coming, and the distance from the origin indicates the wind speed; the further from the centre that concentrations appear, the higher the wind speeds when they were measured. Calm conditions appear close to the centre. The polar plot for NO_2 concentrations measured between 2005 and 2014 is shown in **Figure 4-10**. The greatest concentrations originate from the east and are associated with the key local NO_x sources such as vehicle emissions from the M7 motorway that is located to the east of the Bringelly monitoring station.

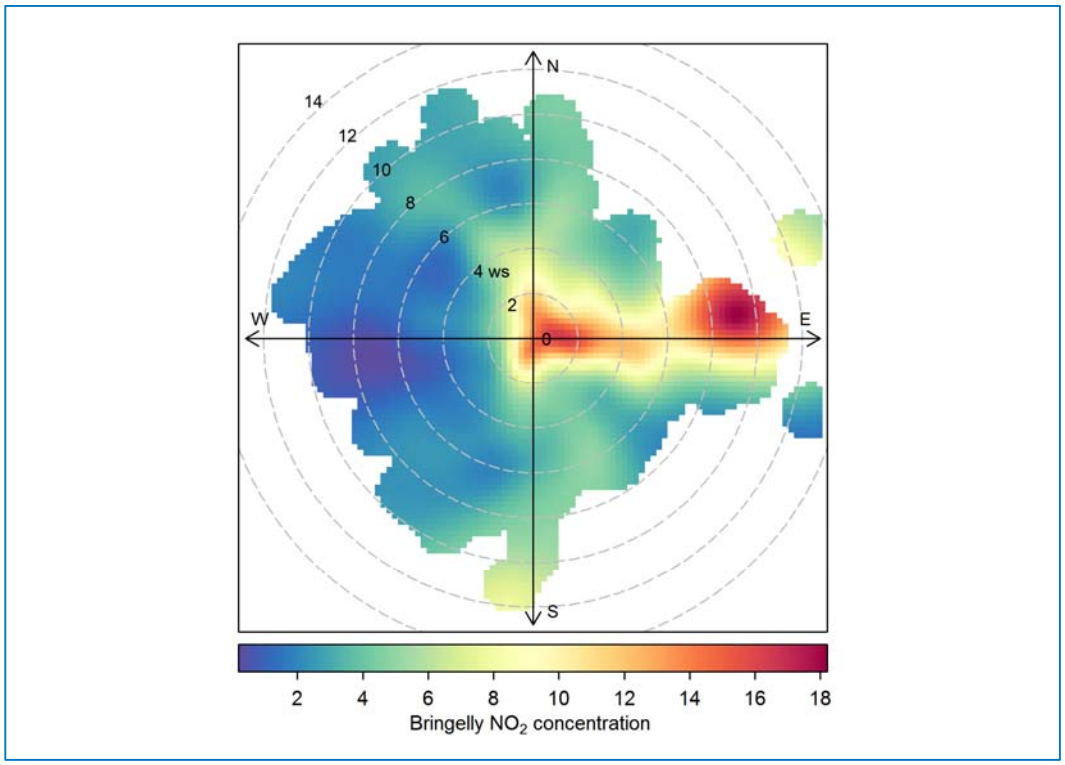


Figure 4-11: Polar plot of normalised NO_2 concentration at Bringelly

4.2.2 Ozone

Shown in **Table 4-5** are the maximum hourly and 4-hourly average O_3 concentrations over the past ten years at Bringelly. The data show that there have been multiple exceedances of one of the NSW EPA criteria (equivalent to the NEPM goal) in the region over the past ten years. The NEPM (Ambient Air) allows for one day of exceedance per year, and as such has been exceeded on several occasions. The long term trend in the monthly mean O_3 concentrations are shown in **Figure 4-12** and clearly illustrate the seasonal variability in ozone concentrations. This variability is associated with the availability of sunlight, where during the summer months sunlight drives photochemical activity that generates ozone.

Table 4-5: Maximum 1-hour and 4-hour average O_3 concentrations at Bringelly

Year	1-Hour maximum (µg/m³)	4-Hour maximum (µg/m³)	Exceedances of 1-hour standard (days per year)	Exceedances of 4-hour standard (days per year)
EPA criterion (NEPM goal)	**214**	**171**	**(1)**	**(1)**
2005	261	235	8	5
2006	240	218	6	3
2007	255	219	10	5
2008	199	155	0	0
2009	257	232	7	3
2010	223	179	2	1
2011	268	226	5	2
2012	188	149	0	0
2013	231	207	3	1
2014	265	237	4	3

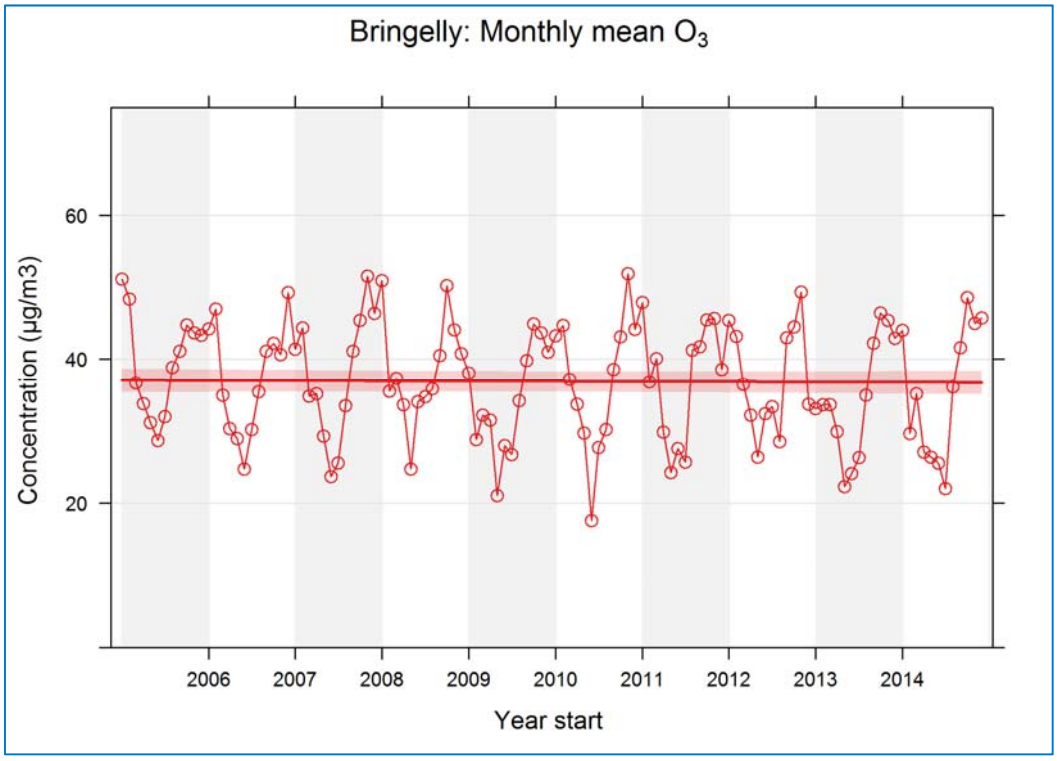


Figure 4-12: Monthly mean O_3 concentrations at Bringelly

4.2.3 Particulate matter

4.2.3.1 PM_{10}

Table 4-6 shows that maximum concentrations of 24-hour average PM_{10} have been fairly constant over the last 10 years, generally ranging between 40 µg/m³ and 97 µg/m³. The exception is 2009, where elevated 24-hour average PM_{10} concentrations were measured on a number of occasions as a result of a series of dust storms (recorded on 23/09/09, 26/09/09, 28/09/09, 29/09/09 and 22/11/09) that in some instances affected much of the state. Aside from 2009, the annual mean concentrations appear to

generally be decreasing with no exceedances of the annual criterion (30µg/m³).This is supported by the mean monthly trend shown in **Figure 4-13**.

Table 4-6: Maximum 24-hour and annual average PM_{10} concentrations at Bringelly

Year	24-Hour maximum (µg/m³)	Annual average (µg/m³)	No. of exceedances of 24-hour standard
EPA criterion	**50**	**30**	**n/a**
2005	55	19	2
2006	72	20	3
2007	51	18	1
2008	63	16	1
2009	1684	25	6
2010	41	15	No exceedances
2011	86	16	2
2012	40	16	No exceedances
2013	97	17	3
2014	43	17	No exceedances

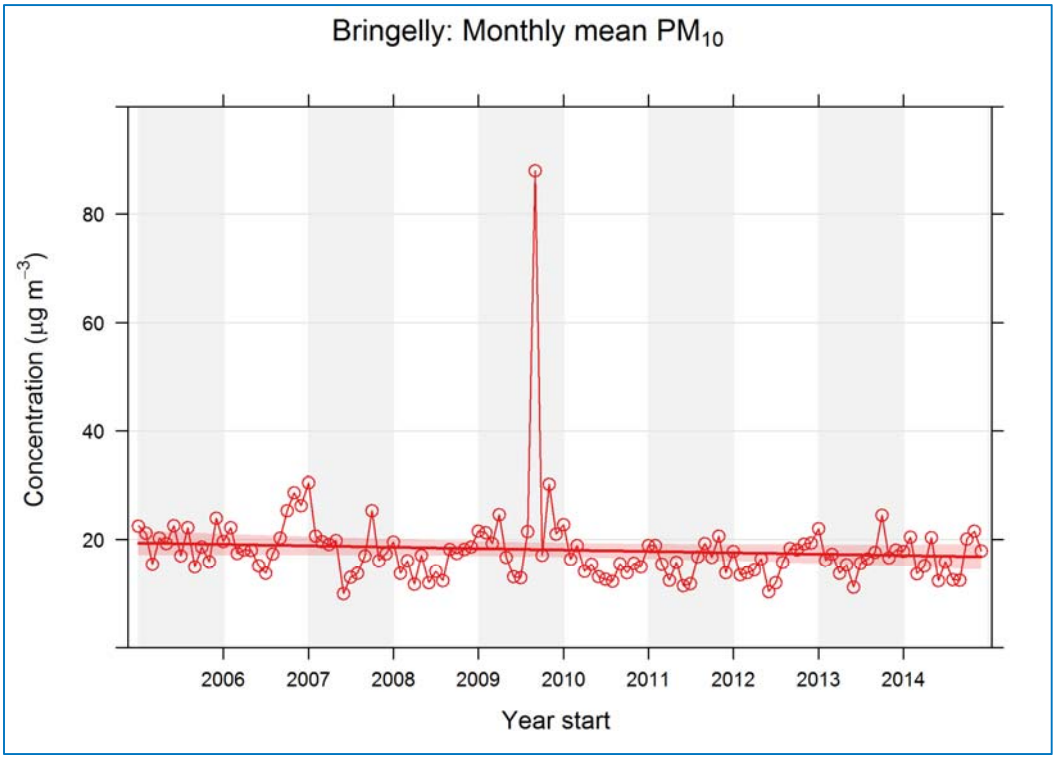


Figure 4-13: Monthly mean PM_{10} concentrations at Bringelly

A polar plot for the Bringelly PM_{10} monitoring data measured between 2005 and 2014 is shown in **Figure 4-14.** The greatest concentrations originate from the northwest, and to a lesser extent the east, west and southeast. The dominant northwest source is likely to be a function of natural events such as bushfires and dust storms that tend to be associated with hot dry prevailing winds originating from this direction. To the east and southwest are the densely populated precincts of Liverpool and Campbelltown which encompass a multitude of potential PM sources.

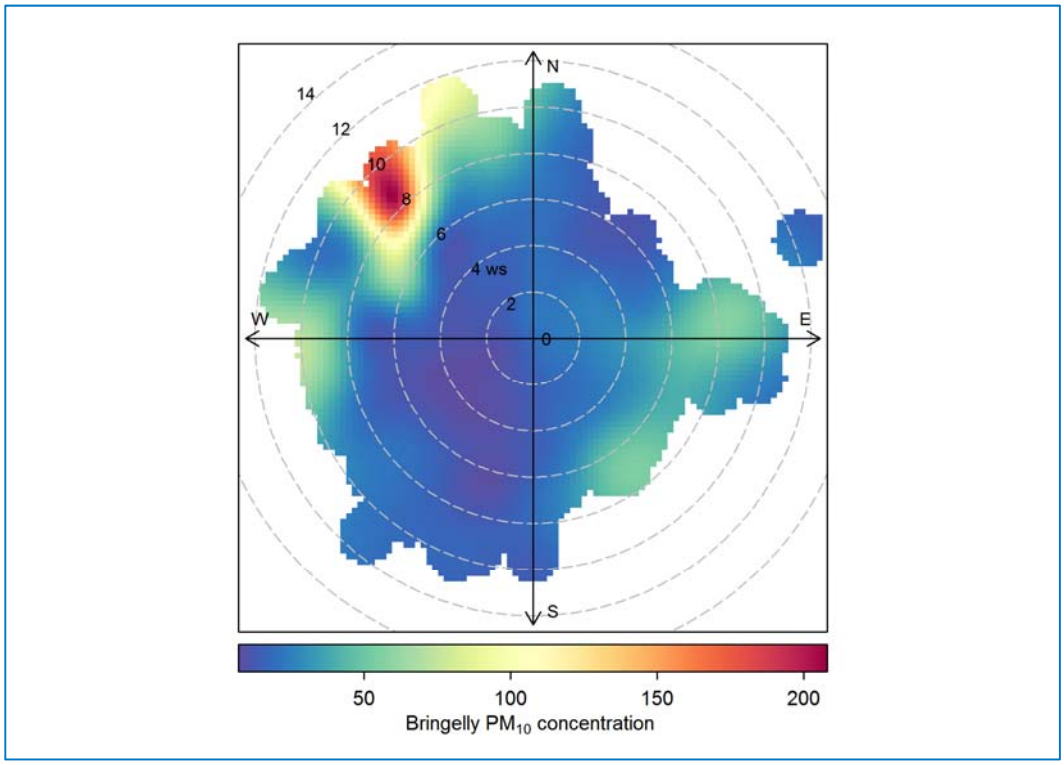


Figure 4-14: Polar plot of normalised PM_{10} concentration at Bringelly

4.2.3.2 $PM_{2.5}$

As $PM_{2.5}$ data are not measured at the Bringelly monitoring station, data from Liverpool and Richmond were selected to characterise the background (existing) concentrations of $PM_{2.5}$. Data is presented for the past ten years in **Table 4-7**. In general, data indicate that $PM_{2.5}$ concentrations are higher at Liverpool than Richmond, with combustion emissions from urbanisation anticipated to be a major source of the measured differences. There are a number of days across the monitoring period where the 24-hour average measurements are above the NEPM goal of 25 µg/m^3. As with the PM_{10} monitoring data (see **Section 4.2.3.1),** the dust storms from 2009 have also been captured in the data set, recording up to 268 µg/m^3 at Liverpool.

The long term trend in $PM_{2.5}$ concentrations in Western Sydney is shown in the monthly mean measurements in **Figure 4-15** and **Figure 4-16** for Liverpool and Richmond respectively. A clear upward trend in the data at both sites is observed from 2013 onwards. This timing corresponds with a change in monitoring techniques across the OEH monitoring network from the use of tapered element oscillating microbalances (TEOMs) to beta attenuation monitors (BAMs). Accordingly, this change is considered an artefact of the monitoring technique rather than an actual increase in $PM_{2.5}$ concentrations.

Table 4-7: Maximum 24-hour and annual average $PM_{2.5}$ concentrations at Liverpool and Richmond

Year	24-Hour max (µg/m³)		Annual average (µg/m³)		No. of exceedances of 24-hour standard	
	Liverpool	Richmond	Liverpool	Richmond	Liverpool	Richmond
NEPM advisory goal	**25**		**8**		**n/a**	
2005	31	23	8	6	2	0
2006	48	78	9	6	3	1
2007	23	21 (a)	7	6 (a)	0	0
2008	32	18	6	7	1	0
2009	268	149	8	6	5	2
2010	22	21	6	4	0	0
2011	38	43	6	5	2	2
2012	25	117	9	5	0	2
2013	74	83	9	8	2	14
2014	24	25	9	7	0	0

Notes: (a) Less than 75% data retrieval for year

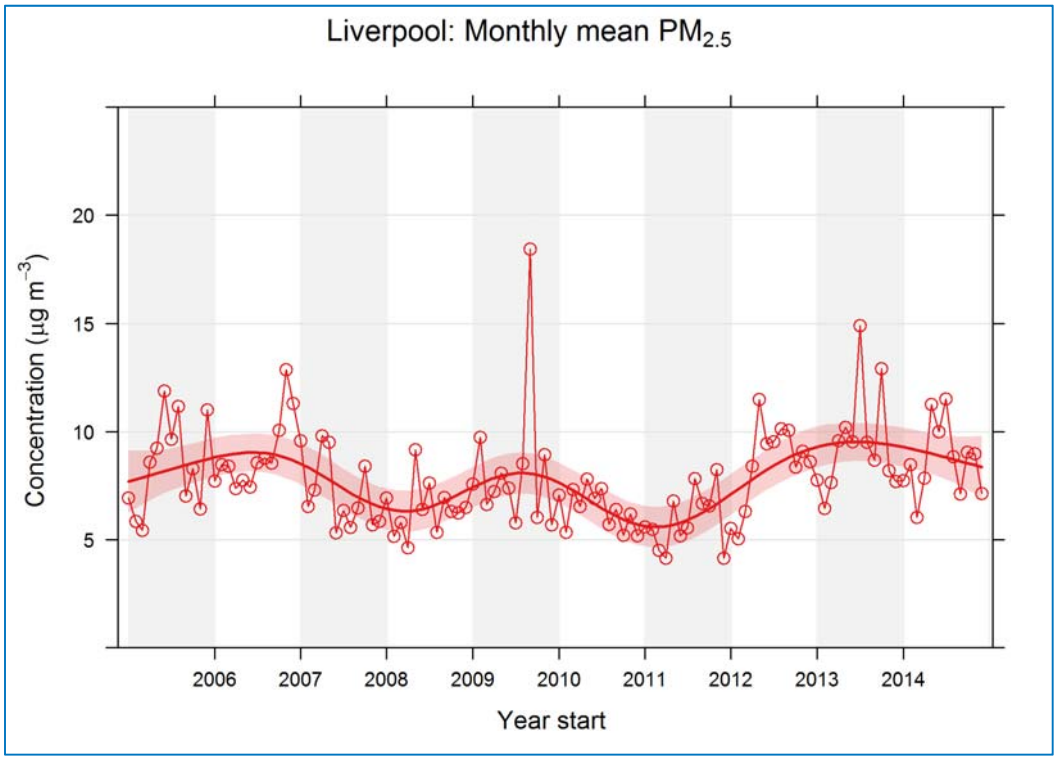


Figure 4-15: Monthly mean $PM_{2.5}$ concentrations at Liverpool

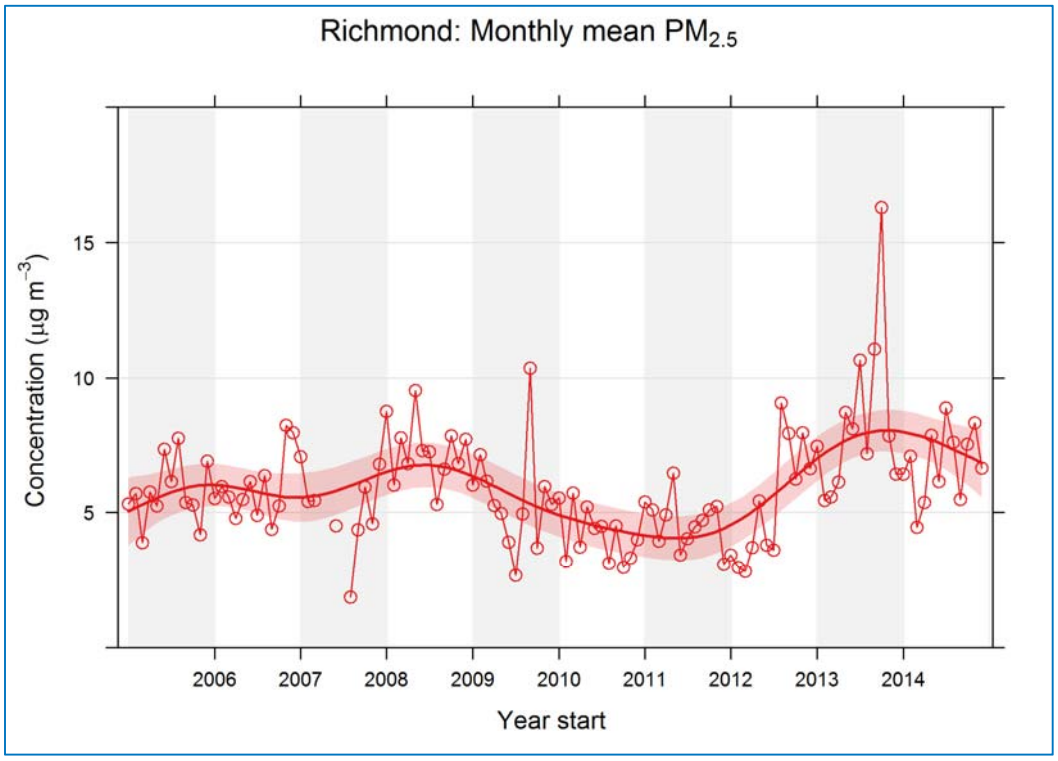


Figure 4-16: Monthly mean $PM_{2.5}$ concentrations at Richmond

4.2.3.3 Ultrafine particulate matter

A considerable amount of attention in recent years has focussed on ultrafine particles (UFPs). These are particles with a diameter of less than 0.1 µm. Whilst there is some evidence particles in this size range are associated with adverse health effects (see **Appendix B**), it is not currently practical to incorporate them into an environmental impact assessment. There are several reasons for this, including the rapid transformation of such particles in the atmosphere, the need to treat UFPs in terms of number rather than mass, the lack of robust emission factors and concentration-response functions, the lack of ambient background measurements, and the absence of air quality standards.

In relation to concentration-response functions, the **WHO Regional Office for Europe (2013)** has stated the following:

> *'… the richest set of studies provides quantitative information for $PM_{2.5}$. For ultrafine particle numbers, no general risk functions have been published yet, and there are far fewer studies available. Therefore, at this time, a health impact assessment for ultrafine particles is not recommended.'*

For the purpose of this assessment, we have therefore assumed that the effects of UFPs on health are adequately represented through an evaluation of the impacts of $PM_{2.5}$.

4.2.3.4 Deposited dust

The measurement of deposited dust is typically undertaken to evaluate specific industries such as quarries and mining projects. Accordingly, publicly available data representative of existing local conditions are not available for this assessment. It is acknowledged that there are several quarries in the area, however, any such monitoring data are likely to be impacted by these operations and therefore provide an overly conservative estimate. On that basis, it was considered appropriate to adopt a

(conservative) assumption of background dust loadings of 2 g/m^2/month. The adopted value thus allows for the construction of the airport to incrementally contribute an additional 2 g/m^2/month to meet the NSW EPA's cumulative criterion of 4 g/m^2/month.

4.2.4 Carbon monoxide

As CO data is unavailable at the OEH Bringelly weather station, data has been taken from Macarthur as it is the closest available site. **Table 4-8** shows CO concentrations at Macarthur for the past 10 years. 1-hour maximum concentrations of CO show a reasonably stable trend through the years with a slight decrease after 2006. The 8-hour maximum concentrations also show a slight decrease that occurred after 2007. There have been no exceedances of 1-hour or 8-hour CO health criteria at Macarthur.

The long term trend in CO concentrations is shown in the monthly mean measurements in **Figure 4-17** for Macarthur. Only a short data set is available from the Campbelltown West monitoring station and therefore has limited value. There is a sharp decrease in the mean monthly CO concentrations measured at Macarthur in 2009, only to rise again and be relatively stable from 2010 onwards. The reason for this is not clear, and may be a function of the monitoring instrumentation rather than a regional trend.

Table 4-8: Maximum 15-minute, 1-hour and 8-hour average CO concentrations at Macarthur and Campbelltown West

Year	15-minute maximum (mg/m^3)		1-hour maximum (mg/m^3)		8-hour maximum (mg/m^3)	
	Macarthur	C' West	Macarthur	C' West	Macarthur	C' West
EPA criterion	**100**	**100**	**30**	**30**	**10**	**10**
2005	-	-	2.3 (a)	-	1.2 (a)	-
2006	-	-	2.5	-	2.3	-
2007	-	-	2.4	-	2.2	-
2008	-	-	1.5	-	1.1	-
2009	-	-	1.6	-	0.9	-
2010	-	-	2.0	-	1.1	-
2011	-	-	2.1	-	1.3	-
2012	-	-	1.1 (a)	1.1 (a)	0.8 (a)	0.8 (a)
2013	-	-	-	10.5	-	8.6
2014	-	2.1	-	1.5	-	1.2

Notes: (a) Less than 75% data retrieval for year

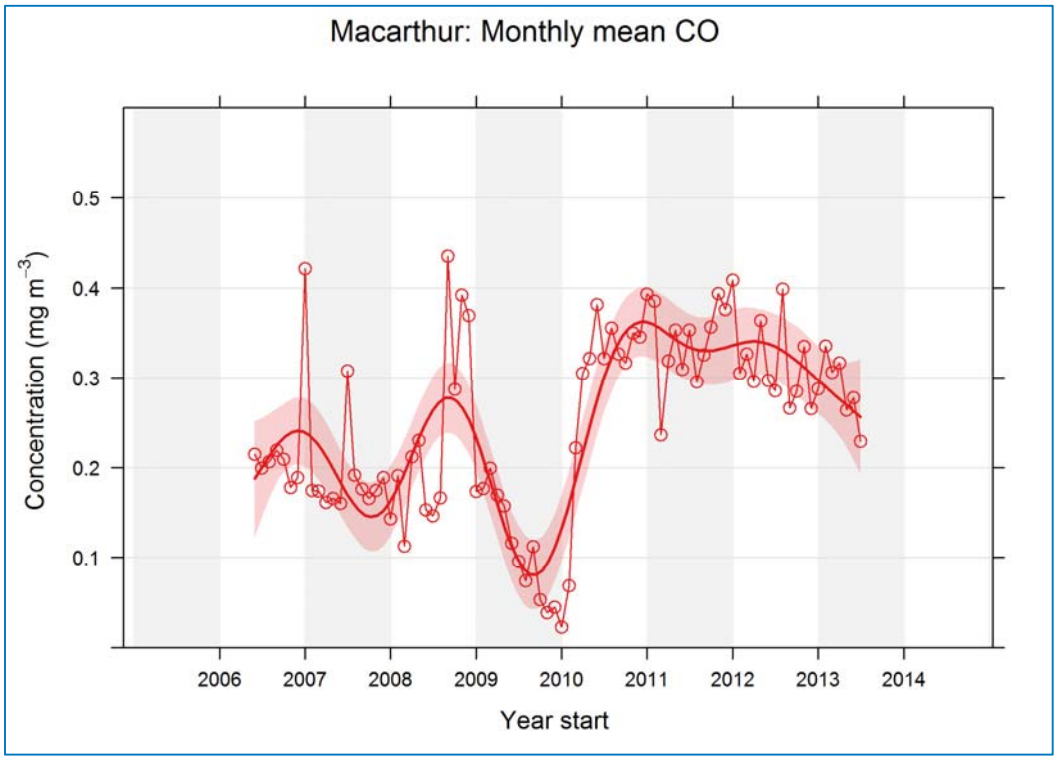


Figure 4-17: Monthly mean CO concentrations at Macarthur

4.2.5 Sulphur dioxide

To establish baseline SO_2 concentrations for the study area, data has been reviewed from multiple monitoring stations. This is because between January and May 2014 the Bringelly SO_2 instrument was subject to calibration issues and the data may was considered unreliable during this period. Data from the next closest site at Campbelltown West was therefore also reviewed. **Table 4-9** provides a summary of the SO_2 measurements over the past 10 years.

SO_2 also shows fluctuating 1-hour maximum concentrations at Macarthur. In 2007 and 2008, 1-hour maximum concentrations of SO_2 rose by 50% from the 2006 level. Concentrations decreased during 2010 and 2011 and subsequently rose again in 2011. 24-hour concentrations follow a similar trend to the 1-hour maximums with a significant drop in 2010 and subsequent increase in 2011. Annual average SO_2 concentrations appear to have decreased from 2010 to 2011. No exceedances of the OEH impact assessment criterion were observed for any of the required averaging periods for the time period reviewed.

The long term trend in SO_2 concentrations at Bringelly is shown in the monthly mean measurements in **Figure 4-17**. Only a short dataset is available from the Campbelltown West monitoring station and therefore it has limited value. There is a decrease in the mean monthly SO_2 concentrations measured in 2009, only to rise again and be relatively stable from 2010 onwards.

A polar plot for the Bringelly SO_2 monitoring data measured between 2005 and 2014 is shown in **Figure 4-19**. The greatest concentrations originate from the east, and are most likely associated with vehicle emissions and industry located in this direction.

Table 4-9: Maximum 15-minute, 1-hour, 8-hour and annual average SO_2 concentrations at Bringelly, and Campbelltown West

Year	10-minute maximum (µg/m³)	1-hour maximum (µg/m³)		24-hour maximum (µg/m³)		Annual average (µg/m³)	
	C' West	Bringelly	C' West	Bringelly	C' West	Bringelly	C' West
EPA criterion							
2004	-	43	-	6.8	-	0.6	-
2005	-	26	-	7.5	-	0.7	-
2006	-	26	-	6.3	-	1.0	-
2007	-	49	-	8.2	-	1.2	-
2008	-	54	-	7.5	-	0.3	-
2009	-	34	-	9.2	-	-0.8	-
2010	-	23	-	5.7	-	0.7	-
2011	-	31	-	5.2	-	0.3	-
2012	-	43	23 (a)	5.1	5.7 (a)	0.5	1.4 (a)
2013	-	31	26	7.0	6.8	0.7	1.3
2014 (b)	80 (c)	26	34	8.5	9.9	0.7	1.2

Notes: (a) Less than 75% data retrieval for year.
(b) Calibration issue with instrument between January and May 2014. The data have been included for completeness.
(c) Hi resolution data was available for Campbelltown West only.

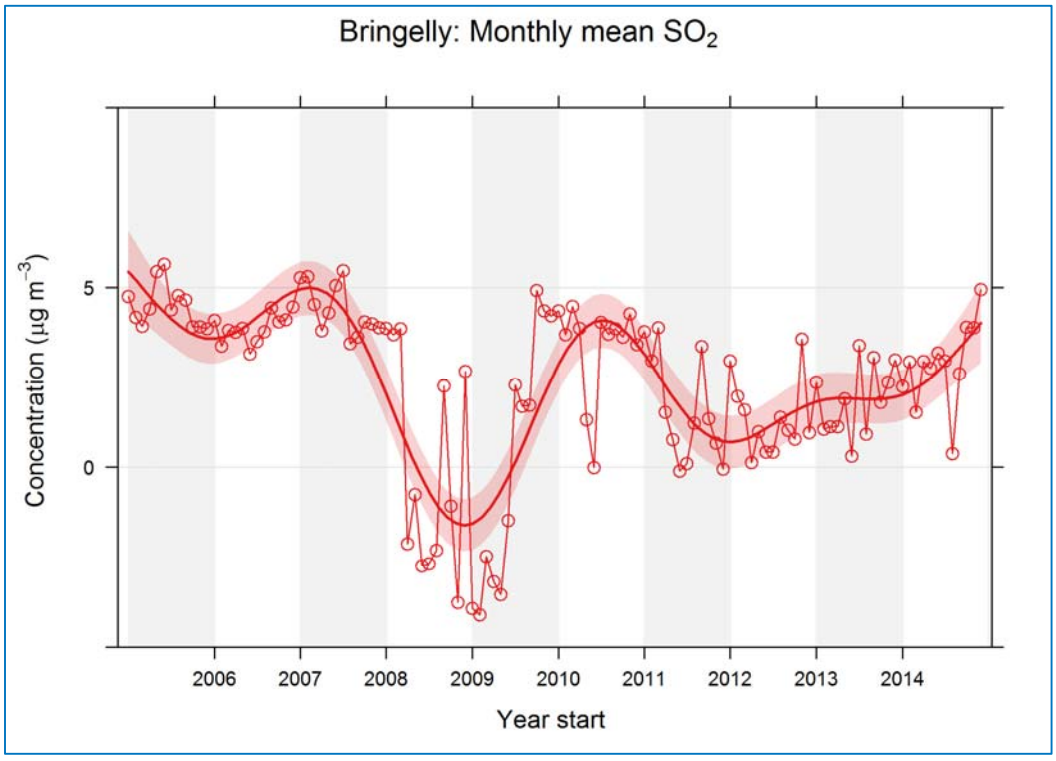


Figure 4-18: Monthly mean SO_2 concentrations at Bringelly

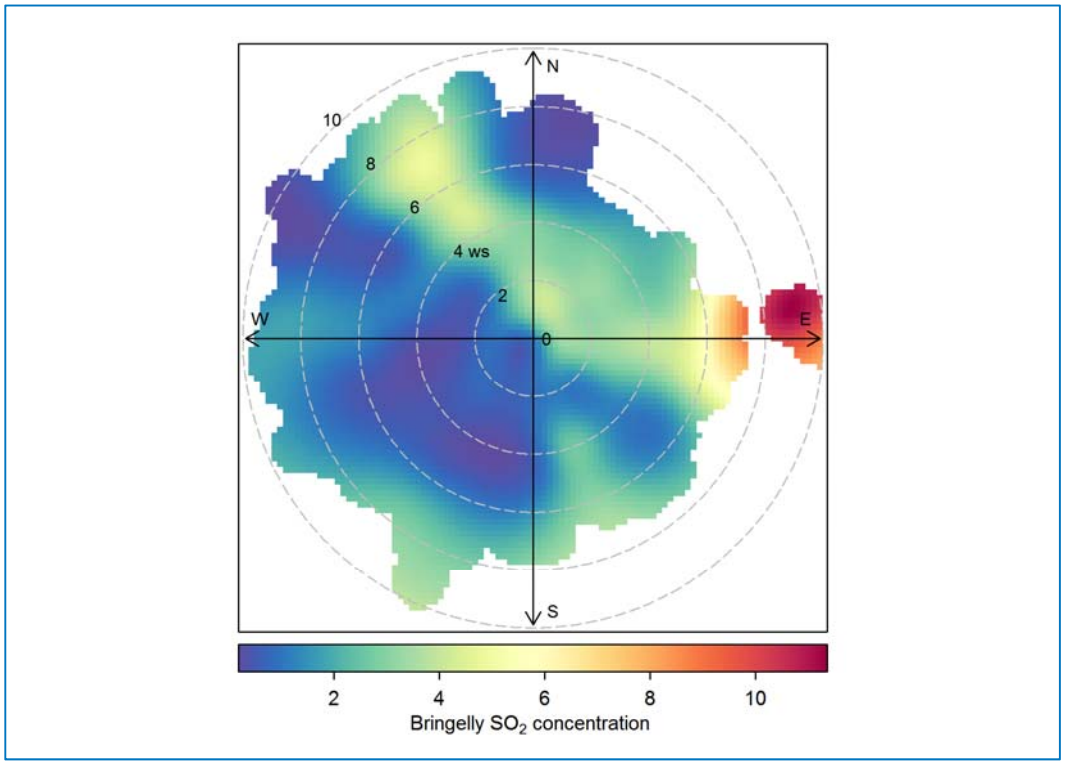


Figure 4-19: Polar plot of normalised SO_2 concentration at Bringelly

4.2.6 Air toxics

Continuous monitoring of air toxics is not measured as part of the OEH air quality monitoring network or under any other program at present. It is understood that a campaign of air toxics monitoring is currently underway, however no details of the study or results are available. To establish baseline air toxic concentrations, it is therefore necessary to reference a historical measurement campaign.

Between 1996 and 2001, the EPA (then Department of Environment and Conservation (DEC)) conducted the Air Toxics Monitoring Project (ATMP) which investigated concentrations of the NEPM air toxics (benzene, toluene, xylene and PAHs such as benzo[a]pyrene) for 24-hour periods at numerous locations across Sydney and NSW **(DEC 2004a, DEC 2004b)**.

The Ambient Air Quality Monitoring and Fuel Quality Testing Project (AAQMFQTP) collected 24-hour concentrations of formaldehyde at Rozelle and Turella for a one-year period from October 2008 to October 2009. The full report is not in the public domain, however results have been published as part of the NSW EPA's *Current Air Quality in New South Wales* technical paper **(DECCW, 2010)**.

The ATMP found ambient concentrations of most tested substances were well below international ambient air quality goals at the time. The AAQMFQTP also found low concentrations of all chemical pollutants, with many observations below the detection limit of the method. Concentrations of the five air toxics noted in the Air Toxics NEPM were low compared to the relevant measurement investigation level (see **Table 2-3**).

Table 4-10: Historical air toxics monitoring data

Study	Location	Averaging period	Benzene	Toluene	Xylene (m +p)	Xylene (o)	Form-aldehyde	PAH	B[a]P
		Unit	ppm	ppm	ppm	ppm	µg/m³	ng/m³	ng/m³
ATMP (1996 – 2001)	Sydney CBD	Annual	8.0	17.3	3.8	10.4	n/a	7.2	0.8
		24-hr	18.1	41.1	12.8	29.4	n/a	14.3	1.7
	Rozelle	Annual	3.8	9.0	1.9	4.7	n/a	2.4	0.2
		24-hr	21.3	65.8	11.4	31.3	n/a	11.4	1.4
	St Marys	Annual	1.4	3.3	0.5	1.9	n/a	n/a	n/a
		24-hr	4.2	13.6	3.3	7.6	n/a	n/a	n/a
	Blacktown	Annual	n/a	n/a	n/a	n/a	n/a	2.5	0.2
		24-hr	n/a	n/a	n/a	n/a	n/a	14.3	1.9
AAQMFQTP (2008 – 2009)	Turella	Annual	1.4	7.4	3.3	1.4	1.9	n/a	n/a
		24-hr	n/a	n/a	n/a	n/a	5.9	n/a	n/a
	Rozelle	Annual	1.0	3.7	2.4	0.9	1.8	n/a	n/a
		24-hr	n/a	n/a	n/a	n/a	4.3	n/a	n/a

4.2.1 Odour

The airport site is relatively isolated from other industry that has the potential to be odorous. The exception is the poultry industry with a number of broiler and egg-laying farms in the vicinity, particularly to the east of the airport site. Multiple sources of odour are typically only treated cumulatively when similar in character, and as such consideration of background odour has not been included as part of this assessment.

4.3 Adopted background concentrations

Various time periods are used in the air quality criteria (**Table 2-2**) and the availability of data for different air quality metrics is variable. Therefore, three different approaches were used to determine background concentrations for assessment purposes.

- For annual averages, the highest concentrations from the OEH monitoring sites (for 2014) were taken to represent the background concentration at the airport for the Stage 1 and longer term development scenarios.
- For short-term maxima where monitoring data exists, the maximum value was adopted.
- The exception to this was for NO_2, PM_{10} and $PM_{2.5}$, for which time-varying background data was used (see **Section 3.4.1**).

The adopted background concentrations are presented in **Table 4-11**.

Table 4-11: Summary of assumed background concentrations

Pollutant	Averaging period	Year	Value used for background		Location
CO	15 min.	2014	2.1	mg/m³	Campbelltown West
	1 hour	2014	1.5	mg/m³	
	8 hours	2014	1.2	mg/m³	
NO_2	1 hour	2014	Varying		Bringelly
	1 year	2014	10	µg/m³	
PM_{10}	24 hours	2014	Varying		Bringelly
	1 year	2014	17	µg/m³	
$PM_{2.5}$	24 hours	2014	Varying		Bringelly (b)
	1 year	2014	7	µg/m³	
Deposited dust	1 year	n/a	2	g/m²/month	n/a
SO_2	10 min.	2014	80	µg/m³	Campbelltown West
	1 hour	2014	34	µg/m³	
	24 hours	2014	9.9	µg/m³	
	1 year	2014	1.2	µg/m³	
Benzene	1 year	2008-09	1.0	µg/m³	Rozelle
Toluene (a)	24 hours	2008-09	15.3	µg/m³	Rozelle
	1 year	2008-09	3.7	µg/m³	
Xylenes (a)	24 hours	2008-09	16.6	µg/m³	Rozelle
	1 year	2008-09	2.4	µg/m³	
Formaldehyde	24 hours	2008-09	4.3	µg/m³	Rozelle
B[a]p	1 year	2008-09	0.2	ng/m³	Blacktown

Notes: (a) 24-hour average value has been pro-rated based on the 1996-2001 data from **Table 4-10**.
(b) Based on 2014 $PM_{2.5}$ / PM_{10} ratio of 0.31 at Liverpool and Richmond.

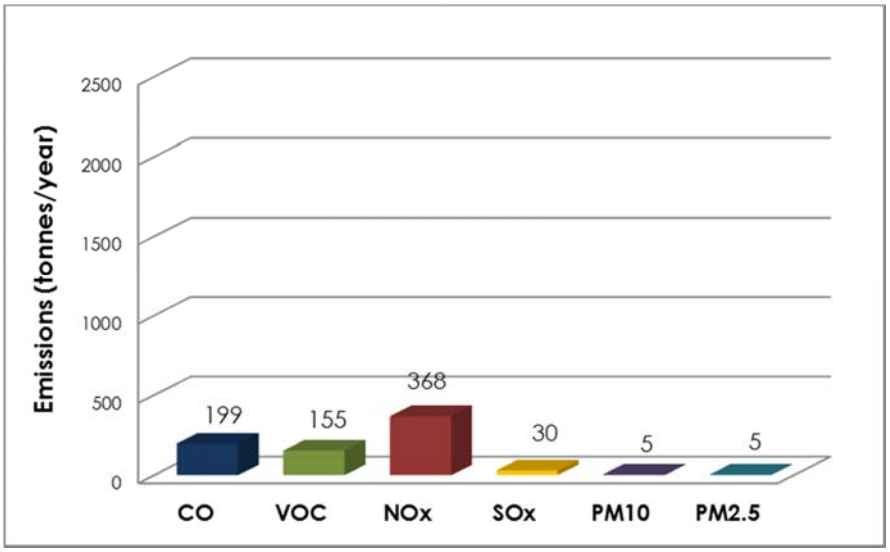
5 OPERATIONAL IMPACT ASSESSMENT

This Chapter describes the results of the emission calculations and air dispersion modelling. Emission inventories were compiled using activity data for the Stage 1 development and longer term development.

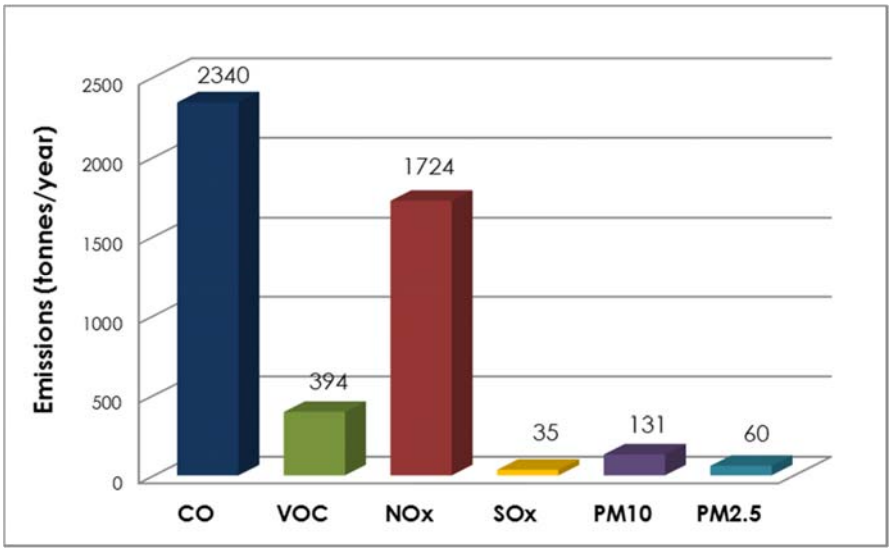
5.1 Emissions

5.1.1 Stage 1 development

The emissions of criteria pollutants from the airport operations during Stage 1 are presented in **Figure** 5-1. The incremental emissions comprie aircraft, APUs, GSE, parking facilities, terminal traffic, stationary sources and training fires. Cumulative emissions include the respective airport sources and in addition emissions from the external roadways.



Airport emissions (incremental)



Airport and external road emissions (cumulative)

Figure 5-1: Total estimated emissions for criteria pollutants during Stage 1 development

The marked difference between the airport emission inventory in isolation compared with that of the external road emissions shown in **Figure 5-1** is further illustrated in **Figure 5-2**. **Figure 5-2** shows the airport emissions and external road emissions as a percentage of the total emissions modelled, by pollutant for the Stage 1 development.

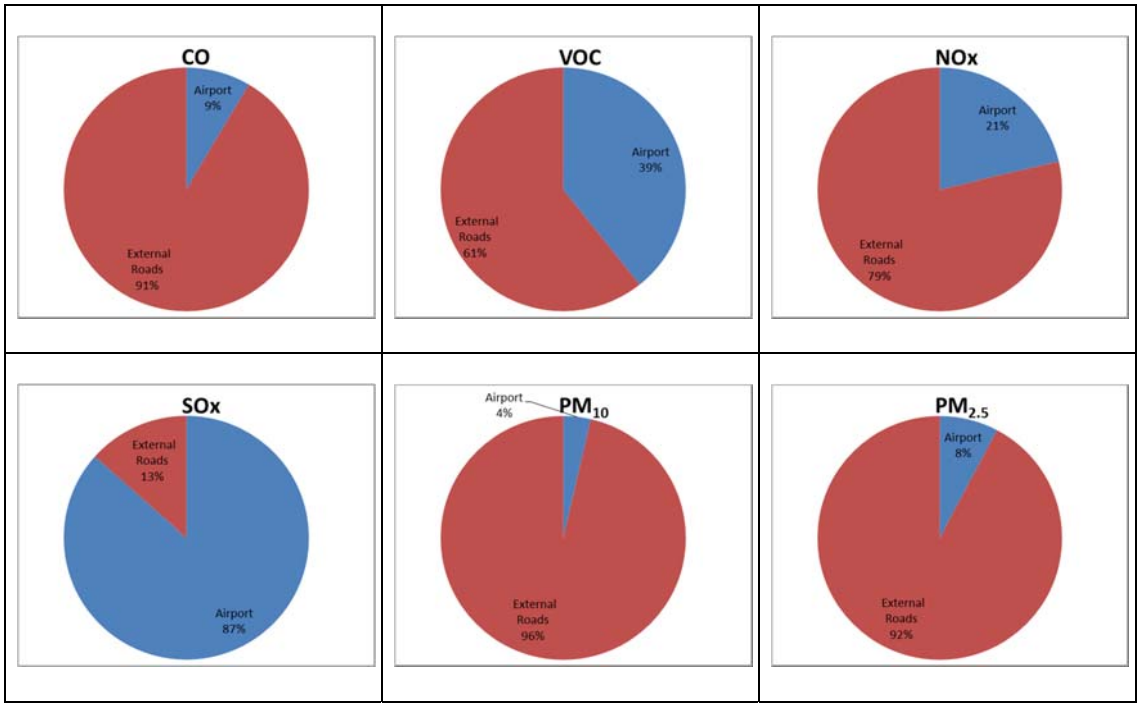


Figure 5-2: Estimated airport and external roads emissions as a percentage of total modelled for criteria pollutants during Stage 1 development

The emission inventory for the Stage 1 airport development is presented by source type in **Table 5-1**. In each table, the percentage contribution of each source category is shown alongside the emission value. Emission totals have been provided with and without the cumulative contributions from external roadways.

The external roadways are estimated to contribute by far the largest source of emissions for this modelling scenario. This is attributed to the extent of the road network, the number of vehicles using the road network and the associated emissions that have been included in the modelling (see **Appendix C**) and should be considered in context.

Review of the incremental emissions (i.e. those emissions from within the airport site only) show that the emissions from aircraft engines are the most significant source.

Emissions from APUs, GSE, parking facilities and terminal traffic were also established as significant emission sources. In the case of CO, the largest single source was GSE (24%), while for NO_x, APUs were the next largest source (5%). Stationary sources, in particular fuel tanks, are a significant contributor to VOC emissions. Of the on-site fuel storage facility, evaporative losses from jet fuel at the fuel farm is calculated to account for over 99% of losses compared with those from diesel and petroleum, reflecting this fuel source's volatility.

When the cumulative contributions from the external roadways are considered, they account for an estimated 97% of PM_{10}, 93% of $PM_{2.5}$ and 79% of NO_x total emissions with the remaining emissions comprising those from the airport.

Table 5-1: Airport emission inventory for criteria pollutants – Stage 1 development

Category	Emissions (tonnes per year)											
	CO		VOC		NO_x		SO_2		PM_{10}		$PM_{2.5}$	
Aircraft engines	126.5	64%	26.5	17%	335.9	91%	23.3	77%	1.8	39%	1.8	39%
GSE	48.6	24%	2.0	1%	4.5	1%	0.5	2%	0.3	6%	0.3	6%
APUs	4.7	2%	0.5	0%	17.3	5%	1.6	5%	1.1	23%	1.1	23%
Parking Facilities	9.4	5%	1.0	1%	0.4	0%	0.0	0%	0.0	1%	0.0	0%
Terminal traffic	4.9	2%	0.5	0%	1.2	0%	0.0	0%	0.2	4%	0.1	2%
Stationary Sources	2.4	1%	62.0	40%	4.4	1%	4.7	16%	0.3	7%	0.3	7%
Boilers	1.9	1%	0.1	0%	2.4	1%	0.0	0%	0.2	4%	0.2	4%
Engine tests	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Fuel tanks	-	-	54.5	35%	-	-	-	-	-	-	-	-
Generators	0.4	0%	0.1	0%	2.0	1%	0.1	0%	0.1	3%	0.1	3%
Paint and Solvent	-	-	7.2	5%	-	-	-	-	-	-	-	-
Training Fires	0.0	0%	0.1	0%	0.0	0%	0.0	0%	0.7	15%	0.7	15%
Total (airport)	**199**	**100%**	**155**	**100%**	**368**	**100%**	**30**	**100%**	**5**	**100%**	**5**	**100%**
External roadways	2141	91%	239	72%	1355	79%	4.7	13%	126	96%	54.9	92%
Airport	199	9%	155	28%	368	21%	30	87%	5	4%	5	8%
Total including external roadways	**2340**	**100%**	**394**	**100%**	**1724**	**100%**	**35**	**100%**	**131**	**100%**	**60**	**100%**

Notes: (a) Includes contribution from airport traffic on roadways outside the airport site.

Forecast emissions from the proposed airport have also been considered in the context of the Sydney airshed. Projected emissions data for the Sydney airshed were prepared by **EPA (2012a)** for the years 2016, 2021, 2026, 2031 and 2036. The projected emissions for 2031 have been compared with the total emissions from the proposed airport and shown in **Table 5-2**. As the Sydney airshed forecast emissions are not available for 2030, it has been assumed that they will be the same as 2031. The emissions from the airport represent up to 0.7% (NO_x) of the total anthropogenic emissions within the Sydney airshed.

Table 5-2: Forecast Sydney airshed emissions compared with forecast airport emissions during Stage 1

Pollutant	Forecast Sydney airshed emissions in 2031 (tonnes/year)	Forecast airport emissions in 2030 (tonnes/year)	Forecast airport emissions compared with Sydney airshed in 2030 (%)
CO	166,802	199	0.1%
VOC	98,369	155	0.2%
NO_x	51,452	368	0.7%
SO_2	18,522	30	0.2%
PM_{10}	10,446	5	<0.1%
$PM_{2.5}$	12,834	5	<0.1%

Source: Forecast 2031 Sydney Airshed emissions from EPA 2012a.
Note: Forecast airport emissions does not include contributions from external roadways

Given the contribution of aircraft engine emissions to local air quality, a split of emissions by operational mode is provided in **Figure 5-3** for the Stage 1 development.

The relative contributions of the different modes are a function of both the efficiency of fuel combustion and the rate of fuel consumption. For CO and VOC, the main source of aircraft emissions was taxiing in and out, and also start-up in the case of VOCs. For NO_X, the main sources were take-off and climb-out. All modes of operation contributed significantly to SO_X, PM_{10} and $PM_{2.5}$ emissions, with the largest single source being take-off.

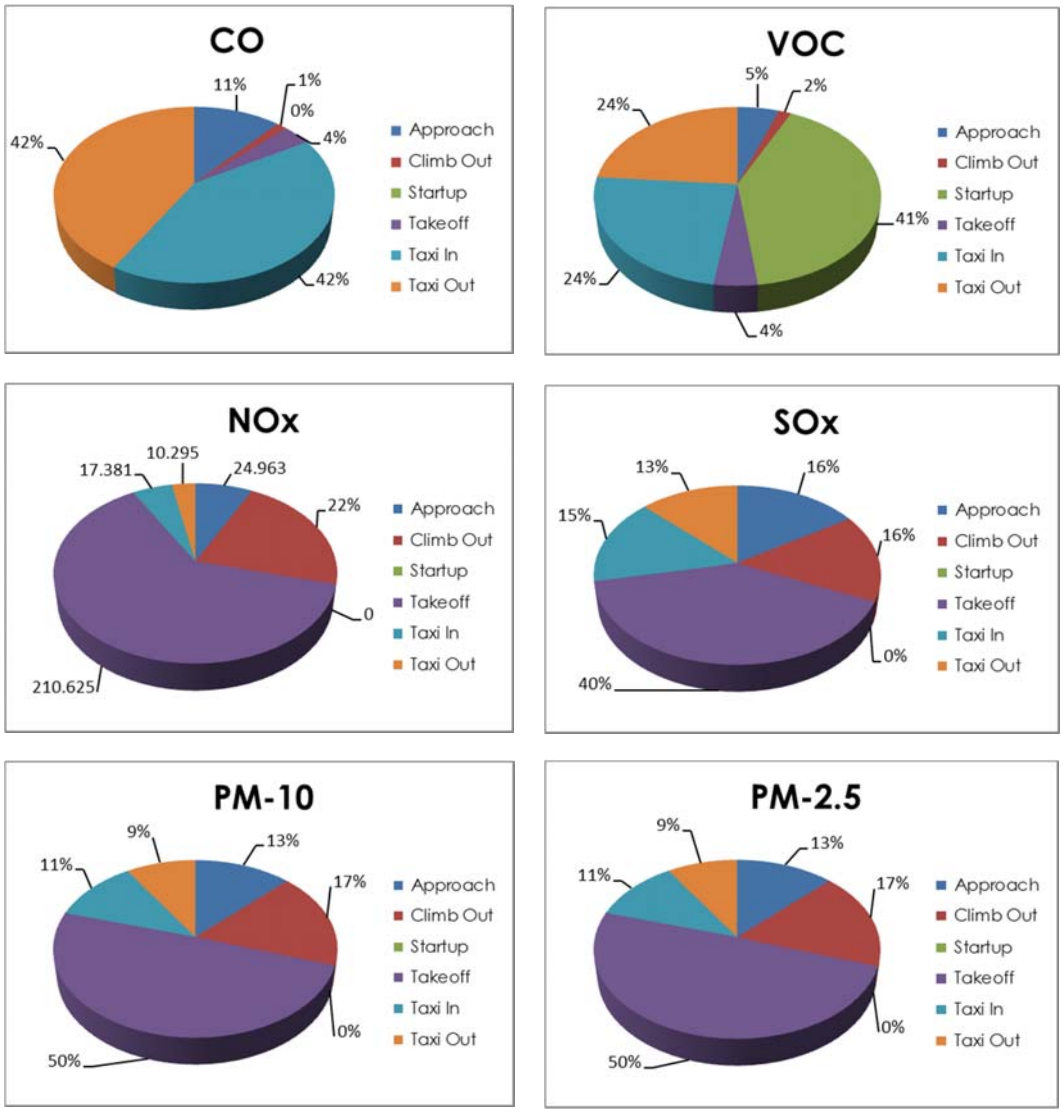
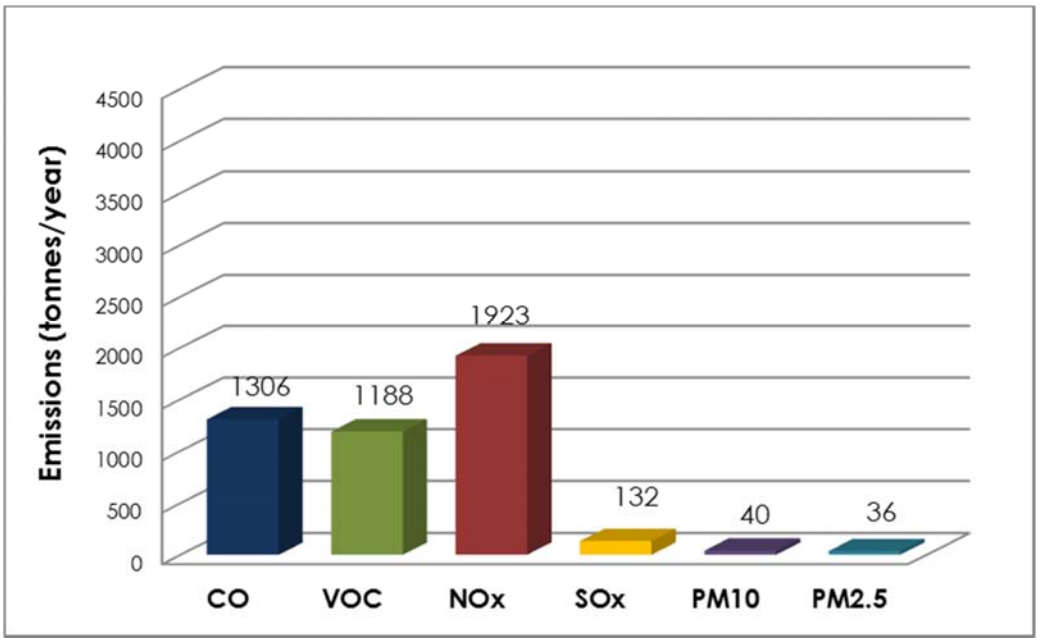


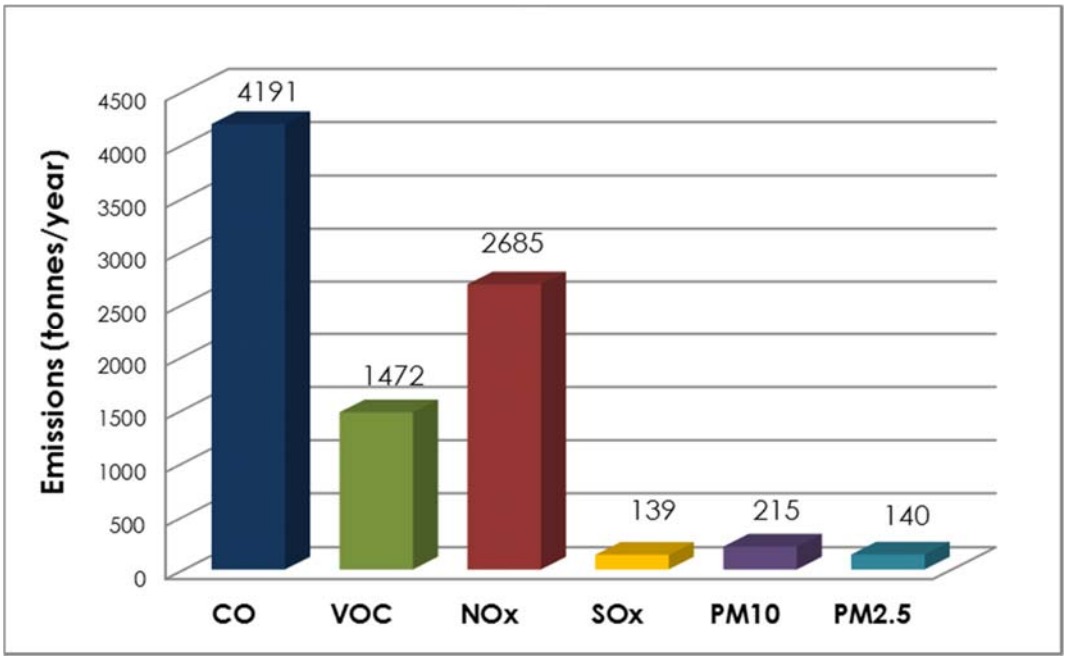
Figure 5-3: Estimated aircraft emissions by operational mode for Stage 1 development

5.1.1 Longer term development

Total emissions of criteria pollutants from the airport operations during the longer term development are presented in **Figure 5-4**. The incremental emissions comprise aircraft, APUs, GSE, parking facilities, terminal traffic, stationary sources and training fires. Cumulative emissions include the respective airport sources and in addition emissions from the external roadways.



Airport emissions (incremental)



Airport and external road emissions (cumulative)

Figure 5-4: Total estimated emissions for criteria pollutants for longer term development

Again, the marked difference between the airport emission inventory in isolation compared with that of the external road emissions shown in Figure 5-4 is further illustrated in Figure 5-5. **Figure 5-5** shows the

airport emissions and external road emissions as a percentage of the total emissions modelled, by pollutant for the Stage 1 development.

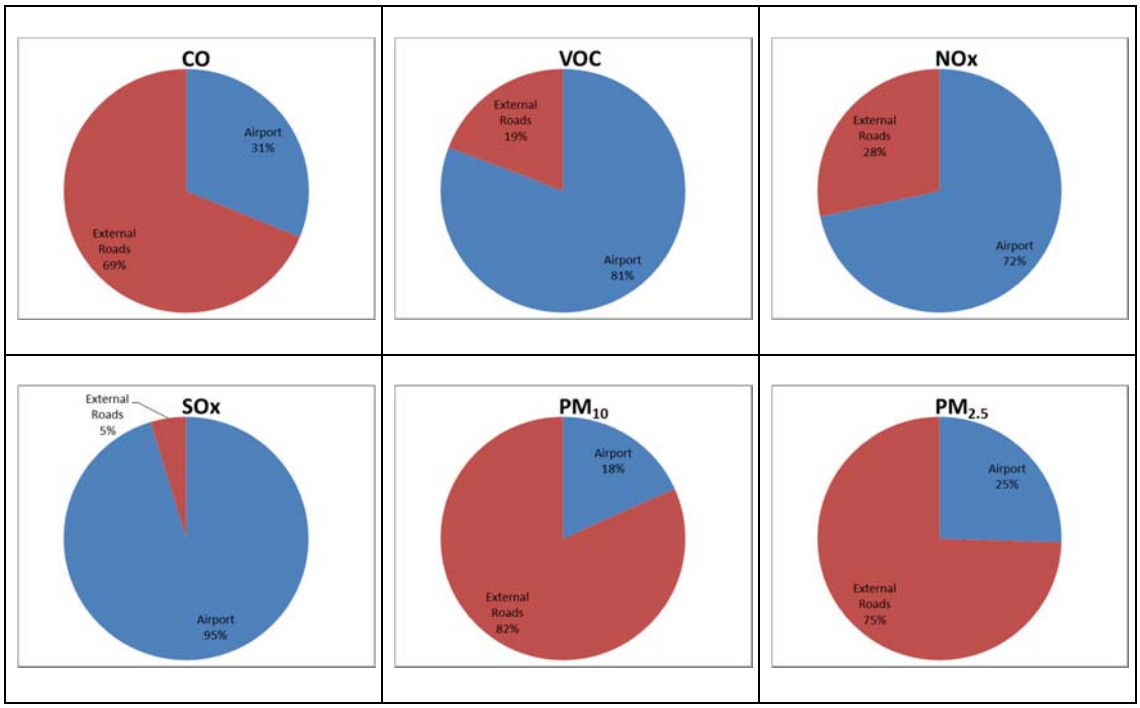


Figure 5-5: Estimated airport and external roads emissions as a percentage of total modelled for criteria pollutants during longer term development

The emission inventory results for the longer term development are presented by source type in **Table** 5-3. In each table, the percentage contribution of each source category is shown alongside the emission value. Emission totals have been provided with and without the cumulative contributions from external roadways.

The incremental emissions from the airport show that the emissions from aircraft engines are the most significant source.

Emissions from APUs, GSE, parking facilities and terminal traffic were also important. In the case of CO, the largest single source after aircraft was terminal traffic (14%), while for NO_x, APUs were the next largest source (3%).

When the cumulative contributions from the external roadways are considered, they account for an estimated 82% of PM_{10}, 75% of $PM_{2.5}$ and 28% of NO_x emissions with the remaining emissions comprising those from the airport.

Table 5-3: Airport emission inventory for criteria pollutants – longer term development

Category	Emissions (tonnes per year)											
	CO		VOC		NO_x		SO_2		PM_{10}		$PM_{2.5}$	
Aircraft	729	56%	131.9	11%	1,756	91%	116	88%	7.8	20%	7.8	22%
GSE	159	12%	7.2	1%	15.0	1%	1.7	1%	1.0	3%	1.0	3%
APUs	18	1%	1.8	0%	64.4	3%	6.6	5%	3.9	10%	3.9	11%
Parking Facilities	127	10%	13.7	1%	5.7	0%	0.1	0%	0.3	1%	0.2	0%
Terminal traffic	182	14%	17.8	2%	38.1	2%	0.3	0%	8.3	21%	4.7	13%
Stationary Sources	15.3	1%	507	43%	21.6	1%	6.5	5%	1.6	4%	1.6	4%
Boilers	14.5	1%	1.0	0%	17.8	1%	0.1	0%	1.3	3%	1.3	4%
Engine tests	0.0	0%	1.2	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
Fuel tanks	-	-	441	37%	-	-	-	-	-	-	-	-
Generators	0.8	0%	0.2	0%	3.8	0%	0.3	0%	0.3	1%	0.3	1%
Paint and Solvent	-	-	63.2	5%	-	-	-	-	-	-	-	-
Training Fires	61.1	5%	2.0	0%	0.5	0%	0.1	0%	14.9	38%	14.9	42%
Total (airport)	**1,306**	**100%**	**1,188**	**100%**	**1,923**	**100%**	**132**	**100%**	**40**	**100%**	**36**	**100%**
External roadways	2885	69%	283	19%	762	28%	6.5	5%	176	82%	105	75%
Airport	1,306	31%	1,188	81%	1,923	72%	132	95%	40	18%	36	25%
Total including external roadways	**3,820**	**100%**	**938**	**100%**	**2,609**	**100%**	**130**	**100%**	**204**	**100%**	**133**	**100%**

5.2 Dispersion modelling results

5.2.1 Overview

The concentrations of the criteria pollutants (CO, NO_2, SO_2, PM_{10}, $PM_{2.5}$ and VOCs) were determined for residential, on-site and community receptors located in the local area (see **Section 3.2**). As the residential receptors are generally located in similar areas as the community receptors, only the residential and on-site receptors have been discussed in the following section. The tabulated results for all receptors are provided in **Appendix F**.

Contour plots have also been prepared to show the spatial distribution of each pollutant, and these are also provided in **Appendix F**. It should be noted that contour plots for one-hour average NO_2 (both for the airport and with cumulative contributions), and maximum cumulative 24-hour average PM_{10} and $PM_{2.5}$ (with background contributions) are based on outputs for the receptors only and not on the entire modelling grid. For NO_2, this is because the OLM method (see **Section 3.4.1**) used to convert NO_x to NO_2 and would not necessarily characterise the dispersion conditions. For the maximum 24 hour average PM_{10} and $PM_{2.5}$, daily contemporaneous background contributions were referenced.

The incremental emissions comprise aircraft, APUs, GSE, parking facilities, terminal traffic, stationary sources and training fires. Cumulative predictions include the respective airport sources and in addition emissions from the external roadways and background contributions.

5.2.2 Stage 1 development

5.2.2.1 Nitrogen dioxide

The dispersion modelling results for maximum 1-hour and annual average NO_2 are presented in **Table** 5-4**.** As discussed in **Section 3.4.1**, the OLM Level 2 method has been applied for the prediction of NO_2 concentrations surrounding the airport site. This takes account of the 1-hour and annual NO_2 and O_3

monitoring data combined with the hourly predicted NO_x concentration at each sensitive receptor location for each of the respective averaging periods.

The results of the dispersion modelling demonstrate compliance at all residential receptors for the maximum 1-hour and annual average NO_2 concentrations when considering the airport in isolation (incremental) and combined with the external roadways and background sources (cumulative).

The maximum 1-hour NO_2 concentration is predicted to occur at receptor R3, located to the southwest of the airport site (see **Figure 3-1**). The incremental and cumulative contributions are predicted to be 60% and 70% of the AEPR ambient objective of 320 µg/m^3. The contribution from external roadways is shown to be negligible in the evaluation of cumulative impacts for some receptors, such as at R2 located at Luddenham. The contribution of external roads to the total predicted cumulative concentration is more pronounced at other receptors such as R22 at Rossmore.

The annual average results are less than 50% of the NSW EPA criterion of 62 µg/m^3. The increase in the predicted glcs for NO_2 from the external roadways is between 9% and 127%.

Table 5-4: Predicted cumulative NO_2 concentrations during Stage 1 development

Receptor ID	Receptor description	Airport increment (µg/m^3)		Cumulative - Airport + External Roads + Existing Background (µg/m^3)	
		1-hour	Annual	1-hour	Annual
Ambient objective / Assessment criterion		*320*	*62*	*320*	*62*
R1	Bringelly	84	11	139	18
R2	Luddenham	91	13	91	15
R3	Greendale, Greendale Road	194	12	227	14
R4	Kemps Creek	76	11	160	25
R6	Mulgoa	84	12	90	14
R7	Wallacia	90	11	92	13
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	86	13	105	19
R14	Lawson Road, Badgerys Creek	147	13	160	22
R15	Mersey Rd, Greendale	130	13	138	17
R17	Luddenham Road	96	13	115	18
R18	Cnr Adams & Elizabeth Drive	107	17	110	22
R19	Cnr Adams & Anton Road	111	19	121	23
R21	Cnr Willowdene Ave and Vicar Park Lane	171	13	179	16
R22	Rossmore, Victor Ave	68	11	145	17
R23	Wallacia, Greendale Rd	87	11	101	13
R24	Badgerys Creek 1 NE	166	18	169	25
R25	Badgerys Creek 2 SW	104	12	108	16
R27	Greendale, Dwyer Rd	80	11	86	12
R30	Rossmore residential	66	11	131	20
R31	Mt Vernon residential	142	12	143	19

5.2.2.2 Particulate matter (PM_{10})

Table 5-5 presents a summary of the maximum 24-hour average and annual average PM_{10} concentrations from the airport in isolation (incremental) and combined with the external roadways

and background sources (cumulative). The predicted PM_{10} concentrations at the community receptors are provided in **Appendix F**.

The results show that the predicted PM_{10} concentrations to be below the NSW EPA impact assessment criterion of 50 µg/m³ and 30 µg/m³ for the 24-hour and annual averaging periods respectively. There are no AEPR ambient objectives for PM_{10}. For both averaging periods, the background PM_{10} contributes more than half of the respective criterion.

The contour plots show the extent of the predicted impacts across the local area (**Appendix F**). It can be seen that in addition to the airport, the contribution from roadways plays a significant role in the ground level concentrations. For example, receptor R30 is well removed from the airport site in comparison to other residential receptors but is located in close proximity to a major roadway. By way of example, the contribution of emissions to the maximum 24-hour average PM_{10} concentrations predicted at receptor R30 are shown in **Figure 5-6**.

Table 5-5: Predicted incremental and cumulative PM_{10} concentrations during Stage 1 development

		Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative – Airport + external roadways + existing background (µg/m³)	
Receptor ID	**Receptor description**	**24-hour**	**Annual**	**24-hour**	**Annual**	**24-hour**	**Annual**
Ambient objective / Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*50*	*30*
R1	Bringelly	0.5	<0.1	7.8	1.1	44	18
R2	Luddenham	0.5	<0.1	2.0	0.3	43	17
R3	Greendale, Greendale Road	1.0	<0.1	3.3	0.2	43	17
R4	Kemps Creek	0.6	<0.1	15.8	1.7	46	19
R6	Mulgoa	0.5	<0.1	1.9	0.2	43	17
R7	Wallacia	0.4	<0.1	2.0	0.2	43	17
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.6	<0.1	3.8	0.6	44	18
R14	Lawson Road, Badgerys Creek	1.5	0.1	7.1	1.1	44	18
R15	Mersey Rd, Greendale	1.1	0.1	2.5	0.5	44	18
R17	Luddenham Road	0.7	<0.1	3.5	0.6	43	18
R18	Cnr Adams & Elizabeth Drive	0.7	0.1	3.7	0.7	44	18
R19	Cnr Adams & Anton Road	2.0	0.2	3.0	0.6	44	18
R21	Cnr Willowdene Ave and Vicar Park Lane	0.9	<0.1	3.3	0.4	43	17
R22	Rossmore, Victor Ave	0.9	<0.1	4.5	0.6	44	18
R23	Wallacia, Greendale Rd	0.6	<0.1	3.0	0.2	43	17
R24	Badgerys Creek 1 NE	4.1	0.4	6.0	1.2	44	18
R25	Badgerys Creek 2 SW	0.6	<0.1	2.8	0.6	43	18
R27	Greendale, Dwyer Rd	0.1	<0.1	1.7	0.2	43	17
R30	Rossmore residential	0.3	<0.1	7.5	1.4	45	18
R31	Mt Vernon residential	0.9	<0.1	5.6	0.6	43	18

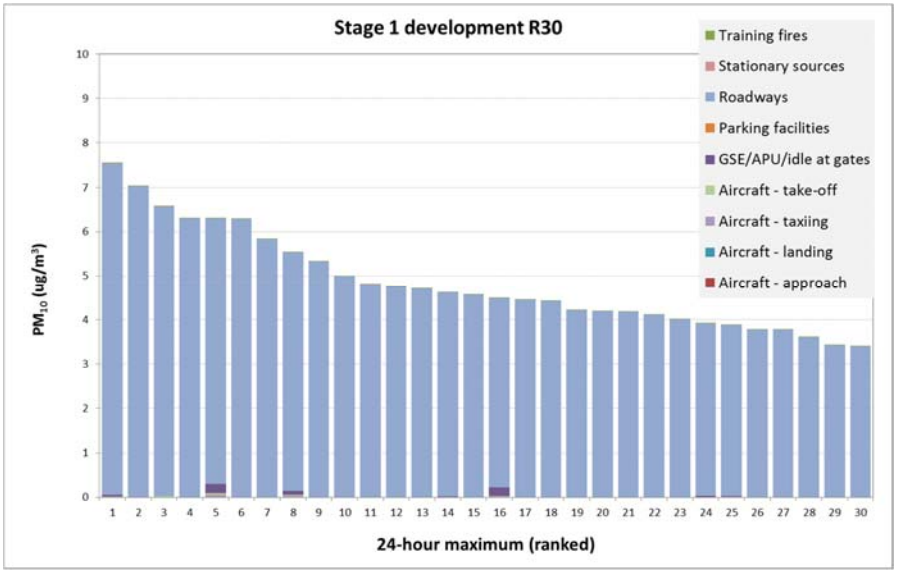


Figure 5-6: Contributions to PM_{10} concentrations at R30

5.2.2.3 Particulate matter ($PM_{2.5}$)

Table 5-6 presents a summary of the maximum 24-hour average and annual average $PM_{2.5}$ concentrations from the airport in isolation and combined with the external roadways and background sources (cumulative). The predicted $PM_{2.5}$ impacts at the community receptors are provided in **Appendix F**.

The results show that the predicted $PM_{2.5}$ concentrations during the Stage 1 development are anticipated to be below the NEPM advisory reporting goals of 25 µg/m^3 and 8 µg/m^3 for the 24-hour and annual averaging periods respectively when emissions from the airport are combined with external roadways and background sources. There are no AEPR ambient objectives or NSW EPA criterion for $PM_{2.5}$. For both averaging periods, the background is anticipated to contribute more than half of the respective (cumulative) criterion.

The predicted cumulative concentrations for the 24-hour averaging period account for between 52% and 60% of the NEPM advisory reporting goal. The adopted background of 7 µg/m^3 is a significant contributor to the predicted annual average $PM_{2.5}$ concentrations.

The highest predicted 24-hour average $PM_{2.5}$ concentrations are at residential receptor R4. As shown in **Figure 5-7** roadways are the greatest contributor by source.

The contour plots show the geographical pattern of dispersion across the local area (**Appendix F**). It can be seen that in addition to the airport, the contribution from external roadways plays a significant role in the ground level predictions.

Table 5-6: Predicted incremental and cumulative $PM_{2.5}$ concentrations during Stage 1 development

Recept or ID	Receptor description	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative – Airport + external roadways + existing background (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
NEPM advisory goal		*n/a*	*n/a*	*n/a*	*n/a*	*25*	*8*
R1	Bringelly	0.5	<0.1	3.6	0.5	14	8

R2	Luddenham	0.5	<0.1	1.0	0.2	14	7
R3	Greendale, Greendale Road	1.0	<0.1	2.0	0.1	13	7
R4	Kemps Creek	0.6	<0.1	6.5	0.8	15	8
R6	Mulgoa	0.5	<0.1	1.0	0.1	13	7
R7	Wallacia	0.4	<0.1	0.9	0.1	13	7
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.6	<0.1	1.6	0.3	14	7
R14	Lawson Road, Badgerys Creek	1.4	0.1	4.0	0.6	14	8
R15	Mersey Rd, Greendale	1.0	0.1	1.4	0.3	14	7
R17	Luddenham Road	0.7	<0.1	1.5	0.3	14	7
R18	Cnr Adams & Elizabeth Drive	0.7	0.1	1.8	0.4	14	7
R19	Cnr Adams & Anton Road	1.9	0.2	2.4	0.4	14	7
R21	Cnr Willowdene Ave and Vicar Park Lane	0.8	<0.1	1.5	0.2	14	7
R22	Rossmore, Victor Ave	0.9	<0.1	2.0	0.3	14	7
R23	Wallacia, Greendale Rd	0.6	<0.1	1.3	0.1	13	7
R24	Badgerys Creek 1 NE	3.9	0.3	4.3	0.7	14	8
R25	Badgerys Creek 2 SW	0.6	<0.1	1.3	0.3	13	7
R27	Greendale, Dwyer Rd	0.1	<0.1	0.7	0.1	13	7
R30	Rossmore residential	0.3	<0.1	3.5	0.7	14	8
R31	Mt Vernon residential	0.9	<0.1	2.2	0.3	14	7

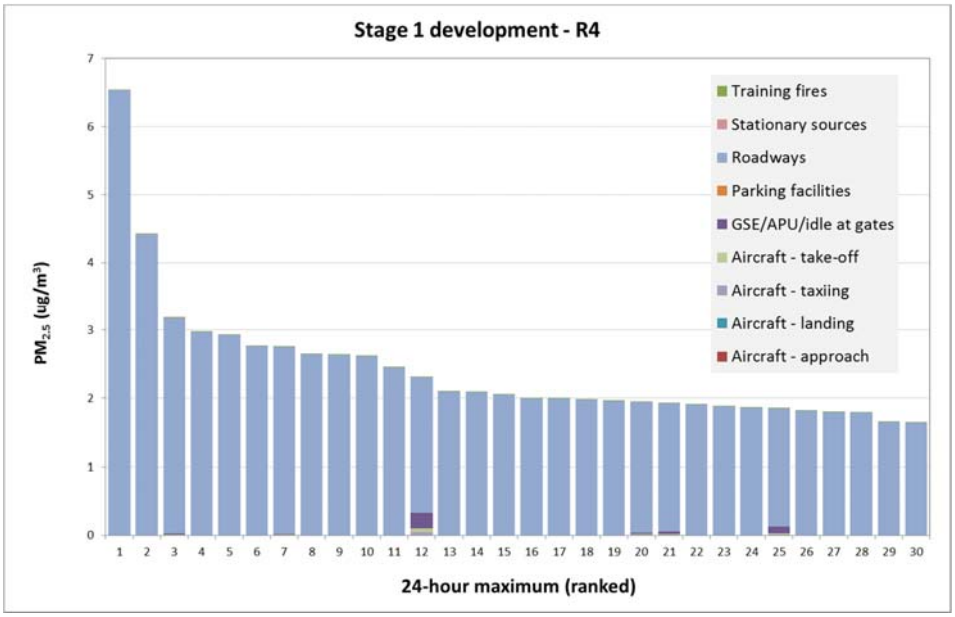


Figure 5-7: Contributions to $PM_{2.5}$ concentrations at R4

5.2.2.4 Carbon monoxide

The predicted maximum 15-minute, 1-hour and 8-hour CO concentrations at each of the residential receptors were added to the emissions from external roadways and adopted background concentrations and presented in **Table 5-7**.

At all receptors, for all averaging periods, the CO concentrations are predicted to be well below the corresponding AEPR ambient objective and NSW EPA impact assessment criteria.

The spread of the projected impacts for the short term averaging periods (see the contour plots in **Appendix F**) shows higher concentrations centred over the airport and along roadways.

Table 5-7: Predicted incremental and cumulative CO concentrations during Stage 1 development

Receptor ID	Receptor description	Airport (µg/m³)			Airport + external roadways (µg/m³)			Cumulative – Airport + external roadways + existing background (µg/m³)		
		15-minute	1-hour	8-hour	15-minute	1-hour	8-hour	15-minute	1-hour	8-hour
Ambient objective / Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*100*	*30*	*10*
R1	Bringelly	0.6	0.4	0.1	3.2	2.4	0.3	5.3	3.9	1.5
R2	Luddenham	0.5	0.4	0.1	0.5	0.4	0.1	2.6	1.9	1.3
R3	Greendale, Greendale Road	0.9	0.7	0.1	1.6	1.2	0.2	3.7	2.7	1.4
R4	Kemps Creek	0.7	0.5	0.1	2.0	1.5	0.5	4.1	3.0	1.7
R6	Mulgoa	0.7	0.5	0.1	0.9	0.7	0.1	3.0	2.2	1.3
R7	Wallacia	0.3	0.2	0.0	0.9	0.7	0.1	3.0	2.2	1.3
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.9	0.7	0.1	1.5	1.1	0.2	3.6	2.6	1.4
R14	Lawson Road, Badgerys Creek	1.8	1.4	0.2	3.1	2.3	0.3	5.2	3.8	1.5
R15	Mersey Rd, Greendale	1.1	0.8	0.2	1.4	1.0	0.2	3.5	2.5	1.4
R17	Luddenham Road	0.5	0.4	0.1	1.1	0.8	0.2	3.2	2.3	1.4
R18	Cnr Adams & Elizabeth Drive	0.7	0.5	0.1	1.8	1.4	0.2	3.9	2.9	1.4
R19	Cnr Adams & Anton Road	2.3	1.7	0.3	2.4	1.8	0.3	4.5	3.3	1.5
R21	Cnr Willowdene Ave and Vicar Park Lane	1.1	0.8	0.2	1.7	1.3	0.2	3.8	2.8	1.4
R22	Rossmore, Victor Ave	1.0	0.8	0.1	1.1	0.9	0.2	3.2	2.4	1.4
R23	Wallacia, Greendale Rd	0.4	0.3	0.1	0.7	0.5	0.1	2.8	2.0	1.3
R24	Badgerys Creek 1 NE	3.1	2.3	0.5	3.1	2.3	0.5	5.2	3.8	1.7
R25	Badgerys Creek 2 SW	0.5	0.4	0.1	1.0	0.8	0.1	3.1	2.3	1.3
R27	Greendale, Dwyer Rd	0.2	0.1	0.0	0.3	0.2	0.1	2.4	1.7	1.3
R30	Rossmore residential	0.4	0.3	0.1	2.6	1.9	0.4	4.7	3.4	1.6
R31	Mt Vernon residential	0.8	0.6	0.1	0.9	0.6	0.2	3.0	2.1	1.4

5.2.2.5 Sulphur dioxide

The predicted maximum 10-minute, 1-hour, 24-hour and annual average SO_2 concentrations at each of the residential receptors were added to the contributions from external roadways and adopted background concentrations and presented in **Table 5-8** (10-minute and 1-hour averaging periods) and **Table 5-9** (24-hour and annual averaging periods).

At all receptors, for all averaging periods, the SO_2 concentrations are predicted to be well below the corresponding AEPR ambient objectives and NSW EPA impact assessment criteria.

The spatial distribution of the annual average predictions (see the contours plots in **Appendix F**) indicates that slightly higher concentrations are predicted to occur to the north and northeast of the airport site, consistent with the annual prevailing winds (see **Section 4.1.1**).

Table 5-8: Predicted incremental and cumulative maximum 10-minute and 1-hour SO_2 concentrations during Stage 1 development

Receptor	Receptor description	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative – Airport + external roadways + existing background (µg/m³)	
		10-minute	1-hour	10-minute	1-hour	10-minute	1-hour
Ambient objective / Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*700*	*570*
R1	Bringelly	28	19	29	19	109	53
R2	Luddenham	18	12	19	12	99	46
R3	Greendale, Greendale Road	63	42	65	43	145	77
R4	Kemps Creek	24	16	24	16	104	50
R6	Mulgoa	122	81	122	81	202	115
R7	Wallacia	66	44	66	44	146	78
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	64	42	64	43	144	77
R14	Lawson Road, Badgerys Creek	85	56	86	57	166	91
R15	Mersey Rd, Greendale	49	32	49	32	129	66
R17	Luddenham Road	133	88	133	88	213	122
R18	Cnr Adams & Elizabeth Drive	39	26	41	27	121	61
R19	Cnr Adams & Anton Road	102	67	102	68	182	102
R21	Cnr Willowdene Ave and Vicar Park Lane	51	34	52	34	132	68
R22	Rossmore, Victor Ave	25	16	25	16	105	50
R23	Wallacia, Greendale Rd	83	55	84	56	164	90
R24	Badgerys Creek 1 NE	87	57	87	57	167	91
R25	Badgerys Creek 2 SW	84	56	85	56	165	90
R27	Greendale, Dwyer Rd	16	11	16	11	96	45
R30	Rossmore residential	24	16	24	16	104	50
R31	Mt Vernon residential	90	59	90	59	170	93

Table 5-9: Predicted incremental and cumulative maximum 24-hour and annual average SO_2 concentrations during Stage 1 development

Receptor	Receptor description	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative – Airport + external roadways + existing background (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
Ambient objective / Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*228*	*60*
R1	Bringelly	1.8	0.1	2.0	0.1	11.9	1.3
R2	Luddenham	1.4	0.2	1.4	0.2	11.3	1.4
R3	Greendale, Greendale Road	4.6	0.2	4.7	0.2	14.6	1.4
R4	Kemps Creek	2.2	0.1	2.3	0.1	12.2	1.3
R6	Mulgoa	2.4	0.1	2.4	0.1	12.3	1.3
R7	Wallacia	1.5	0.1	1.5	0.1	11.4	1.3
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	2.2	0.2	2.2	0.3	12.1	1.5
R14	Lawson Road, Badgerys Creek	4.6	0.3	4.9	0.3	14.8	1.5
R15	Mersey Rd, Greendale	3.9	0.3	3.9	0.3	13.8	1.5
R17	Luddenham Road	2.7	0.2	2.8	0.2	12.7	1.4
R18	Cnr Adams & Elizabeth Drive	2.5	0.6	2.5	0.6	12.4	1.8
R19	Cnr Adams & Anton Road	4.4	0.8	4.5	0.8	14.4	2.0
R21	Cnr Willowdene Ave and Vicar Park Lane	3.8	0.2	3.8	0.2	13.7	1.4
R22	Rossmore, Victor Ave	2.4	0.1	2.5	0.1	12.4	1.3
R23	Wallacia, Greendale Rd	2.8	0.1	2.9	0.1	12.8	1.3
R24	Badgerys Creek 1 NE	7.4	0.7	7.4	0.7	17.3	1.9
R25	Badgerys Creek 2 SW	2.2	0.1	2.2	0.2	12.1	1.4
R27	Greendale, Dwyer Rd	0.6	0.1	0.7	0.1	10.6	1.3
R30	Rossmore residential	1.7	0.1	1.9	0.1	11.8	1.3
R31	Mt Vernon residential	4.2	0.1	4.3	0.2	14.2	1.4

5.2.2.6 Air toxics

The predicted concentrations of the four air toxics evaluated within the assessment are shown in **Table** 5-10 for the 99.9th percentile, **Table 5-11** for the 24-hour averaging period and **Table 5-12** for the annual averaging period**.** The 99.9th percentile results have been assessed against the NSW impact assessment criteria, which is evaluated as increment only (i.e. does not incorporate existing background concentrations). All predicted concentrations were below the relevant criteria.

The 99.9th percentile 1-hour maximum results demonstrate compliance with the NSW EPA impact assessment criteria, with the exception of formaldehyde with an exceedance shown at the on-site receptor R24.

The 24-hour and annual average concentrations of benzene, toluene and xylenes were predicted to be orders of magnitude lower than the NEPM investigation levels. The concentration of formaldehyde was less than 20% of the investigation level.

Table 5-10: Predicted incremental 99th percentile 1-hour average air toxic concentrations during Stage 1 development

Receptor ID	Receptor description	Airport (µg/m³)				Airport + external roadways (µg/m³)			
		Benzene	Toluene	Xylene	Formaldehyde	Benzene	Toluene	Xylene	Formaldehyde
NSW impact assessment criterion		*29*	*360*	*180*	*20*	*29*	*360*	*180*	*20*
R1	Bringelly	0.1	<0.1	<0.1	0.7	2.0	0.8	0.5	14.9
R2	Luddenham	0.2	0.1	0.1	1.5	1.3	0.5	0.3	9.3
R3	Greendale, Greendale Road	0.2	0.1	<0.1	1.2	1.2	0.5	0.3	8.8
R4	Kemps Creek	0.1	<0.1	<0.1	0.9	2.3	0.9	0.6	17.1
R6	Mulgoa	0.1	<0.1	<0.1	0.7	0.8	0.3	0.2	5.6
R7	Wallacia	0.1	<0.1	<0.1	0.7	0.6	0.2	0.2	4.3
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.1	<0.1	<0.1	0.8	1.0	0.4	0.3	7.4
R14	Lawson Road, Badgerys Creek	0.3	0.1	0.1	2.2	1.3	0.5	0.3	9.3
R15	Mersey Rd, Greendale	0.3	0.1	0.1	1.8	1.5	0.6	0.4	11.0
R17	Luddenham Road	0.1	0.1	<0.1	1.0	0.9	0.3	0.2	6.2
R18	Cnr Adams & Elizabeth Drive	0.2	0.1	<0.1	1.4	1.3	0.5	0.4	9.8
R19	Cnr Adams & Anton Road	0.4	0.1	0.1	2.6	2.2	0.8	0.6	16.1
R21	Cnr Willowdene Ave and Vicar Park Lane	0.2	0.1	0.1	1.5	1.1	0.4	0.3	8.1
R22	Rossmore, Victor Ave	0.2	0.1	<0.1	1.1	0.8	0.3	0.2	5.8
R23	Wallacia, Greendale Rd	0.1	<0.1	<0.1	0.9	0.6	0.2	0.2	4.6
R24	Badgerys Creek 1 NE	0.6	0.2	0.2	4.2	3.1	1.2	0.8	**22.6**
R25	Badgerys Creek 2 SW	0.3	0.1	0.1	2.0	1.8	0.7	0.5	13.5
R27	Greendale, Dwyer Rd	0.1	0.1	<0.1	1.0	0.9	0.4	0.2	6.8
R30	Rossmore residential	0.1	<0.1	<0.1	0.5	1.6	0.6	0.4	11.8
R31	Mt Vernon residential	0.2	0.1	0.1	1.4	1.0	0.4	0.3	7.0

Table 5-11: Predicted incremental and cumulative 24-hour average air toxic concentrations during Stage 1 development

Receptor ID	Receptor description	Airport (µg/m³)			Airport + external roadways (µg/m³)			Cumulative – Airport + external roadways + existing background (µg/m³)		
		Toluene	Xylene	Formaldehyde	Toluene	Xylene	Formaldehyde	Toluene	Xylene	Formaldehyde
NEPM investigation level		*4,160*	*1,170*	*53*	*4,160*	*1,170*	*53*	*4,160*	*1,170*	*53*
R1	Bringelly	<0.1	<0.1	0.9	0.1	0.1	2.1	15.4	16.7	6.4
R2	Luddenham	0.1	0.1	1.6	0.1	0.1	1.5	15.4	16.7	5.8
R3	Greendale, Greendale Road	0.1	0.1	1.5	0.1	0.1	1.6	15.4	16.7	5.9

R4	Kemps Creek	0.1	<0.1	1.1	0.2	0.1	3.4	15.5	16.7	7.7
R6	Mulgoa	<0.1	<0.1	0.8	0.1	<0.1	1.0	15.4	16.6	5.3
R7	Wallacia	<0.1	<0.1	0.8	<0.1	<0.1	0.9	15.3	16.6	5.2
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	<0.1	<0.1	0.8	0.1	<0.1	1.2	15.4	16.6	5.5
R14	Lawson Road, Badgerys Creek	0.1	0.1	2.4	0.1	0.1	2.7	15.4	16.7	7.0
R15	Mersey Rd, Greendale	0.1	0.1	2.0	0.1	0.1	1.8	15.4	16.7	6.1
R17	Luddenham Road	0.1	<0.1	1.1	0.1	<0.1	1.1	15.4	16.6	5.4
R18	Cnr Adams & Elizabeth Drive	0.1	0.1	1.5	0.1	0.1	1.4	15.4	16.7	5.7
R19	Cnr Adams & Anton Road	0.1	0.1	2.7	0.2	0.1	3.0	15.5	16.7	7.3
R21	Cnr Willowdene Ave and Vicar Park Lane	0.1	0.1	1.7	0.1	0.1	1.5	15.4	16.7	5.8
R22	Rossmore, Victor Ave	0.1	<0.1	1.2	0.1	0.1	1.4	15.4	16.7	5.7
R23	Wallacia, Greendale Rd	0.1	<0.1	1.1	0.1	<0.1	1.1	15.4	16.6	5.4
R24	Badgerys Creek 1 NE	0.2	0.2	4.6	0.3	0.2	5.1	15.6	16.8	9.4
R25	Badgerys Creek 2 SW	0.1	0.1	2.1	0.1	0.1	2.4	15.4	16.7	6.7
R27	Greendale, Dwyer Rd	0.1	<0.1	1.0	0.1	<0.1	1.3	15.4	16.6	5.6
R30	Rossmore residential	<0.1	<0.1	0.5	0.1	0.1	2.4	15.4	16.7	6.7
R31	Mt Vernon residential	0.1	0.1	1.4	0.1	0.1	1.5	15.4	16.7	5.8

Table 5-12: Predicted incremental and cumulative annual average air toxic concentrations during Stage 1 development

Receptor ID	Receptor description	Airport (µg/m³)			Airport + external roadways (µg/m³)			Cumulative – Airport + external roadways + existing background (µg/m³)		
		Toluene	Xylene	Formaldehyde	Toluene	Xylene	Formaldehyde	Toluene	Xylene	Formaldehyde
NEPM investigation level		*10*	*406*	*935*	*10*	*406*	*935*	*10*	*406*	*935*
R1	Bringelly	0.01	<0.01	<0.01	0.02	0.01	1.0	3.7	2.4	6.4
R2	Luddenham	0.02	0.01	0.01	0.01	0.01	1.0	3.7	2.4	5.8
R3	Greendale, Greendale Road	0.01	<0.01	<0.01	0.01	<0.01	1.0	3.7	2.4	5.9
R4	Kemps Creek	0.01	<0.01	<0.01	0.03	0.02	1.1	3.7	2.4	7.7
R6	Mulgoa	0.01	<0.01	<0.01	0.01	<0.01	1.0	3.7	2.4	5.3
R7	Wallacia	0.01	<0.01	<0.01	0.01	<0.01	1.0	3.7	2.4	5.2
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.01	0.01	<0.01	0.01	0.01	1.0	3.7	2.4	5.5
R14	Lawson Road, Badgerys Creek	0.02	0.01	<0.01	0.02	0.02	1.1	3.7	2.4	7.0
R15	Mersey Rd, Greendale	0.01	0.01	<0.01	0.01	0.01	1.0	3.7	2.4	6.1
R17	Luddenham Road	0.01	0.01	<0.01	0.01	0.01	1.0	3.7	2.4	5.4
R18	Cnr Adams & Elizabeth Drive	0.03	0.01	0.01	0.02	0.01	1.1	3.7	2.4	5.7
R19	Cnr Adams & Anton Road	0.04	0.02	0.01	0.02	0.02	1.1	3.7	2.4	7.3
R21	Cnr Willowdene Ave and Vicar Park Lane	0.01	<0.01	<0.01	0.01	0.01	1.0	3.7	2.4	5.8
R22	Rossmore, Victor Ave	0.01	<0.01	<0.01	0.01	0.01	1.0	3.7	2.4	5.7
R23	Wallacia, Greendale Rd	<0.01	<0.01	<0.01	<0.01	<0.01	1.0	3.7	2.4	5.4
R24	Badgerys Creek 1 NE	0.06	0.02	0.02	0.04	0.03	1.1	3.7	2.4	9.4
R25	Badgerys Creek 2 SW	0.02	0.01	<0.01	0.02	0.01	1.0	3.7	2.4	6.7
R27	Greendale, Dwyer Rd	0.01	<0.01	<0.01	0.01	<0.01	1.0	3.7	2.4	5.6
R30	Rossmore residential	<0.01	<0.01	<0.01	0.02	0.02	1.1	3.7	2.4	6.7
R31	Mt Vernon residential	0.01	<0.01	<0.01	0.01	0.01	1.0	3.7	2.4	5.8

5.2.2.7 Odour

5.2.2.7.1 Aircraft exhaust

The 99th percentile 1-hour odour predictions for emissions from aircraft exhaust during the Stage 1 development are presented in **Table 5-13**. Due to significant uncertainties in future emission inventories, the predicted odour concentrations for the longer term development have not been assessed.

The odour concentrations for Stage 1 are predicted to be below the threshold detection level of 1 OU at all residential receptors. At R24, the predicted odour concentration is 1 OU, indicating when a receptor (i.e. a person) is located in this area, they may on occasion detect odour from aircraft exhausts. This is, however, less than the NSW EPA odour performance criterion of 2 OU.

The spatial extent of odour impacts (see **Appendix F**) indicates that the highest odour concentrations would be largely limited to within the airport site.

Table 5-13: Predicted 99th percentile odour concentrations from aircraft exhaust

Receptor ID	Receptor description	1-hour 99th percentile
Criterion		*2*
R1	Bringelly	<1
R2	Luddenham	<1
R3	Greendale, Greendale Road	<1
R4	Kemps Creek	<1
R6	Mulgoa	<1
R7	Wallacia	<1
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	<1
R14	Lawson Road, Badgerys Creek	<1
R15	Mersey Rd, Greendale	<1
R17	Luddenham Road	<1
R18	Cnr Adams & Elizabeth Drive	1
R19	Cnr Adams & Anton Road	1
R21	Cnr Willowdene Ave and Vicar Park Lane	<1
R22	Rossmore, Victor Ave	<1
R23	Wallacia, Greendale Rd	<1
R24	Badgerys Creek 1 NE	1
R25	Badgerys Creek 2 SW	<1
R27	Greendale, Dwyer Rd	<1
R30	Rossmore residential	<1
R31	Mt Vernon residential	<1

5.2.2.7.2 Waste water treatment plant

The 99th percentile 1-hour odour predictions for emissions from the on-site WWTP are presented in **Table 5-14**. The predicted odour concentrations for the longer term development have not been assessed, as this is anticipated to beyond the design lifetime of the proposed WWTP.

The odour concentrations for Stage 1 are predicted to be below the threshold detection level of 1 OU at all residential receptors.

The spatial extent of the odour contours (see **Appendix G**) indicates that the highest odour concentrations would be largely limited to within the airport site.

Table 5-14: Predicted 99th percentile odour concentrations from WWTP

Receptor ID	Receptor description	1-hour 99th percentile
Criterion		*2*
R1	Bringelly	<1
R2	Luddenham	<1
R3	Greendale, Greendale Road	<1
R4	Kemps Creek	<1
R6	Mulgoa	<1
R7	Wallacia	<1
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	<1
R14	Lawson Road, Badgerys Creek	<1
R15	Mersey Rd, Greendale	<1

R17	Luddenham Road	<1
R18	Cnr Adams & Elizabeth Drive	<1
R19	Cnr Adams & Anton Road	<1
R21	Cnr Willowdene Ave and Vicar Park Lane	<1
R22	Rossmore, Victor Ave	<1
R23	Wallacia, Greendale Rd	<1
R24	Badgerys Creek 1 NE	<1
R25	Badgerys Creek 2 SW	<1
R27	Greendale, Dwyer Rd	<1
R30	Rossmore residential	<1
R31	Mt Vernon residential	<1

5.2.1 Longer term development

Given the uncertainty regarding the future reduction in vehicular and aircraft engine emissions and the anticipated general reduction in background emissions over time, for the longer term development, ground level concentration predictions were assessed only for the key criteria pollutants comprising NO_2, PM_{10}, and $PM_{2.5}$.

5.2.1.1 Oxides of nitrogen

The dispersion modelling results for maximum 1-hour and annual average NO_2 are presented in **Table 5-15.** Exceedances are shown in bold. As discussed in **Section 3.4.1**, the OLM Level 2 method has been applied for the prediction of NO_2 concentrations surrounding the airport site. This takes account of the hourly 1-hour and annual NO_2 and O_3 monitoring data combined with the hourly predicted NO_x concentration at each sensitive receptor location for each of the respective averaging periods.

The results of the dispersion modelling demonstrate compliance with the NSW EPA criterion of 62 µg/m^3 at all residential receptors for annual average NO_2 concentrations when considering the airport in isolation (incremental) and combined with the external roadways and background sources (cumulative). The increase in the predicted glcs for NO_2 from the external roadways is between 4% and 157%.

The results of the dispersion modelling indicate that exceedances of the 1-hour average AEPR objective of 320 µg/m^3 may be experienced at seven of the 20 selected residential and on-site receptors. These elevated concentrations are predicted to occur for between 1 and 2 hours per year. The maximum 1-hour NO_2 concentration is predicted to occur at receptor R14, located to the northwest of the airport site (see **Figure 3-1**).

Table 5-15: Predicted cumulative NO_2 concentrations during longer term development

Receptor ID	Receptor description	Airport increment (µg/m³)			Cumulative - Airport + External Roads + Existing Background (µg/m³)		
		1-hour		Annual	1-hour		Annual
Criterion		*320*	*Number of hours > 320*	*62*	*320*	*Number of hours > 246*	*62*
R1	Bringelly	237	0	17	246	0	25
R2	Luddenham	111	0	22	112	0	24
R3	Greendale, Greendale Road	**347**	1	22	**368**	1	24
R4	Kemps Creek	223	0	17	244	0	31
R6	Mulgoa	188	0	18	189	0	19
R7	Wallacia	241	0	17	243	0	18
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	155	0	21	164	0	26
R14	Lawson Road, Badgerys Creek	**517**	1	34	**519**	1	45
R15	Mersey Rd, Greendale	**343**	2	31	**349**	2	34
R17	Luddenham Road	310	0	22	313	0	26
R18	Cnr Adams & Elizabeth Drive	229	0	38	229	0	43
R19	Cnr Adams & Anton Road	211	0	47	211	0	50
R21	Cnr Willowdene Ave and Vicar Park Lane	**408**	1	24	**424**	1	27
R22	Rossmore, Victor Ave	242	0	18	246	0	23
R23	Wallacia, Greendale Rd	**342**	1	15	**347**	1	17
R24	Badgerys Creek 1 NE	**335**	1	55	**337**	1	57
R25	Badgerys Creek 2 SW	281	0	23	287	0	26
R27	Greendale, Dwyer Rd	116	0	14	117	0	16
R30	Rossmore residential	312	0	14	319	0	36
R31	Mt Vernon residential	**345**	1	22	**355**	1	26

5.2.1.2 Particulate matter (PM_{10})

Table 5-16 presents a summary of the maximum 24-hour average and annual average PM_{10} concentrations from the airport in isolation (incremental) and combined with the external roadways and background sources (cumulative). Exceedances are shown in bold. The predicted PM_{10} concentrations at the community receptors are provided in **Appendix F**. There are no AEPR ambient objectives for PM_{10}.

The results show that the predicted PM_{10} concentrations during the longer term development are anticipated to be above the NSW EPA impact assessment criterion of 50 µg/m³ on occasion at one receptor (R24). Receptor R24 is located within the airport site and represents the air quality conditions likely to be experienced on-site (i.e. by both airport staff and passengers).

The predicted PM_{10} concentrations demonstrate compliance with the NSW impact assessment criterion of 30 µg/m³ at all receptors. The background contribution contributes more than half of the respective cumulative criterion.

Table 5-16: Predicted incremental and cumulative PM_{10} concentrations during longer term development

Receptor ID	Receptor description	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative – Airport + external roadways + existing background (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*50*	*30*
R1	Bringelly	3.7	0.1	13.7	1.9	46	19
R2	Luddenham	1.7	0.3	3.6	0.7	43	18
R3	Greendale, Greendale Road	5.7	0.3	7.3	0.6	43	18
R4	Kemps Creek	2.6	0.2	14.7	3.7	48	21
R6	Mulgoa	1.8	0.1	4.5	0.4	43	17
R7	Wallacia	1.3	0.1	2.6	0.4	43	17
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	2.2	0.2	4.4	1.2	45	18
R14	Lawson Road, Badgerys Creek	9.6	0.7	15.8	3.1	47	20
R15	Mersey Rd, Greendale	6.1	0.5	8.6	1.3	46	18
R17	Luddenham Road	3.4	0.2	6.9	1.2	45	18
R18	Cnr Adams & Elizabeth Drive	5.3	0.6	9.4	1.7	46	19
R19	Cnr Adams & Anton Road	5.3	0.8	6.9	1.4	45	18
R21	Cnr Willowdene Ave and Vicar Park Lane	5.9	0.3	6.9	0.9	44	18
R22	Rossmore, Victor Ave	4.1	0.2	7.7	1.3	46	18
R23	Wallacia, Greendale Rd	2.3	0.1	3.7	0.4	43	17
R24	Badgerys Creek 1 NE	31.6	8.9	40.9	11.2	**72**	28
R25	Badgerys Creek 2 SW	3.6	0.5	5.1	1.2	43	18
R27	Greendale, Dwyer Rd	1.4	0.1	2.6	0.4	43	17
R30	Rossmore residential	1.7	0.1	24.0	5.0	49	22
R31	Mt Vernon residential	4.2	0.2	6.5	1.1	44	18

5.2.1.3 Particulate matter ($PM_{2.5}$)

Table 5-17 presents a summary of the maximum 24-hour average and annual average $PM_{2.5}$ concentrations for the airport separately and in combination with background sources. Exceedances are shown in bold. The predicted $PM_{2.5}$ impacts at the community receptors are provided in **Appendix G**. There are no AEPR ambient objectives for $PM_{2.5}$.

The results show that the predicted $PM_{2.5}$ concentrations during the longer term development are predicted to be (on occasion, in the case of 24-hour averages) above the NEPM advisory reporting goals of 25 µg/m³ and 8 µg/m³ for the 24-hour and annual averaging periods at a number of receptors. This is not unexpected for residential receptor R24 given that it is located within the airport site. The annual goal is predicted to be exceeded at four residential receptors. This is also not unexpected given that the background contributes to almost 90% of the NEPM goal.

The contour plots show the geographical pattern of dispersion across the local area (**Appendix G**). It can be seen that in addition to the airport, the contribution from airport traffic on external roadways plays a significant role in the ground level predictions.

Table 5-17: Predicted incremental and cumulative $PM_{2.5}$ concentrations during longer term development

Recept or ID	Receptor description	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative – Airport + external roadways + existing background (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
NEPM advisory goal		*n/a*	*n/a*	*n/a*	*n/a*	*25*	*8*
R1	Bringelly	2.4	0.1	9.1	1.2	16	8
R2	Luddenham	1.5	0.2	2.4	0.5	14	8
R3	Greendale, Greendale Road	4.3	0.2	5.8	0.4	14	7
R4	Kemps Creek	2.0	0.1	8.4	2.1	18	**9**
R6	Mulgoa	1.6	0.1	3.2	0.3	13	7
R7	Wallacia	1.1	0.1	1.8	0.3	14	7
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	1.6	0.2	2.8	0.8	15	8
R14	Lawson Road, Badgerys Creek	6.8	0.6	11.3	2.1	18	**9**
R15	Mersey Rd, Greendale	4.6	0.5	6.6	1.0	16	8
R17	Luddenham Road	2.8	0.2	4.4	0.8	15	8
R18	Cnr Adams & Elizabeth Drive	3.8	0.5	6.6	1.1	16	8
R19	Cnr Adams & Anton Road	4.0	0.6	5.1	1.0	15	8
R21	Cnr Willowdene Ave and Vicar Park Lane	4.0	0.2	4.7	0.6	14	8
R22	Rossmore, Victor Ave	2.9	0.2	4.8	0.9	16	8
R23	Wallacia, Greendale Rd	1.7	0.1	2.5	0.3	14	7
R24	Badgerys Creek 1 NE	18.6	5.3	24.7	6.8	**34**	**14**
R25	Badgerys Creek 2 SW	2.3	0.4	3.3	0.9	14	8
R27	Greendale, Dwyer Rd	1.1	0.1	1.6	0.3	13	7
R30	Rossmore residential	1.2	0.1	15.9	3.4	23	**10**
R31	Mt Vernon residential	2.9	0.2	4.5	0.7	14	8

5.3 Summary of dispersion model results

For both scenarios, the highest off-site concentrations of the air quality metrics evaluated were generally predicted to occur at the receptors located to the north and north-east of the proposed airport. This is anticipated to be a function of the prevalence of south-westerly winds and the proximity of these receptors to activities at the proposed airport.

Impacts of the proposed airport have been assessed against the AEPR ambient objectives, the NSW EPA air quality criteria and the NEPM-AAQ. A summary of the predicted impacts is provided below.

- Stage 1 development
  - There were no predicted exceedances of the AEPR ambient objectives, NSW EPA impact assessment criteria or NEPM goals at the residential or on-site receptors investigated.
- Longer term development
  - NO_2

- *Annual average*: There were no exceedances of the annual average NSW EPA criterion at any of the receptors.
- *One-hour average*: There were five residential receptors that were, on occasion, predicted to exceed the one-hour AEPR ambient criterion (up to four times during the modelling year). At the most impacted residential receptor, the maximum predicted concentration was 162% of the AEPR ambient objective (320 µg/m^3) and 211% of the NSW EPA criterion (246 µg/m^3). Both of the on-site receptors were also predicted to exceed the AEPR ambient objective, up to 11 times per year.

o PM_{10}

- *Annual average*: There were no exceedances of the annual average NSW EPA criterion at any of the receptors.
- *24-hour average*: There was one on-site receptor that was, on occasion, predicted to exceed the 24-hour NSW EPA criterion of 50 µg/m^3. For the residential receptors there were no predicted exceedances of the criterion.

o $PM_{2.5}$

- *Annual average*: The NEPM-AAQ goal of 8 µg/m^3 was predicted to be exceeded at two receptors, including one on-site receptor. The residential receptor is located adjacent to a major roadway and found to be more impacted by roadway emissions than the airport.
- *24-hour average*: There was one on-site receptor that was, on occasion, predicted to exceed the 24-hour NEPM-AAQ goal of 25 µg/m^3. For the residential receptors there were no predicted exceedances of the goal.

Based on the outcomes of the dispersion modelling it is recommended that the mitigation and management measures should focus on NO_x and to a lesser extent, PM_{10} and $PM_{2.5}$ emissions as the number of passengers that use the airport increases over time.

Finally, it is noted that the above assessment of the longer term scenario forecasts emissions approximately 50 years into the future and assumes no improvement in background air quality conditions. Further, the assessment also assumes there is limited improvement in aircraft emissions, which leads to the conclusion that these emission estimates are very conservative. Based on the current trend in air quality improvements observed for the area, it is likely that background air quality will improve with time. However, Western Sydney is the focus of development of future residential and industrial areas that may to some extent offset the anticipated trends in improved air quality.

5.4 Mitigation and management measures

The outcomes of the dispersion modelling indicate that the airport emissions during the Stage 1 development would not result in exceedances of any of the air quality metrics investigated as part of this assessment. However, the predicted impacts for the longer term development show that the air emissions from the airport will have the potential to result in some adverse air quality impacts. On that basis, the recommended mitigation and management measures have been separated into those that can be addressed now and those that can be considered in the future as the number of passenger using the airport increases.

5.4.1 Measures for the Stage 1 development

As no adverse air quality impacts were predicted for the Stage 1 development, the following mitigation and management measures are recommended as part of best practice measures for the airport operators.

It is recommended that an air quality monitoring station is installed. Ideally, the monitoring station would be co-located with the BoM weather station to the north-west of the airport site. The recommended

pollutants to be monitored include; Oxides of nitrogen (NO_x, NO and NO_2), CO, O_3, PM_{10}, $PM_{2.5}$ and VOCs. Such monitoring will enable WSA to:

- Provide a valuable benchmark for current (baseline) performance, in the event potential mitigation measures are adopted in the future;
- Evaluate the relative benefit of any future mitigation or control measures adopted through comparison with baseline data; and
- Demonstrate to the regulator and community that the issue is being addressed.

It is also recommended that fixed system APU and GSE are integrated (where practical) into the airport design. A best practice measure for on-site emissions management is the implementation of mains powered APU and GSE at the airport gates, typically comprising 400 Hz electric power and preconditioned air (PCA) is supplied to the aircraft.

A summary of the proposed air quality management measures for the operation phase of the stage 1 development is provided in **Table 5-18**.

Table 5-18: Mitigation specific to air quality management during operation phase

	Mitigation measure	Timing
Management of air quality and odour		
1	Develop and implement an operational air quality and odour management plan to be included as part of the operational management plan for the proposed airport.	Operation
Monitoring		
2	Install an air quality monitoring station at the airport site to monitor NOx, NO, NO_2, CO, O_3, PM_{10}, $PM_{2.5}$ and VOCs.	Pre-construction baseline, operation
Emissions		
3	Consider best available techniques to reduce emissions of ozone precursors, which may include: • replacing conventionally fuelled ground support equipment with electric or hydrogen powered belt loaders, pushback tractors, bag tugs, and cargo loaders; • using remote ground power for remote aircraft parking positions; • installing co-generation or tri-generation in-lieu of traditional gas fired boilers or solar hot water systems to replace gas fired boilers; • avoiding certain activities, such as training fires, maintenance (spray painting) during the ozone seasons; • using underground fuel hydrant systems and/or vapour recovery systems for refuelling and fuel storage; and • promoting the use of public transport to the airport.	Operation

5.4.2 Measures for the longer term development

The dispersion modelling identified that NO_x emissions contributed 91% of the emissions from the airport and therefore mitigation and management measures focus on reducing NO_x emissions. It is noted that NO_x emissions from GSE and APUs also play an important role, so the mitigation measure proposed for the Stage 1 development (i.e. installation of fixed system APU and GSE) should reduce NO_x emissions for the longer term development as well.

The identified particulate matter impacts were restricted to the longer term development and also to those receptors located on-site or in close proximity to major external roadways. These impacts were also a function of a high background, as in the case of $PM_{2.5}$.

The following literature was assessed for mitigation and management measures detailing relevant methods of reducing NO_x emissions during operations at the airport:

- Proposals for mitigation of pollutant emissions from aircraft at Lisbon Airport **(Ribeiro et al., 2011)**
- Heathrow Air Quality Strategy 2011-2020 **(Heathrow Airport Holdings, 2011)**
- Guidance Manual: Airport Greenhouse Gas Emissions Management **(ACI, 2009)**
- Aircraft Engine Emission Reduction Programme Zurich Airport **(Unique, 2005)**
- San Diego County Regional Airport Authority Air Quality Management Plan **(C&S Companies, KB Environmental, & Synergy Consultants, Inc., 2009)**
- Air Quality Management – London City Airport **(Moorcoft, 2010)**
- Calgary Airport Parallel Runway Project Air Quality Report **(AECOM, 2010)**
- Aviation and the Environment: Strategic Framework Needed to Address the Challenged Posed by Aircraft Emissions **(GAO, 2003)**

Based on these documents, a number of mitigation measures are suggested for managing air quality impacts from the airport. A number of these measures have been adopted by other airports internationally and are summarised in **Table 5-19**.

It is acknowledged some of the measures listed below are up to the individual airline and out of the control of the terminal operator. Nevertheless, these measures are useful as a guideline for potential NO_x reduction.

Table 5-19: Emissions mitigation measures adopted at various international airports

	Mitigation measure	Comments	Recommendation
1	Pushback by taxi to/from runway **(Ribeiro et al., 2011; Unique, 2005)**.	Aircraft would be towed between stands and runway with the aircraft engine switched off.	*This measure should be implemented where practical.*
2	Use of an automatic system for aircraft taxiing **(Ribeiro et al., 2011; Unique, 2005)**.	This could involve a fixed rail on the ground where an automatic towbar is moved. The towbar would move the aircraft to and from the runway.	*This measure should be evaluated for practical application during detailed design.*
3	Improve sequencing of aircraft **(Unique, 2005).**	Improving sequencing of aircraft will reduce the need for aircraft to queue. This would reduce unnecessary time spent with the engine on. This can be performed by virtual queueing and Collaborative Decision Making **(ACI, 2009)**.	*Highly recommended.*
4	Use market-based measures to manage demand for on-site car parking	Encourage passengers to use public transport when travelling to and from the airport.	*Highly recommended.*
5	Provide dedicated public transport at an early stage of airport development.	Providing dedicated and high capacity public transport e.g. express buses or a train line will encourage the use of public transport for passengers and staff, thereby reducing emissions from individual vehicles.	*A dedicated rail line is part of the longer term development. For Stage 1, the airport will be served by dedicated bus transit facilities.*
6	Adopt a NOx charge for aircraft **(Heathrow Airport Holdings, 2011**).	Varying charges dependent upon aircraft and/or fuel type can provide incentives for airlines to use clean aircraft and adopt new aircraft technologies more quickly.	*NO_2 impacts are anticipated as part of the longer term development and should be considered as a future measure.*
7	Where possible, buildings (including commercial) should be equipped with cool roofs. **(C&S Companies, KB Environmental, & Synergy Consultants, Inc., 2009).**	Cool roofs utilise materials that store less heat, thereby minimising energy requirements for cooling during warmer seasons. Cool pavements have been successfully used in extremely hot climates **(Santamouris et al, 2012)** such as Sydney during summertime. It should be noted however that in areas of high or turbulent winds (i.e. parts of the airport that may create wind-tunnels) cool pavements would not be practical.	*This measure is recommended where practical.*
8	Implement an air quality monitoring strategy **(Moorcoft, 2010)**.	Air pollutants should be monitored on-site with an air quality report prepared annually to examine trends in pollutant concentrations and identify any criterion exceedances.	*Highly recommended.*
9	Aircraft equipped with two engines taxi with only one engine or aircraft equipped with four engines taxi with only two engines **(Ribeiro et al., 2011; Unique, 2005; GAO, 2003)**.	The achievable taxi speed is the same when only half of the engines are used. This would reduce the amount of NO_x emissions when aircraft are on the ground. It is noted that for aircraft taking off more power will be needed for initial momentum.	*This measure is recommended where practical.*
10	Reduction of reverse thrust deployment when landing **(Unique, 2005; AECOM, 2010).**	Reverse thrust is used to help slow the aircraft after landing. Reducing the duration that this is applied can reduce emissions after landing.	*This measure is recommended where practical.*
11	APUs to be powered by mains electricity whenever possible	This will reduce air pollutant emissions, especially NO_2.	*Highly recommended.*
12	Active involvement with aircraft manufacturers and research bodies for improved emissions-related data **(Heathrow Airport Holdings, 2011)**.	Being involved with aircraft manufacturers and research bodies will improve understanding of aircraft emissions, and will assist in efforts to provide cleaner technologies.	*Encouraged to be undertaken by airport operator.*

6 FUEL DUMPING

Contrary to public perception, fuel jettisoning is extremely rare and generally only occurs during an emergency, as a safety precaution when a plane must land prematurely. At take-off, aircraft are heavier than they are at landing due to the unburned fuel that is to be burned during the flight. As aircraft can only safely land when the specified maximum landing weight is reached, prior to an emergency landing, weight must sometimes be removed from the plane during flight. This occurs in the form of an expulsion of fuel from the plane's wing tips, tail or fuselage **(Aerospaceweb, 2005).** Potential adverse effects from fuel dumping have been addressed with reference to the ***Air Navigation (Fuel Spillage) Regulations 1999*** **(Cth)** and the procedures for fuel dumping in Australia (Aeronautical Information Package (AIP) **(Air Services Australia, 2014).** The cause, frequency and volume of fuel jettisoned, as well as results from a prior scientific study on fuel dumping are outlined below.

Fuel dumping events are extremely rare worldwide. For example, All Nippon Airways (Japan's largest airline by revenues and passenger numbers in 2012) experienced only three cases of fuel dumping during 2013. All of these occurred off the east coast of Japan away from urban areas **(ANA Holdings, n.d)**. As fuel jettisoning is usually only a safety feature of long-range aircraft, most planes are forced to burn the fuel in their exhaust prior to landing by circling in the air as opposed to dumping unburnt fuel. In Australia, common aircraft such as the Airbus A320 and Boeing 737 are not even capable of fuel jettisoning. Fuel dumping instances in Australia are also very rare with only 10 occurrences in 2014 from 698, 856 domestic movements and 31, 345 international movements **(GHD, 2015b)**. Worldwide it is estimated that up to 6,800 tonnes of fuel was released over oceans in the 1990s **(Aerospaceweb, 2005).** The significant cost of fuel means that fuel dumps only occur when necessary. It is in the airlines' best interest to conserve fuel and consider alternate options prior to fuel dumping.

There are specific protocols in place to regulate fuel dumping in Australian airspace in accordance with the ***Air Navigation (Fuel Spillage) Regulations 1999***. The Aeronautical Information Package (AIP) **(Air Services Australia, 2014)** indicates that where possible, the pilot should obtain authority from Air Traffic Control (ATC) before commencing a fuel dump and receive instruction on where the fuel dump is to be performed. Fuel dumps are required to occur in clear air at 6,000 ft. (approximately 2,000 m) above ground level, and in an area nominated by the ATC to ensure that all fuel is vaporised before reaching the ground. The AIP also requires that reasonable precautions must be taken to ensure the safety of persons and property in the air and on the ground.

Civilian aircraft generally use Jet-A1 grade fuel which contains up to approximately 20% by volume aromatic hydrocarbons (including benzene) and approximately 2% by volume of naphthalene's (including Polycyclic Aromatic Hydrocarbons) **(IARC, 1989)**. This aircraft fuel is a source of volatile organic compounds (VOCs) and carbon dioxide (CO_2) when unburnt fuel droplets are released. The dumping of this unburnt fuel may therefore have an impact on local air quality. This is particularly significant for pollutants with long residence times. For example, VOCs such as benzene can occur in a predominantly vapour phase with a residence time of between 1 day and 2 weeks depending on climate and other pollutant concentrations **(Harrison et al, 2010)**. This may cause concern due to the known carcinogenic effect of benzene over long-term exposure **(Harrison et al, 2010)**. However, since fuel dumping is a rare event and protocols are in place to ensure fuel-dumps occur over the ocean, fuel dumping is not likely to have significant impacts on local air quality or human health.

The results of a previous study on fuel dumping indicate that when JP-4 fuel is jettisoned above 1,500m in above freezing temperatures, 98% will evaporate before reaching ground level **(Clewell, 1980)**. Due to the dispersion of fuel after release, the highest concentrations of fuel at ground level during calm, sunny and cool weather conditions (with wind speeds of 3m/s), were determined to occur 7km downwind away from the location of the aerial dumping. The maximum concentrations were determined to be 0.021ppm with a maximum duration of airborne jet fuel at any site being 17 minutes. These results indicate that vaporisation and dispersion of fuel occurs very quickly when jettisoned and is unlikely to have a significant local impact on air quality at the airport site, even under calm weather conditions.

Due to improvements in fuel efficiency and lightweight aircraft material, the amount of fuel dumped from aircraft under emergency situations has decreased substantially, with this trend anticipated to continue. As fuel efficiency, technology and airspace management continue to improve, volumes of fuel required to be carried on planes will steadily decline in the future. Major Australian airlines already have goals in place to implement these improvements. Qantas, for example, is currently aiming to improve its fuel efficiency by 1.5% per year until 2020 **(Department of Resources, Energy and Tourism, 2013)**. The Qantas Group Fuel Optimisation Program also has strategies in place to reduce travel distance and unnecessary aircraft weight. These strategies will help to reduce the volume of fuel carried by aircraft and reduce the amount of fuel dumped in event of an emergency.

Local effects of fuel dumping will be limited due to the inability of many aircraft to perform fuel dumps, the rapid vaporisation and wide dispersion of jettisoned fuel, the strict guidelines on fuel dumping altitudes and locations, and the anticipated reduction in fuel dumping events and volumes in the future. For these reasons, fuel dumping is not considered likely to have a significant immediate or future impact on local air quality.

7 CONSTRUCTION IMPACT ASSESSMENT

7.1 Dispersion modelling results

7.1.1 Overview

The concentrations of PM_{10}, $PM_{2.5}$, dust deposition and odour were determined for 18 residential receptors and 75 community receptors located in the local area (see **Section 3.2**). As the residential receptors are generally located in the similar areas as the community receptors, only the residential receptors have been discussed in the following results. Note that the two on-site receptors have not been considered in the construction assessment as the purpose of the on-site receptors was to evaluate the potential exposures of airport staff and passengers at the facility, noting that airport terminal staff are likely to have a much longer exposure. During construction these uses will not yet exist. The tabulated results for all receptors are provided in **Appendix G**.

Contour plots for each of the pollutants and relevant averaging periods are also provided in **Appendix G**. It should be noted that contour plots for maximum 24-hour average PM_{10} and $PM_{2.5}$ (with background contributions) could not be produced. This is because in determining the maximum 24 hour average PM_{10} and $PM_{2.5}$, daily contemporaneous background contributions were used.

7.1.2 Bulk earthworks

Table 7-1 presents a summary of the maximum 24-hour average and annual average concentrations due to the on-site construction activities. **Table 7-2** summarises the cumulative results including other sources/background predictions. The predicted dust impacts at the community receptors are provided in **Appendix G**.

The results show that the predicted dust impacts during the site establishment works are predicted to be below the NSW EPA impact assessment criterion and NEPM advisory goal for each of the reported air quality parameters.

The contour plots show the spatial extent of PM predicted concentrations across the local area. While the predicted concentrations remain low at all off-site residential receptors, the nature of the plume spread for the 24-hour and annual averaging periods is highest to the northeast and southwest of the airport site, consistent with the prevailing winds measured at Badgerys Creek AWS (**Section 4.1.1**).

Table 7-1: Predicted incremental PM and dust deposition results during bulk earthworks

		PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		Dust depos. (g/m²/ month)
Receptor	Receptor description	24-hour	Annual	24-hour	Annual	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*2*
R1	Bringelly	1.0	0.1	0.4	<0.1	1×10^{-5}
R2	Luddenham	2.1	0.3	0.5	0.1	7×10^{-5}
R3	Greendale, Greendale Road	2.7	0.1	1.4	0.1	2×10^{-5}
R4	Kemps Creek	1.3	0.1	0.8	<0.1	2×10^{-5}
R6	Mulgoa	0.4	0.1	0.2	<0.1	1×10^{-5}
R7	Wallacia	0.6	0.1	0.3	<0.1	1×10^{-5}
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	2.0	0.3	0.7	0.1	5×10^{-5}
R14	Lawson Road, Badgerys Creek	4.8	0.6	2.0	0.2	1×10^{-4}
R15	Mersey Rd, Greendale	3.3	0.4	1.2	0.1	5×10^{-5}
R17	Luddenham Road	2.2	0.3	0.6	0.1	6×10^{-5}

Receptor	Receptor description	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		Dust depos. (g/m²/ month)
		24-hour	Annual	24-hour	Annual	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*2*
R18	Cnr Adams & Elizabeth Drive	6.5	1.0	1.8	0.2	2×10^{-4}
R19	Cnr Adams & Anton Road	7.2	0.9	2.1	0.2	2×10^{-4}
R21	Cnr Willowdene Ave and Vicar Park Lane	2.9	0.5	0.7	0.1	1×10^{-4}
R22	Rossmore, Victor Ave	1.4	0.1	0.7	<0.1	2×10^{-5}
R23	Wallacia, Greendale Rd	0.8	0.1	0.3	<0.1	2×10^{-5}
R27	Greendale, Dwyer Rd	1.2	0.2	0.4	<0.1	3×10^{-5}
R30	Rossmore residential	0.7	0.1	0.3	<0.1	7×10^{-6}
R31	Mt Vernon residential	1.8	0.1	1.0	<0.1	2×10^{-5}

Table 7-2: Predicted cumulative PM and dust deposition results during bulk earthworks

Receptor	Receptor description	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		Dust depos. (g/m²/ month)
		24-hour	Annual	24-hour	Annual	Annual
Criterion		*50*	*30*	*25*	*8*	*4*
R1	**Bringelly**	**43.0**	**17.1**	**13.5**	**7.0**	**2.0**
R2	Luddenham	42.7	17.3	13.3	7.1	2.0
R3	Greendale, Greendale Road	42.7	17.1	13.3	7.1	2.0
R4	Kemps Creek	42.6	17.1	13.3	7.0	2.0
R6	Mulgoa	42.6	17.1	13.3	7.0	2.0
R7	Wallacia	42.6	17.1	13.3	7.0	2.0
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	43.4	17.3	13.5	7.1	2.0
R14	Lawson Road, Badgerys Creek	43.0	17.6	13.4	7.2	2.0
R15	Mersey Rd, Greendale	44.6	17.4	14.0	7.1	2.0
R17	Luddenham Road	44.2	17.3	13.7	7.1	2.0
R18	Cnr Adams & Elizabeth Drive	44.2	18.0	13.7	7.2	2.0
R19	Cnr Adams & Anton Road	43.9	17.9	13.6	7.2	2.0
R21	Cnr Willowdene Ave and Vicar Park Lane	42.9	17.5	13.4	7.1	2.0
R22	Rossmore, Victor Ave	42.7	17.1	13.3	7.0	2.0
R23	Wallacia, Greendale Rd	42.6	17.1	13.3	7.0	2.0
R27	Greendale, Dwyer Rd	43.0	17.2	13.4	7.0	2.0
R30	Rossmore residential	42.7	17.1	13.4	7.0	2.0
R31	Mt Vernon residential	42.6	17.1	13.3	7.0	2.0

7.1.3 Aviation infrastructure

Table 7-3 presents a summary of the maximum 24-hour average and annual average concentrations at each of the 20 residential receptors, due to the aviation infrastructure works. **Table 7-4** summarises

the results cumulatively with other sources/background predictions. The predicted dust impacts at the community receptors are provided in **Appendix G**.

The results show that the predicted dust impacts during the aviation infrastructure works are forecast to be below the NSW EPA impact assessment criterion and NEPM advisory goal for each of the reported air quality parameters.

The contour plots show a similar trend to that described for the bulk earthworks, with maximum off-site concentrations predicted to the northeast and southwest of the airport site.

Table 7-3: Predicted incremental results during aviation infrastructure works

		PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		Dust depos. (g/m²/ month)
Receptor	Receptor description	24-hour	Annual	24-hour	Annual	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*2*
R1	Bringelly	2.7	0.2	2.3	0.2	7×10^{-6}
R2	Luddenham	2.7	0.4	2.4	0.3	4×10^{-5}
R3	Greendale, Greendale Road	8.0	0.3	5.4	0.2	2×10^{-5}
R4	Kemps Creek	11.0	0.2	2.8	0.2	1×10^{-5}
R6	Mulgoa	1.3	0.1	0.7	0.1	7×10^{-6}
R7	Wallacia	1.7	0.1	0.9	0.1	1×10^{-5}
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	4.0	0.4	3.3	0.3	2×10^{-5}
R14	Lawson Road, Badgerys Creek	25.4	1.2	6.6	0.7	5×10^{-5}
R15	Mersey Rd, Greendale	7.3	0.6	5.9	0.5	3×10^{-5}
R17	Luddenham Road	5.3	0.4	2.4	0.3	3×10^{-5}
R18	Cnr Adams & Elizabeth Drive	11.0	1.1	7.8	1.0	1×10^{-4}
R19	Cnr Adams & Anton Road	8.7	1.1	7.0	1.1	1×10^{-4}
R21	Cnr Willowdene Ave and Vicar Park Lane	4.6	0.7	3.9	0.7	1×10^{-4}
R22	Rossmore, Victor Ave	6.6	0.3	2.2	0.2	1×10^{-5}
R23	Wallacia, Greendale Rd	2.1	0.2	1.2	0.2	1×10^{-5}
R27	Greendale, Dwyer Rd	2.6	0.2	2.9	0.2	2×10^{-5}
R30	Rossmore residential	2.3	0.1	1.5	0.1	4×10^{-6}
R31	Mt Vernon residential	5.9	0.2	2.9	0.2	1×10^{-5}

Table 7-4: Predicted cumulative results during aviation infrastructure works

		PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		Dust depos. (g/m²/ month)
Receptor	Receptor description	24-hour	Annual	24-hour	Annual	Annual
Criterion		*50*	*30*	*25*	*8*	*4*
R1	Bringelly	45	17	14	7	2
R2	Luddenham	43	17	13	7	2
R3	Greendale, Greendale Road	43	17	13	7	2
R4	Kemps Creek	43	17	13	7	2

Receptor	Receptor description	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)		Dust depos. (g/m²/ month)
		24-hour	Annual	24-hour	Annual	Annual
Criterion		*50*	*30*	*25*	*8*	*4*
R6	Mulgoa	43	17	13	7	2
R7	Wallacia	43	17	13	7	2
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	47	17	14	7	2
R14	Lawson Road, Badgerys Creek	50	18	14	8	2
R15	Mersey Rd, Greendale	46	18	17	8	2
R17	Luddenham Road	44	17	15	7	2
R18	Cnr Adams & Elizabeth Drive	45	18	15	8	2
R19	Cnr Adams & Anton Road	44	18	15	8	2
R21	Cnr Willowdene Ave and Vicar Park Lane	43	18	14	8	2
R22	Rossmore, Victor Ave	43	17	13	7	2
R23	Wallacia, Greendale Rd	43	17	13	7	2
R27	Greendale, Dwyer Rd	43	17	14	7	2
R30	Rossmore residential	43	17	14	7	2
R31	Mt Vernon residential	43	17	13	7	2

7.1.4 Asphalt plant

The 99th percentile 1-hour odour predictions for emissions from the asphalt plant are presented in **Table 7-5**. The extent of plume spread (see **Appendix G**) indicates that the highest odour concentrations would be largely limited to within the airport site. The 2 OU contour (the adopted impact assessment criterion) does spread outside of the airport site a relatively short distance to the north of the site boundary, however this area is currently unoccupied and therefore not considered to result in adverse odour impacts.

Table 7-5: Predicted 99th percentile odour concentration from asphalt plant

Receptor	Receptor ID	1-hour 99th percentile odour (OU)
Criterion		*2*
R1	Bringelly	<0.1
R2	Luddenham	<0.1
R3	Greendale, Greendale Road	<0.1
R4	Kemps Creek	0.1
R6	Mulgoa	<0.1
R7	Wallacia	<0.1
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.3
R14	Lawson Road, Badgerys Creek	1.7
R15	Mersey Rd, Greendale	0.1
R17	Luddenham Road	0.4
R18	Cnr Adams & Elizabeth Drive	0.5

Receptor	Receptor ID	1-hour 99th percentile odour (OU)
Criterion		*2*
R19	Cnr Adams & Anton Road	0.1
R21	Cnr Willowdene Ave and Vicar Park Lane	<0.1
R22	Rossmore, Victor Ave	0.2
R23	Wallacia, Greendale Rd	<0.1
R27	Greendale, Dwyer Rd	<0.1
R30	Rossmore residential	<0.1
R31	Mt Vernon residential	0.2

7.2 Mitigation and management

While a quantitative approach has been adopted for the assessment of the potential impacts of construction activities at nearby residences, a risk based approach has been used to identify risks and to recommend appropriate mitigation measures. The approach used is based on that described by the IAQM methodology.

In accordance with the IAQM methodology**,** the bulk earthworks and aviation infrastructure works are associated with a high level of risk for demolition, earthworks, and construction and vehicles traveling on unsealed surfaces and transporting materials onto the road network (track-out) components. The risk category definitions are provided in **Table 7-6.** Sensitive receptors, including those of ecological significance, were also identified as being located within 350m of construction activities. On that basis, the overall outcome was taken to be 'high risk'.

The results are shown in **Table 7-7** to **Table 7-12**, which detail the issue, proposed mitigation measure and the applicable timing in the development process. Most of the recommended measures are routinely employed as 'good practice' on construction sites. At the airport site, particular attention should be paid to controlling dust generated by track-out due to the overall level of risk and the potential proximity to sensitive receptors.

A Dust Management Plan (DMP) should be developed to address the construction of the proposed airport. This document would form part of the overarching Construction Environmental Management Plan (CEMP). This should contain details of the site-specific mitigation measures to be applied. Additional guidance on the control of dust at construction sites is provided as part of the NSW EPA Local Government Air Quality Toolkit[b]. Detailed guidance is also available from the UK **(GLA, 2006)** and the United States **(Countess Environmental, 2006)**.

Table 7-6: Risk category definition for each stage of construction (IAQM, 2014)

Type of activity	Site category definitions		
	Large	Medium	Small
Demolition	Building volume >50,000 m^3, potentially dusty construction material (e.g. concrete), on-site crushing and screening, demolition activities >20 m above ground level.	Building volume 20,000–50,000m^3, potentially dusty construction material, demolition activities 10-20 m above ground level.	Building volume <20,000 m^3, construction material with low potential for dust release (e.g. metal cladding, timber), demolition activities <10 m above ground and during wetter months.

[b] http://www.epa.nsw.gov.au/air/lgaqt.htm

Type of activity	Site category definitions		
	Large	Medium	Small
Earthworks	Site area >10,000 m^2, potentially dusty soil type (e.g. clay, which will be prone to suspension when dry due to small particle size), >10 heavy earth-moving vehicles active at any one time, formation of bunds>8 m in height, total material moved >100,000 tonnes.	Site area 2,500-10,000 m^2, moderately dusty soil type (e.g. silt), 5-10 heavy earth moving vehicles active at any one time, formation of bunds 4-8 m in height, total material moved 20,000-100,000 tonnes.	Site area <2,500 m^2, soil type with large grain size (e.g. sand), <5 heavy earth moving vehicles active at any one time, formation of bunds <4 m in height, total material moved <20,000 tonnes, earthworks during wetter months.
Construction	Total building volume >100,000 m^3, piling, on site concrete batching; sandblasting	Building volume 25,000-100,000 m^3, potentially dusty construction material (e.g. concrete), piling, on site concrete batching.	Total building volume <25,000 m^3, construction material with low potential for dust release (e.g. metal cladding or timber).
Track-out	>50 HDV (>3.5t) OUTWARD movements in any one day, potentially dusty surface material (e.g. high clay content), unpaved road length >100 m.	10-50 HDV (>3.5t) OUTWARD movements in any one day, moderately dusty surface material (e.g. high clay content), unpaved road length 50–100 m.	<10 HDV (>3.5t) OUTWARD movements in any one day, surface material with low potential for dust release, unpaved road length <50 m.

Table 7-7: Mitigation specific to communications / community engagement

	Mitigation measure	Action for site risk
1	Develop and implement a stakeholder communications plan that specifically addresses construction and includes community engagement before work commences on-site.	Highly recommended
2	Display the name and contact details of person(s) accountable for environmental management at the airport site boundary.	Highly recommended
3	Display the head or regional office contact information	Highly recommended

nstTable 7-8: Mitigation specific to dust management

	Mitigation measure	Action for site risk
4	Develop and implement a dust management plan, which may include measures to control other emissions. The dust management plan should include standard measures such as watering of exposed surfaces and covering of stockpiled material. The dust management plan may also include monitoring of dust deposition, dust flux, real time PM10 continuous monitoring and/or visual inspections.	Highly recommended
Site management		
5	Record all dust and air quality complaints, identify cause(s), take appropriate measures to reduce emissions in a timely manner, and record the measures taken.	Highly recommended
6	Make the complaints log available to the relevant authority when asked.	Highly recommended
7	Record in a log book any exceptional incidents that cause dust and/or air emissions, either on- or offsite, and the action taken to resolve the situation.	Highly recommended
Monitoring		
8	Carry out regular site inspections to monitor compliance with the dust management plan, record inspection results, and make an inspection log available to the relevant authority when asked.	Highly recommended
9	Increase the frequency of site inspections by the person accountable for air quality and dust issues on-site when activities with a high potential to produce dust are being carried out and during prolonged dry or windy conditions	Highly recommended

	Mitigation measure	Action for site risk
10	Determine dust deposition, dust flux, or real-time PM10 continuous monitoring locations in consultation with the relevant authorities. Where possible commence baseline monitoring at least three months before work commences on site or before work on a phase	Highly recommended
Preparing and maintaining the site		
11	Avoid site runoff of water or mud. This will reduce the potential for track-out dust emissions.	Highly recommended
Operating vehicle/machinery and sustainable travel		
12	Ensure all vehicles switch off engines when not in use.	Highly recommended
13	Avoid the use of diesel or petrol powered generators and use mains electricity or battery powered equipment where practicable.	Highly recommended
14	Appropriate vehicle speeds on unsealed roads would be considered as part of the dust management plan.	Highly recommended
15	Produce a Construction Logistics Plan to manage the sustainable delivery of goods and materials.	Highly recommended
16	Implement a Travel Plan that supports and encourages sustainable travel for construction workers (public transport, cycling, walking, and car-sharing)	Highly recommended
Operations		
17	Only use cutting, grinding or sawing equipment fitted or in conjunction with suitable dust suppression techniques such as water sprays.	Highly recommended
18	Ensure an adequate water supply on the site for effective dust/particulate matter suppression/mitigation, using non-potable water where possible and appropriate.	Highly recommended
19	Use enclosed chutes and conveyors and covered skips.	Highly recommended
20	Minimise drop heights from conveyors, loading shovels, hoppers and other loading or handling equipment and use fine water sprays on such equipment wherever appropriate.	Highly recommended
21	Ensure equipment is readily available on-site to clean any dry spillages, and clean up spillages as soon as reasonably practicable after the event using wet cleaning methods.	Highly recommended

Table 7-9: Mitigation specific to demolition

	Mitigation measure	Action for site risk
22	Soft strip inside buildings before demolition (retaining walls and windows in the rest of the building where possible, to provide a screen against dust).	Highly recommended
23	Ensure effective water suppression is used during demolition operations. Hand held sprays are more effective than hoses attached to equipment as the water can be directed to where it is needed. In addition high volume water suppression systems, manually controlled, can produce fine water droplets that effectively bring the dust particles to the ground.	Highly recommended
24	Avoid use of explosive blasting in demolition works, using appropriate manual or mechanical alternatives.	Highly recommended
25	Bag and remove any biological debris or damp down such material before demolition.	Highly recommended

Table 7-10: Mitigation specific to earthworks

	Mitigation measure	Action for site risk S5
26	Re-vegetate earthworks and exposed areas/soil stockpiles to stabilise surfaces as soon as practicable.	Highly recommended
27	Use hessian, mulches or trackifiers where it is not possible to re-vegetate or cover with topsoil, as soon as practicable.	Highly recommended
28	Minimise exposed areas as far as is practical.	Highly recommended

Table 7-11: Mitigation specific to construction

	Mitigation measure	Action for site risk
29	Avoid scrabbling (roughening of concrete surfaces) if possible.	Highly recommended
30	Ensure sand and other aggregates are stored in bunded areas and are not allowed to dry out, unless this is required for a particular process, in which case ensure that appropriate additional control measures are in place.	Highly recommended
31	Ensure bulk cement and other fine powder materials are delivered in enclosed tankers and stored in silos with suitable emission control systems to prevent escape of material and overfilling during delivery.	Highly recommended
32	For smaller supplies of fine powder materials ensure bags are sealed after use and stored appropriately to prevent dust.	Desirable

Table 7-12: Mitigation specific to track-out

	Mitigation measure	Action for site risk
33	Use water-assisted dust sweeper(s) on the access and local roads to remove, as necessary, any material tracked out of the site. This may require the sweeper to be continuously in use.	Highly recommended
34	Avoid dry sweeping of large areas.	Highly recommended
35	Vehicles should be covered to prevent escape of material during transport.	Highly recommended
36	Inspect on-site haul routes for integrity and instigate necessary repairs to the surface as soon as reasonably practicable.	Highly recommended
37	Record all inspections of haul routes and any subsequent action in a site log book.	Highly recommended
38	Ensure hard surfaced haul routes are regularly cleaned and damped down with fixed or mobile sprinkler systems or mobile water bowsers.	Highly recommended
39	Implement a wheel washing system (with rumble grids to dislodge accumulated dust and mud prior to leaving the site where reasonably practicable).	Highly recommended
40	Ensure there is an adequate area of hard surfaced road between the wheel wash facility and the site exit, wherever site size and layout permits.	Highly recommended
41	Ensure access gates are located at least 10 m from receptors where possible.	Highly recommended

7.3 Significance of risks

For almost all construction activity, the aim should be to prevent significant effects on receptors through the use of effective mitigation. Experience shows that this is normally possible. Hence the residual effect will normally be 'not significant' **(IAQM, 2014)**.

However, even with a rigorous Dust Management Plan in place, it is not possible to guarantee that the dust mitigation measures will be effective all the time. There is the risk that the on-site office buildings - in addition to a small number of residential properties, community facilities and businesses in the immediate vicinity of the airport site - might experience some occasional dust soiling impacts. This does not imply that impacts are likely, or that if they did occur, that they would be frequent or persistent. Given the distances between the construction sites and the receptors, overall construction dust is unlikely to represent a serious ongoing problem. Any effects would be temporary and relatively short-lived, and would only arise during dry weather with the wind blowing towards a receptor, at a time when dust is being generated and mitigation measures are not being fully effective. The likely scale of this would not normally be considered sufficient to change the conclusion that with mitigation, the effects will be 'not significant'. Nevertheless, particular attention should be paid to controlling dust generated by track-out as these emission have the potential to be in closer proximity to sensitive receptors.

8 GREENHOUSE GAS ASSESSMENT

8.1 Introduction

Consensus within the scientific community is that anthropogenic (man-made) activities, including aviation, increase atmospheric concentrations of greenhouse gases (GHG) which lead to climate change. The Intergovernmental Panel on Climate Change (IPCC) estimated in 2007 that aviation accounts for 2% of global carbon dioxide (CO_2) emissions. However, with airline travel becoming more popular in Australia and around the world, this contribution could reach 5% by 2050 **(SACL, 2012)**.

A GHG assessment has been completed which quantifies the GHG emissions (in tonnes of CO_2-equivalent (tCO_2-e)) for the construction phase and the scope 1, scope 2 and scope 3 emissions associated with the proposed airport operations.

8.2 Assessment Results

8.2.1 Operations

8.2.1.1 Stage 1 emission estimates

Table 8-1 outlines the GHG emissions that are forecasted to occur from sources shown in **Section 3.7.1.1.1** and **3.7.1.1.2** during Stage 1 in 2030. It is clear in **Figure 8.1** that Scope 2 GHG emissions account for the vast majority (83%) of GHG emissions, with Scope 1 GHG emissions accounting for only 17% of total Scope 1 and Scope 2 GHG emissions. Within Scope 1 emissions, **Figure 8.1** shows that the GHG emissions from the APUs are greatest (8%) with the 'Other' sources (5%) including the following:

- fugitive emissions;
- fire training; and
- use of generators, a waste water treatment plant, GSE (diesel) and boilers.

Table 8-1: Stage 1 – Summary of Estimated Annual Scope 1 & 2 GHG Emissions

Scope	Source	Fuel Type	Annual Quantity	Units	Annual Emissions ($t CO_2$-e)
1	Ground Support Equipment	Transport Diesel Oil	0.85	ML	2,292
		Transport Gasoline	2	ML	4,776
1	Auxiliary Power Unit	Stationary Gasoline	5	ML	10,975
1	Boilers	Stationary Natural Gas	1,489,809	m^3	3,005
1	Generators	Stationary Diesel Oil	0.04	ML	113
1	Fire Training	Stationary Kerosene (Jet Fuel)	0.01	ML	14
1	Waste Water Treatment Plant	N/A	1,935	ML	1,204
1	Fugitive Emissions	Transport Kerosene (Jet Fuel)	985	ML	104
1	Fugitive Emissions	Transport Diesel Oil	0.85	ML	0.1
1	Fugitive Emissions	Transport Gasoline	2	ML	0.2
2	Electricity	N/A	124,392,000	kWh	106,977
				TOTAL	**129,462**

Note: Fuel Type reflects the categories in **DoE (2014)b**
Note: Assumptions made within the GHG calculations are provided within **Appendix C**.

Note: Emissions factor was not available for jet fuel, emissions have been assumed to be the same as Avgas.

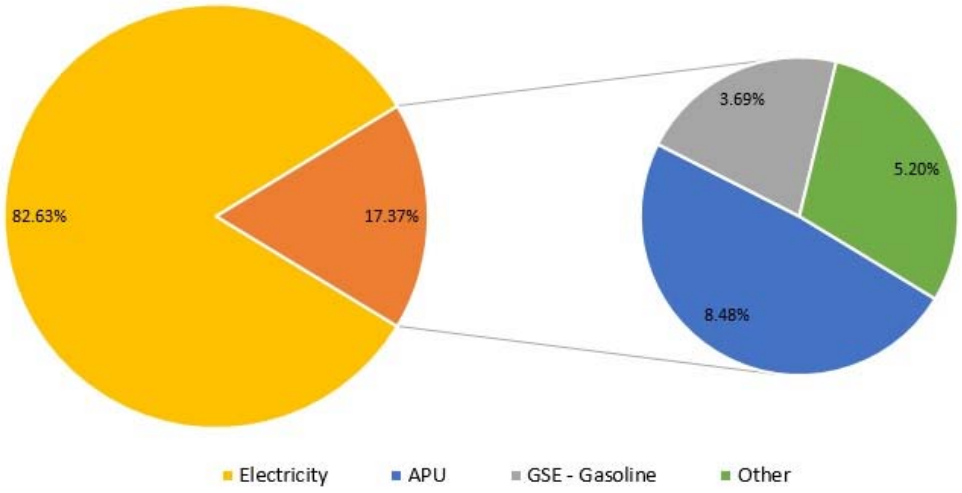


Figure 8.1: Percentage Estimated Scope 1 & 2 GHG Emissions from Stage 1 development

As mentioned in **Section 3.7.1.1.3**, it is not commonplace to report scope 3 emissions due to the potential of double counting GHG emissions between entities. Nevertheless, as they are considered significant for the airport, the most probable primary contributor, jet fuel, has been quantified in **Table** 8-2. It must be noted that this quantity involves only the emissions of departing planes. That is, due to limited information, this study only accounts for the GHG emissions being emitted during the whole flight of departing planes. This method assumes the arriving plane's emissions will be accounted for by the preceding airport. Furthermore, this method is common overseas and has been recommended by the Airport Cooperative Research Program (ACRP) **(ACRP 2009)**. In addition it assumes the anticipated demand (outlined in *Western Sydney Airport: Airport Land Use Master Plan Feasibility – Feasibility Design* (2015)) is equal to the actual demand of jet fuel from outgoing planes.

Table 8-2: Stage 1 – Summary of Estimated Annual Scope 3 GHG Emissions

Scope	Source	Fuel Type	Annual Quantity (ML)	Annual Emissions (t CO_2-e)
3	In Flight Aviation Fuel	Transport Kerosene (Jet Fuel)	986	2,524,504

8.2.1.2 Longer Term Development

Table 8-3 outlines the Scope 1 and Scope 2 GHG emissions that are estimated to occur from sources shown in **Section 3.7.1.1.1** and **Section 3.7.1.1.2** during the longer term development stage.

Figure 8.2 shows that Scope 2 GHG emissions are expected to account for the majority (80%) of Scope 1 and Scope 2 GHG emissions, with Scope 1 GHG emissions expected to comprise the remaining 20%. **Figure 8.2** shows that the GHG emissions from APU's are the largest Scope 1 source.

Table 8-3: Longer Term Development – Summary of Estimated Annual Scope 1 & 2 GHG Emissions

Scope	Source	Fuel Type	Annual Quantity	Units	Annual Emissions ($t CO_2$-e)
1	Ground Support Equipment	Transport Diesel Oil	6	ML	16,910
		Transport Gasoline	13	ML	30,728
1	Auxiliary Power Unit	Stationary Gasoline	33	ML	88,566
1	Boilers	Stationary Natural Gas	11,735,513	m^3	23,674
1	Generators	Stationary Diesel Oil	0.05	ML	143
1	Fire Training	Stationary Kerosene	0.03	ML	74
1	Waste Water Treatment Plant	N/A	9782	ML	6,092
1	Fugitive Emissions	Transport Kerosene (Jet Fuel)	8030	ML	846
1	Fugitive Emissions	Transport Diesel Oil	6	ML	0.7
1	Fugitive Emissions	Transport Gasoline	13	ML	1
2	Electricity	N/A	755,112,000	kWh	649,396
				TOTAL	**816,430**

Note: Fuel Type reflects the categories in **DoE (2014)b**
Note: Assumptions made within the GHG calculations are provided within **Appendix C**.

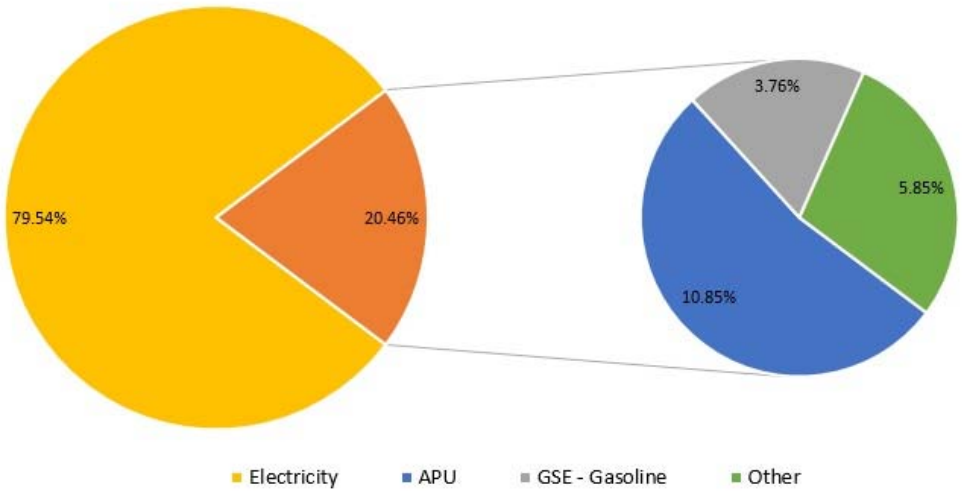


Figure 8.2: Percentage Estimated Scope 1 & 2 GHG Emissions from longer term development

As mentioned in **Section 3.7.1.1.3**, it is not commonplace to report scope 3 emissions due to the potential of double counting GHG emissions between entities. Nevertheless, as they are considered significant for the airport, the most probable primary contributor, jet fuel, has been quantified in **Table 8-2**. It must be noted that this quantity involves only that of departing planes. That is, this study only accounts for the GHG emissions being emitted during the whole flight of departing planes. This method assumes the arriving plane's emissions will be accounted for by the preceding airport. Furthermore, this method is common overseas as it has been recommended by the ACRP **(ACRP 2009)**. In addition it assumes the anticipated demand (outlined in *Western Sydney Airport: Airport Land Use Master Plan Feasibility – Feasibility Design* (2015)) is equal to the actual demand of jet fuel from outgoing planes.

Table 8-4: Longer Term Development Stage – Summary of Estimated Annual Scope 3 GHG Emissions

Scope	Source	Fuel Type	Annual Quantity	Units	Annual Emissions ($t CO_2$-e)
3	In Flight Aviation Fuel	Transport Kerosene (Jet Fuel)	8,030	ML	20,570,033

8.2.2 Construction Emission Estimates

Table 8-5 outlines the GHG emissions from two primary sources during construction. In both cases, a conservative approach has been applied. When calculating the emissions from construction equipment, it was assumed the construction of aviation infrastructure used as much fuel as during bulk earthworks. Further, it was assumed that during the commissioning phase, no fuel was used from construction equipment. It was assumed during the construction period, equipment would be used for six working days a week and 6 days per month allocated for public holidays and bad weather where there would be no construction activity.

In addition, it was assumed that 50% of the vegetation cleared was carbon and 3.67 tonnes of CO_2-e is generated per tonne of carbon cleared **(AGO 1999, 2000, 2002 and 2003)**.

Table 8-5: Summary Table of GHG Emissions during Construction

Scope	Source	Fuel Type	Quantity	Units	Emissions ($t CO_2$-e)
1	Equipment	Transport Diesel Oil	162	ML	286,111
1	Vegetation Clearing	N/A	39	kt	71,565
				TOTAL	**357,676**

8.2.3 Context

Table 8-6 compares the airport's estimated Stage 1 GHG emissions to NSW's total anthropogenic emissions in 2011-12. It concludes that the airport's Scope 1 and 2 emissions will contribute to less than 0.09% of NSW total emissions for 2011-12.

Table 8-6: Comparison of Greenhouse Gas Emissions

Location	Source Coverage	Reference Year	Emissions Mt CO_2-e
Western Sydney Airport Stage 1	Scope 1 and 2	2030	0.13
NSW	Total	2011-12	154.7

Source: **DoE (2014a)**.
Source: **CER (2015)**.

Table 8-7 summarises Australia's current and forecasted sectoral breakdown of GHG emissions. As aviation is considered a part of 'Transport' it can be concluded that the Stage 1 development Scope 1 & 2 GHG emission estimates represent approximately 0.11% of Australia's projected 2030 transport-related GHG emission inventory..

Table 8-7: Australian Sectoral Breakdown of 2014-15 Projection Results to 2029-30

Sector	2013-14 Mt CO_2-e	2029-30 Mt CO_2-e
Electricity	180	224
Direct Combustion	93	129
Transport	92	115
Fugitives	41	68
Industrial Processes	32	39
Agriculture	82	92
Waste	13	16
LULUCF	14	41
Total	548	724

Source: **DoE (2015a)**

8.3 Greenhouse Gas and Energy Reduction Measures

Domestically and internationally, aviation is under pressure to address GHG emissions. With increasing energy costs, a focus on environmental policy and a growing public demand for protecting the environment, airports worldwide are implementing GHG emission reduction initiatives. Drawing reduction procedures from other airports and several research documents, such as Airports Council International **(ACI, 2009)** and the Airport Cooperative Research Program **(ACRP, 2014)**, the information below outlines examples of initiatives to reduce or offset direct and indirect GHG emissions from airport and aviation activities. It is noted that many of these measures are the same as those described earlier which would also reduce emissions and any lessening of local air quality conditions.

Table 8-8: Table of Mitigation Measures

Scope	Mitigation Measure
1	Support alternatively fuelled and 'modernised' ground support equipment – including compressed natural gas, hydrogen, electric, compressed air and hybrid vehicles.
	Educate ground support equipment drivers in techniques to conserve fuel and implement a no-idling policy
	Design runways, taxiways, gates and terminals to minimise aircraft and ground support equipment travel distances where practical.
	Aircraft management procedures would consider the reduction of fuel use as far as practical.
	Reduce the use of auxiliary power units by using fixed electrical ground power and preconditioned air supply to aircraft where possible.
2	Specify high efficiency power, heating and cooling plants.
	Make use of renewable energy sources where practical for the generation, use or purchase of electricity, heating and cooling.
	Design energy efficient buildings to meet national / international benchmarking schemes (e.g. 5-star NABERS and Green Star ratings, LEED or BREAM).
3 3	Consider the use of high speed, high capacity public transport to and from the proposed airport as part of the ground transport plan. Support the use of the low emission vehicles to and from the proposed airport, including the provision of recharging stations priority queuing and parking.
	Develop an integrated solid waste management plan to implement waste saving initiatives such as composting and recycling.
	Install tenant energy sub-metering systems.

9 SUMMARY AND CONCLUSIONS

Pacific Environment was engaged to prepare an Air Quality and Greenhouse Gas Assessment as part of an Environmental Impact Statement (EIS), required under *Environment Protection and Biodiversity Conservation Act 1999*. This report has quantified the potential local air quality impacts and greenhouse gas emissions that may arise during the construction and operation phases of the proposed airport. Both the Stage 1 development and longer term development were assessed as part of this report.

This assessment has followed the procedures outlined in the NSW Environment Protection Authority (EPA) document titled *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW* ("Approved Methods", **EPA, 2005**).

9.1 Stage 1 Operational Impacts

For the proposed Stage 1 development, the following pollutants were assessed: NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2, air toxics, odour from exhaust emissions and odour from the on-site waste water treatment plant.

With the exception of airport traffic on roadways external to the site, aircraft movements would be by far the largest source of PM_{10}, $PM_{2.5}$, NO_X and SO_2 for both scenarios, with an associated contribution to the predicted concentrations at the receptors investigated. The operation of Auxiliary Power Units (APUs) and ground support equipment (GSE) would also have an influence on the predicted pollutant concentrations. Stationary sources, in particular evaporative loss from the Jet-A1 fuel tanks as well as aircraft would be a significant contributor to VOC emissions and corresponding ground level concentration predictions.

The highest off-site concentrations of the air quality metrics evaluated were generally predicted to occur at the receptors located to the north and north-east of the proposed airport. This is anticipated to be a function of the prevalence of south-westerly winds and the proximity of these receptors to activities at the proposed airport.

Airport traffic on surrounding road infrastructure was found to be a significant contributor to predicted off-site ground level concentrations, particularly for those receptors located in close proximity to proposed roadways.

There were almost no predicted exceedances of the NSW EPA criteria or NEPM goals at the residential or on-site receptors investigated in this air quality assessment for the proposed Stage 1 operations. The exception is the 99.9th percentile 1-hour maximum for formaldehyde with an exceedance shown at the on-site receptor R24 when assessed against the NSW EPA assessment criterion.

Predicted off-site odour concentrations were below odour detection limits for both aircraft exhaust emissions and odours from the on-site waste water treatment plant.

9.2 Longer Term Operational impacts

When reviewing the results, it is highlighted that limited improvements in emissions were able to be incorporated into the model due to the lack in availability of emission projections for the future aircraft fleet (nominal year 2063) or government policies which may act to reduce other emissions in the future.

With the exception of roadways external to the airport site, aircraft movements were again predicted to be by far the largest source of PM_{10}, $PM_{2.5}$, NO_X and SO_2, with operation of APUs and GSE also having an influence on predicted off-site impacts. Stationary sources, in particular evaporative loss from the Jet-A1 fuel tanks as well as aircraft, were shown to be a significant contributor to VOC emissions and associated off-site impacts.

Given the uncertainties around emission projections for the future aircraft fleet, combined with an expected improvement in aircraft emissions over time, the indicative longer term development was evaluated only for the air quality metrics, namely: NO_2, PM_{10}, and $PM_{2.5}$.

The results of the dispersion modelling indicate that, under the conservative emission assumptions adopted, exceedances of the 1-hour average NO_2 AEPR ambient objective of 320 µg/m^3 may be experienced at seven residential receptors. These exceedances are predicted to occur for between one and two hours per year.

Predicted (cumulative) 24-hour PM_{10} concentrations are anticipated to be above the NSW EPA impact assessment criterion of 50 µg/m^3 on occasion at one on-site receptor (R24). Receptor R24 is located within the airport site to evaluate impacts on airport staff and passengers.

Predicted (cumulative) $PM_{2.5}$ concentrations are anticipated to be above the NEPM advisory reporting goals of 25 µg/m^3 and 8 µg/m^3, for the 24-hour and annual averaging periods respectively, at a number of receptors. The annual goal is predicted to be exceeded at four residential receptors. This is also not unexpected given that the existing background concentrations of this parameter already contribute to around 90 % of the goal.

9.3 Air quality mitigation and management

The most important source of on-site emissions is anticipated to be associated with aircraft taking off and landing, for both the proposed Stage 1 and the longer term development. However, the regulation of aircraft engine emissions is beyond the remit of the proposed Western Sydney Airport. Moreover, potential exceedances of air quality criteria (notably the 1-hour NO_2 and 24-hour / annual $PM_{2.5}$) are predicted to occur due to activities in the vicinity of the airport gates as part of the longer term development. Mitigation of such activities may include the connection of APUs to mains power rather than the current assumption that they are operated by dedicated internal combustion engines.

Current community concern and associated regulatory pressure could be mitigated through the provision of ambient air quality monitoring in the vicinity of the proposed airport. The implementation of such monitoring would provide scientifically robust data to demonstrate that any changes in local air quality associated with the WSA development are within regulatory guidelines.

9.4 Construction impacts

Due to the transient, variable nature of construction activities, it is difficult to accurately quantify air quality impacts from the proposed construction activities. Any effects of the proposed construction on airborne particle concentrations would generally be temporary and relatively short-lived. Moreover, mitigation should be straightforward, as most of the necessary mitigation measures are routinely employed on construction sites. However, in view of the length of the proposed construction period, a quantitative assessment of impacts was completed for the following:

- bulk earthworks (particulate matter (PM) impacts only);
- aviation infrastructure;
- working crew (PM impacts);
- concrete batching plant (PM impacts); and
- asphalt plant (odour impacts).

A risk based approach has been used to identify key construction air quality risks and to recommend appropriate mitigation measures based on the methodology described by the IAQM methodology. Most of the recommended measures are routinely employed as 'good practice' on other construction sites.

A Dust Management Plan should be developed to address the construction of the proposed airport. This document would form part of the overarching CEMP. At the airport site, particular attention should be paid to controlling PM generated by track-out due to the overall level of risk and the potential close proximity of potential track-out PM emissions to sensitive receptors.

9.5 Fuel dumping

Local effects of fuel dumping at the site would be limited due to the inability of many aircraft to perform fuel dumps, the quick vaporisation and dispersion of aircraft fuel, the strict guidelines on fuel dumping altitudes and locations, and the anticipated reduction in fuel dumping events and volumes in the future. For these reasons, fuel dumping is not considered likely to have a significant future impact on local air quality.

9.6 Greenhouse gases

The assessment estimated the GHG emissions from the construction, Stage 1 and longer term development phases of the proposed airport.

Direct (scope 1) and indirect (scope 2) GHG emissions from the Stage 1 development of the proposed airport have been estimated to comprise 0.13 Mt CO_2-e/annum, with the majority of emissions associated with purchased electricity. The proposed Stage 1 development Scope 1 & 2 GHG emission estimates represent approximately 0.11% of Australia's projected 2030 transport-related GHG emission inventory. For this reason, it can be concluded the GHG emissions from the proposed airport would not be material in terms of the national inventory, however a number of mitigation measures have been suggested to reduce these emissions.

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Appendix A TERMS AND ABBREVIATIONS

Term	Description
µg/m^3	Micrograms per cubic metre
Air toxic	Air toxics include benzene, dioxins, lead and other metals. Major sources of these toxics include motor vehicle exhaust and some commercial and industrial processes.
Anthropogenic	Human sourced
APU	Auxiliary Power Unit
ATM	Aircraft transport movement
AWS	Automatic Weather Station
BACT	Best available control technology
BMP	Best management practice
BoM	Bureau of Meteorology
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CO	Carbon monoxide
Contemporaneous assessment	A method described in the *Approved Methods* whereby our daily model predictions are combined with the monitoring data for that matching day or hour in order to determine the cumulative impact.
Criteria pollutant	Those pollutants listed in Table 7.1 of the *Approved Methods* and include: SO_2, NO_2, O3, Pb, PM_{10}, TSP, deposited dust, CO and HF
DEC	Department of Environment and Conservation (now OEH)
DECCW	Department of the Environment, Climate Change and Water (now OEH)
Deposited dust	Any particulate matter that falls out from suspension in the atmosphere. This measurement is expressed in units of mass per area per unit time (e.g. g/m^2/month).
EDMS	Emissions and Dispersion Modelling System
EIS	Environmental Impact Statement
EP&A Act	NSW Environmental Planning and Assessment Act 1979
EPA	(NSW) Environment Protection Agency
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
Fugitive dust	Dust derived from a mixture of sources (non-point source) or not easily defined sources. Examples of fugitive dust include dust from vehicular traffic on unpaved roads, materials transport and handling, and un-vegetated soils and surfaces.
GMR	(Sydney) Greater Metropolitan Region
GSE	Ground support equipment
ha	Hectare
ICAO	International Civil Aviation Organisation
JUHI	Joint User Hydrant Installation
km/hr	Kilometres per hour
KSA	Kingsford Smith Airport
m	Metre
m^2	Square metres
mg/m^3	Milligrams per cubic metre
NEPC	National Environment Protection Council
NEPM	National Environment Protection (Ambient Air Quality) Measure. National Environment Protection Measures are broad framework-setting statutory instruments defined under

Term	Description
	the (*National Environment Protection Council (New South Wales) Act 1995*). They outline agreed national objectives for protecting or managing particular aspects of the environment. NEPMs are similar to environmental protection policies and may consist of any combination of goals, standards, protocols, and guidelines.
NEPM-AAQ	National Environmental Protection (Ambient Air Quality) Measure
NHMRC	National Health and Medical Research Council
NMHC	Non-methane hydrocarbons
NO_2	Nitrogen dioxide
NO_X	Oxides of nitrogen
NSW	New South Wales
Nuisance dust	Dust which reduces environmental amenity without necessarily resulting in material harm. Nuisance dust comprises particles with diameters nominally from about 1 millimetre to 50 micrometres (microns).
O_3	Ozone
OEH	Office of Environment and Heritage
OLM	Ozone Limiting Method
PAHs	Polycyclic aromatic hydrocarbons
PM	Airborne particulate matter
PM_{10}	Airborne particulate matter with an aerodynamic diameter of less than 10 µm.
$PM_{2.5}$	Airborne particulate matter with an aerodynamic diameter of less than 2.5 µm.
POEO Act	Protection of the Environment and Operations Act (1997)
POEO Regulations	Protection of the Environment and Operations Regulations (2010)
ppm	Parts per million
Proposed airport	The proposed Western Sydney Airport which is subject to assessment.
SACL	Sydney Airport Corporation Limited
SO_2	Sulfur dioxide
SO_X	Sulfur oxides
STP	Sewerage Treatment Plant
THC	Total hydrocarbons
TSP	Total suspended particulate
VOCs	Volatile organic compounds

Appendix B CRITERIA AIR POLLUTANTS: HEALTH EFFECTS AND SOURCES

B.1 CARBON MONOXIDE

B.1.1 Health effects

Carbon monoxide (CO) is a colourless, odourless gas. It can be harmful to humans because, when inhaled, it is taken up by haemoglobin in the blood (forming carboxyhaemoglobin) in preference to oxygen, thus reducing the capacity of the blood to transport oxygen. The affinity of CO for haemoglobin is more than 200 times greater than that of oxygen.

At low concentrations the symptoms of CO intoxication include lethargy in healthy adults, and chest pain in people with heart disease. At higher concentrations CO leads to impaired vision and coordination, headaches, dizziness, confusion and nausea. CO is fatal at very high concentrations[a].

Symptoms are not generally reported until the carboxyhaemoglobin level in the blood exceeds 10%. This is approximately the equilibrium value achieved with an ambient concentration of 70 mg/m^3 for a person engaged in light activity. There is evidence that there is a risk for individuals with cardiovascular disease at lower carboxyhaemoglobin levels. A carboxyhaemoglobin level in the blood of 40-50% usually leads to death. However, in most Australian towns and cities the levels of CO in ambient air are well below those that are hazardous to human health. Only in larger cities do CO levels have the potential to have harmful effects[b].

B.1.2 Other effects

CO plays a role in the formation of ground-level ozone through a series of reactions with the following net chemistry:

$CO + 2O_2 + hv \rightarrow CO_2 + O_3$

where **hv** refers to a photon of light

CO also has an indirect radiative forcing effect by elevating concentrations of methane and tropospheric ozone through chemical reactions with other atmospheric constituents (e.g. the hydroxyl radical, OH) that would otherwise destroy them.

B.2 NITROGEN DIOXIDE

B.2.1 Health effects

NO_2 is one of the most important aircraft pollutants. It is an irritant and oxidant which has been linked to a range of adverse health effects, including deterioration in lung function, respiratory symptoms, asthma prevalence and incidence, cancer incidence, and birth outcomes (*e.g.* birth weight). The most consistent associations, however, have been found with respiratory outcomes **(COMEAP, 2009)**. The evidence relating to the health effects of ambient NO_2 concentrations has strengthened in recent years, and some of the main findings are summarised below.

B.2.1.1 Short-term exposure to NO_2

In an extensive review of the health evidence, the **WHO Regional Office for Europe (2013)** noted that many studies have documented associations between day-to-day variations in NO_2 concentration and variations in respiratory symptoms, hospital admissions and mortality.

[a] http://www.epa.gov/iaq/co.html#Health_Effects

[b] http://www.environment.gov.au/protection/publications/factsheet-carbon-monoxide-co

- Short-term exposure to NO_2 has some direct effects on respiratory morbidity, even after adjustment for particles and other pollutants
- There are positive associations between short-term exposure to NO_2 and hospital admissions/visits for cardiovascular and/or cardiac diagnoses, although these outcomes are mixed after adjustment for co-pollutants.
- Significant associations between short-term ambient concentrations of NO_2 and mortality have been reported. In some studies the associations have remained significant after adjustment for $PM_{2.5}$ and black smoke. NO_2 could also act as a marker for other traffic pollutants such as volatile organic compounds, aldehydes and organic compounds bound to primary particles. To summarise, the evidence is suggestive but not sufficient to infer a causal relationship between short-term exposure to NO_2 and all-cause mortality **(USEPA, 2015)**.

B.2.1.2 Long-term exposures to NO_2

Although it is possible that NO_2 acts as a marker for other traffic pollutants, there is likely to be a causal relationship for long-term exposure to NO_2 and respiratory effects. The evidence for cardiovascular effects and total mortality is suggestive, but not sufficient to infer a causal relationship (**WHO Regional Office for Europe, 2013; USEPA, 2015**). There are associations between long-term exposure to NO_2 and morbidity and mortality at concentrations that are at or below the current EU annual mean limit value (40 µg/m^3).

B.3 PARTICULATE MATTER

B.3.1 Health effects

B.3.1.1 Background

The pollutant generally accepted as having the greatest public health impact is particulate matter **(Harrison, 2010)**. The biological effects of inhaled particles are determined by their physical and chemical properties, by their sites of deposition, and by their mechanisms of action. The extent to which particles can penetrate the respiratory tract, and their potential for causing health effects, is directly related to their size (**Harrison *et al.*, 2010**). With normal nasal breathing, larger particles (those greater than 10 µm) are generally deposited in the extrathoracic part (nose, mouth and throat) of the respiratory tract. They adhere to the mucus in the nose, mouth, pharynx and larger bronchi, and from there are removed by either swallowing or expectorating. Particles between 10 and 2.5 µm can enter bronchial and pulmonary regions of the respiratory tract, with increased deposition during mouth breathing which increases during exercise. However, particles with a diameter of less than 2.5 µm can penetrate deep into the human respiratory system. Fine particles can be deposited in the pulmonary region, and it is these which are of particular concern.

In recent years epidemiological evidence has accumulated indicating that airborne particles have a range of adverse effects on health. These effects – which are diverse in scope, severity and duration - include the following:

- Premature mortality.
- Aggravation of cardiovascular disease such as atherosclerosis.
- Aggravation of respiratory disease such as asthma.
- Changes to lung tissue, structure and function.
- Cancer[c].

[c] Particles may contain carcinogenic substances such as polycyclic aromatic hydrocarbons (PAHs) or heavy metals.

- Reproductive and developmental effects.
- Changes in the function of the nervous system.

Importantly, the International Agency for Research on Cancer has recently classified outdoor air pollution as carcinogenic to humans, with a specific emphasis on PM and diesel engine exhaust **(IARC, 2012, 2013)**.

Research shows that particle pollution can exacerbate existing respiratory symptoms, and at high concentrations cause respiratory symptoms. Particles can also adversely impact cardiovascular health. No safe threshold has been identified for the human health effects of particles **(NSW DECCW, 2010)**. The health effects of PM are further complicated by the chemical nature of the particles and by the possibility of synergistic effects with other air pollutants such as sulfur dioxide. Airborne particles also reduce visual amenity and visibility **(NSW DECCW, 2010)**.

B.3.1.2 PM_{10} and $PM_{2.5}$

Ambient concentrations of PM are most commonly defined in terms of two metrics: PM_{10} and $PM_{2.5}$, the mass concentrations of particles with an aerodynamic diameter of less than 10 µm and 2.5 µm respectively. There are many natural and anthropogenic sources of airborne particles, and as a consequence particulate matter displays a wide range of physical and chemical characteristics. When discussing PM sources and composition it is essential to distinguish between 'primary' and 'secondary' particles. Primary particles are emitted directly into the atmosphere as a result of natural processes (e.g. wind erosion, marine aerosols) and anthropogenic processes involving either combustion (e.g. industrial activity, domestic wood heaters, vehicle exhaust) or abrasion (e.g. tyre wear). Secondary particles are not emitted directly, but are formed by reactions involving gas-phase components of the atmosphere. Various studies have shown that secondary particles contribute significantly to PM concentrations, especially $PM_{2.5}$ at background sites, although their characteristics vary significantly with both location and time.

There is sufficient evidence to conclude that short-term and long-term exposure to $PM_{2.5}$ causes illness and death from cardiovascular conditions, and is likely to cause respiratory conditions (**USEPA 2009; WHO Regional Office for Europe, 2013**). The effects observed in relation to $PM_{2.5}$ from a large study conducted in Australia and New Zealand (**EPHC, 2010**) are consistent with the effects reported in the international literature. Associations have also been observed between exposure to $PM_{2.5}$, reproductive and developmental effects, and cancer. In 2009, the USEPA concluded the evidence was suggestive of a causal relationship (**USEPA, 2009**).

There is extensive evidence that short-term exposure to PM_{10} is associated with health effects, and that these effects are independent of the effects of $PM_{2.5}$. In 2009 the USEPA concluded that there was suggestive evidence of a causal relationship between short-term exposure to coarse particles ($PM_{2.5-10}$) and cardiovascular and respiratory effects and mortality (**USEPA, 2009**). Since that time, evidence of these short-term effects has increased significantly, and the WHO has stated that "sufficient evidence exists for proposing a short-term standard for PM_{10}, to protect against the short-term health effects of coarse particles, in addition to fine particles" (**WHO Regional Office for Europe, 2013**). There is substantially less evidence that long-term exposure to PM_{10} has health effects that are independent of those caused by long-term exposure to $PM_{2.5}$. However, in regard to management of long-term exposure, the WHO has stated that "a limit to protect against long-term exposure should be maintained as new evidence is published on health effects of long-term exposure to PM_{10} from Europe, and as long as there remains uncertainty about if these health effects would be eliminated by reduction of long-term exposure to $PM_{2.5}$ alone" (**WHO Regional Office for Europe, 2013**). As with $PM_{2.5}$, the effects observed in the Australian and New Zealand NEPC multi-city study (**EPHC, 2010**) in relation to PM_{10} exposure are consistent with those observed internationally.

There is increasing, but as yet limited, epidemiological evidence on the association between short-term exposure to ultrafine particles and cardiovascular and respiratory health (**WHO Regional Office for Europe, 2013**). This is an area of ongoing research.

Studies have also investigated the relationship between specific PM components (for example, black carbon, secondary organic aerosol (SOA) and secondary inorganic aerosol (SIA)) and health effects (**WHO Regional Office for Europe, 2013**). In the future, the use of these metrics may provide a better indication of exposure to PM from particular sources, such as vehicle exhaust, and may improve the understanding of the associated health risks. While there is some evidence that the relationship between particles and their health effects depends on their chemical composition, the evidence is insufficient to conclude this relationship is causal **(Bell, 2012)**.

The linearity of the relationship between exposure to $PM_{2.5}$ and health response - and correspondingly the existence or otherwise of a threshold for health effects - has been the subject of several studies since the WHO 2005 air quality guidelines global update. For studies of short-term exposure to $PM_{2.5}$ there is substantial evidence of associations down to very low levels. Studies of long-term exposure face greater methodological challenges to fully assess thresholds and linearity, and fewer long-term studies have examined the shape of the concentration–response functions. WHO Regional Office for Europe (2013) commented that long-term studies have not detected significant deviations from linearity (*i.e.* no evidence of a threshold for effects) for the ambient levels of $PM_{2.5}$ observed in Europe. Similarly, researchers in the United States have consistently found no evidence of a threshold concentration below which adverse health effects are not observed (**Pope and Dockery, 2006; Brook *et al.*, 2010; USEPA, 2009**). In Canada, **Crouse *et al.* (2012)** investigated the long-term exposure to ambient $PM_{2.5}$ in non-immigrant adults, and observed associations with cardiovascular mortality at concentrations as low as only a few micrograms per cubic meter. This last study is particularly relevant, because it investigated the effects of $PM_{2.5}$ at levels commonly experienced in Australia.

B.3.1.3 Ultrafine particles

A considerable amount of attention in recent years has focussed on 'ultrafine particles' (UFPs). These are particles with a diameter of less than 0.1 µm. Whilst there is some evidence particles in this size range are associated with adverse health effects, it is not currently practical to incorporate them into an environmental impact assessment. There are several reasons for this, including the rapid transformation of such particles in the atmosphere, the need to treat UFPs in terms of number rather than mass, the lack of robust emission factors, the lack of robust concentration-response functions, the lack of ambient background measurements, and the absence of air quality standards.

In relation to concentration-response functions, the **WHO Regional Office for Europe (2013)** has stated the following:

'… the richest set of studies provides quantitative information for PM2.5. For ultrafine particle numbers, no general risk functions have been published yet, and there are far fewer studies available. Therefore, at this time, a health impact assessment for ultrafine particles is not recommended.'

For the purpose of this assessment it is therefore assumed that the effects of UFPs on health are adequately represented by $PM_{2.5}$.

B.3.2 Other effects

Particulate matter is one of the pollutants that have the capacity to influence climate locally, regionally, and globally; for example, black carbon from combustion sources has much the same effect as a greenhouse gas, although the precise mechanisms are different. Airborne particles also affect radiative transfer in the atmosphere and provide one of the largest uncertainties in estimating the anthropogenic influences upon climate change. White particles such as ammonium sulfate are reflective and have a net cooling effect by reflecting incoming solar radiation back to space. Water-soluble particles can act as cloud condensation nuclei affecting the albedo (reflectivity) of clouds leading to a reduction in land surface warming (**Harrison, 2010**).

Particulate matter can clog the stomatal openings of plants and interfere with photosynthesis functions. When PM concentrations in the atmosphere are well in excess of health criteria, this can therefore lead to stunted growth or mortality in some plant species.

B.4 LEAD

Lead is a highly toxic metal that can be absorbed in the human body through both ingestion and inhalation. It accumulates in the body, and the toxic effects are numerous and severe. The main concern is the potential to impair the intellectual development in children, but lead is also associated with effects on the circulatory system, the central nervous system, and the gastrointestinal system (**NSW DECCW, 2010**).

Under the National Fuel Quality Standards Act 2000, the Australian Government announced a phase-out of leaded petrol in Australia. On 1 January 2002, that phase-out was completed. The sale of leaded petrol in Australia is now prohibited, except in cases specifically authorised by the Minister.

One exception to this relevant to airport operations is the allowance for lead within Aviation Gasoline, or Avgas. Avgas is used in small piston engine powered aircraft within the General Aviation community. Predominately activities such as private pilots, flight training, flying clubs and crop spraying. Piston engines operate using the same basic principles as spark ignition engines of cars, but they have a much higher performance requirement.

There are two main Avgas grades available in Australia - 100 and 100LL low lead. The former is permitted to contain lead up to 1.12 g/litre of fuel and the latter 0.56 g/litre. This is compared with 0.005 g/litre for all conventional grades of petrol.

Notwithstanding the above, the proportion of small piston aircraft servicing the WSA is anticipated to be low (less than 5% of all aircraft). The resultant lead emission inventory associated with Avgas use at the airport is not considered significant and this air quality metric has not been considered further within the assessment.

B.5 OZONE

Ozone is a colourless, strongly oxidising gas that is an important component of summer-time smog in the troposphere. Ground-level ozone is not produced directly from emission sources but is created by complex photochemical reactions involving NO_X and VOCs in the atmosphere. Ozone can be transported over long distances, and in contrast to other pollutants the concentrations are generally highest at rural locations downwind of large cities. Ozone is therefore regarded as a regional air pollution problem. In urban areas ozone is depleted through the titration reaction with NO.

Elevated concentrations of ozone occur in Sydney in the warmer months under suitable weather conditions including sufficient sunlight, high temperatures, and favourable wind conditions (**NSW DECCW, 2010).**

B.5.1 Health effects

As ozone is a powerful oxidant it can react with a wide range of cellular components and biological materials. Even relatively low levels of ozone can cause health effects. In particular, exposure to ozone damages lung tissue and reduces lung function. High concentrations therefore lead to increases in the frequency of respiratory symptoms and in deaths. Breathing ozone can trigger a variety of health problems including chest pain, coughing, throat irritation, and congestion. It can worsen bronchitis, emphysema, and asthma. Ground level ozone also can reduce lung function and inflame the linings of the lungs. Repeated exposure may permanently scar lung tissue. High concentrations of ozone affect not only people with respiratory problems such as asthma, but also healthy adults and children **(NSW DECCW, 2010**).

Evidence from observational studies strongly indicates that higher daily ozone concentrations are associated with increased asthma attacks, increased hospital admissions, increased daily mortality, and other markers of morbidity. The consistency and coherence of the evidence for effects upon asthmatics suggests that ozone can make asthma symptoms worse and can increase sensitivity to asthma triggers[d]. According to **WHO Regional Office for Europe (2013)**, recent epidemiological studies have indicated potentially larger mortality effects than previously thought. This is because new evidence has emerged detailing the negative effects of long-term exposure to ozone on mortality as well as adverse effects such as asthma incidence, asthma severity, hospital care for asthma and lung function growth.

B.5.2 Other effects

Exposure to ozone can reduce the overall productivity of plants by damaging cells and causing the destruction of leaf tissue. Plants become more susceptible to disease, pests, cold and drought, causing economic losses. Ozone may also result in sensitive species dying out, with additional effects on wildlife **(CARB, 2008)**.

Ozone can also cause substantial damage to materials such as rubber, plastics, fabrics, paint and metals. Exposure to ozone progressively damages both functional and aesthetic qualities, and shortens the life spans of materials. Damage from ozone exposure can result in significant economic loss as a result of the increased need for maintenance, upkeep and replacement **(CARB, 2008)**.

B.6 SULFUR DIOXIDE

Sulfur dioxide (SO_2) is an acidic gas which is colourless and has an unpleasant odour. It reacts readily with other substances to form harmful compounds, including sulfate particles. SO_2 can have harmful effects on health, vegetation and materials. The major health concerns associated with exposure to high concentrations of SO_2 include effects on breathing, respiratory illness, alterations in pulmonary defences, and aggravation of existing cardiovascular disease. SO_2 reacts with water vapour to form sulfuric acid (acid rain) that can damage vegetation, alter the mineral content in soils, and corrode materials.

B.7 AIR TOXICS

People exposed to toxic air pollutants at high concentrations may have an increased chance of getting cancer or experiencing other serious health effects. These health effects can include damage to the immune system, as well as neurological, reproductive (e.g., reduced fertility), developmental, respiratory and other health problems. In addition to exposure from breathing air toxics, some toxic air pollutants can deposit onto soils or surface waters, where they are taken up by plants and ingested by animals and are eventually magnified up through the food chain[e].

It is uncommon for air quality assessments to address a large number of organic pollutants. It is more usual for a small number of the most important components to be assessed, with inferences being made in relation to others. The compounds that have been considered here are those included in the Air Toxics NEPM:

- Benzene
- Toluene
- Xylenes (the total of ortho, meta and para isomers)
- Benzo(a)pyrene, as a marker for polycyclic aromatic hydrocarbons (PAHs)

[d] http://www.epa.gov/groundlevelozone/health.html

[e] http://www.epa.gov/oar/toxicair/newtoxics.html#effects

- Formaldehyde

These pollutants are generally less of a concern that in the past. Improvements in fuel quality in recent years have reduced their significance.

B.7.1 Benzene

Benzene is a constituent of road transport fuel, but since 2006 the benzene content of petrol in Australia has been limited to 1% by volume (compared with 5% previously). This reduction has had an immediate and sustained impact on ambient benzene levels.

Short-term inhalation exposure to benzene can cause drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation, and, at high levels, unconsciousness. Long-term inhalation exposure has caused blood disorders including reduced numbers of red blood cells and anaemia. Reproductive effects have been reported for women. Increased incidence of leukaemia has been observed in humans occupationally exposed to benzene. The USEPA has classified benzene as known human carcinogen[f].

B.7.2 Toluene

Toluene is added to gasoline to improve octane ratings, and motor vehicle emissions are the principal source of it in ambient air. The symptoms of exposure to elevated levels of toluene include fatigue, headaches, nausea, irritation of the upper respiratory tract and eyes, and a sore throat. The USEPA has concluded that that there is inadequate information to assess the carcinogenic potential of toluene[g].

B.7.3 Xylenes

Xylenes are released into the atmosphere as fugitive emissions from industrial sources, from auto exhaust, and through volatilization from their use as solvents. Short-term exposure to xylenes results in irritation of the eyes, nose, and throat, gastrointestinal effects, eye irritation, and neurological effects. Long-term exposure results primarily in central nervous system effects, such as headache, dizziness, fatigue, tremors, and incoordination; respiratory, cardiovascular, and kidney effects have also been reported. USEPA has classified mixed xylenes as a Group D, not classifiable as to human carcinogenicity[h].

B.7.4 Polycyclic aromatic hydrocarbons (PAHs)

The term PAH covers a large group of organic compounds with two or more fused aromatic rings. About 500 PAHs and related compounds have been detected in the air (**WHO Regional Office for Europe, 2000**). PAHs are formed by incomplete combustion of fuels, including transport fuels, and can be present in both gas and (more commonly) particle phases. The USEPA has designated 32 PAH compounds as priority pollutants. A short list of compounds is often targeted for measurement in environmental samples. Of these, the most measurements have been made for benzo(a)pyrene, and this compound is used as a marker for PAHs in the Air Toxics NEPM.

PAHs are a concern because they are persistent in the environment for long periods of time. There is little information available on the health effects of exposure to individual PAHs at specific concentrations. Short-term exposure to mixtures of PAHs is known to cause skin irritation and inflammation. Anthracene, benzo(a)pyrene and naphthalene are direct skin irritants, while anthracene and benzo(a)pyrene are reported to cause an allergic skin response. The health effects of long-term exposure to PAHs may include cataracts, kidney and liver damage and jaundice. Naphthalene, a

[f] http://www.epa.gov/ttn/atw/hlthef/benzene.html

[g] http://www.epa.gov/ttn/atw/hlthef/toluene.html

[h] http://www.epa.gov/ttnatw01/hlthef/xylenes.html

specific PAH, can cause the breakdown of red blood cells if inhaled or ingested in large amounts. Long-term studies of workers exposed to mixtures of PAHs and other workplace chemicals have shown an increased risk of skin, lung, bladder and gastrointestinal cancers (**USEPA, 2008; SA Health, 2009**).

B.7.5 Formaldehyde

Formaldehyde is a colourless gas with a pungent odour. Major sources include power plants, manufacturing facilities, incinerators, and automobile exhaust. Short-term and long-term inhalation of formaldehyde can result in respiratory symptoms, and eye, nose, and throat irritation. Limited human studies have reported an association between formaldehyde exposure and lung and nasopharyngeal cancer. USEPA considers formaldehyde a probable human carcinogen[i].

[i] http://www.epa.gov/ttn/atw/hlthef/formalde.html

Appendix C CHARACTERISATION OF EMISSION SOURCES IN EDMS

C.1 EDMS SOURCE CONFIGURATION

Figure C-1 and Figure C-2 show how the airport was configured in EDMS for the proposed Stage 1 and longer term development scenarios. The key shows the different source categories that were modelled, as well as receptor locations and buildings.

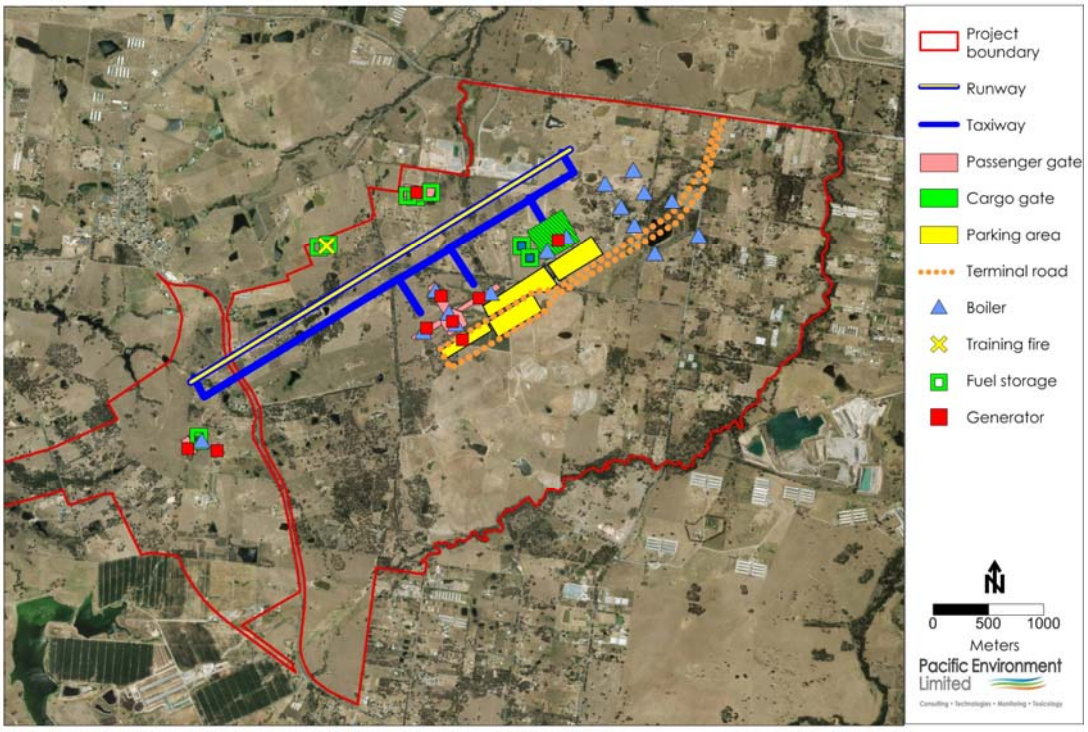


Figure C-1: EDMS source configuration for Stage 1 development

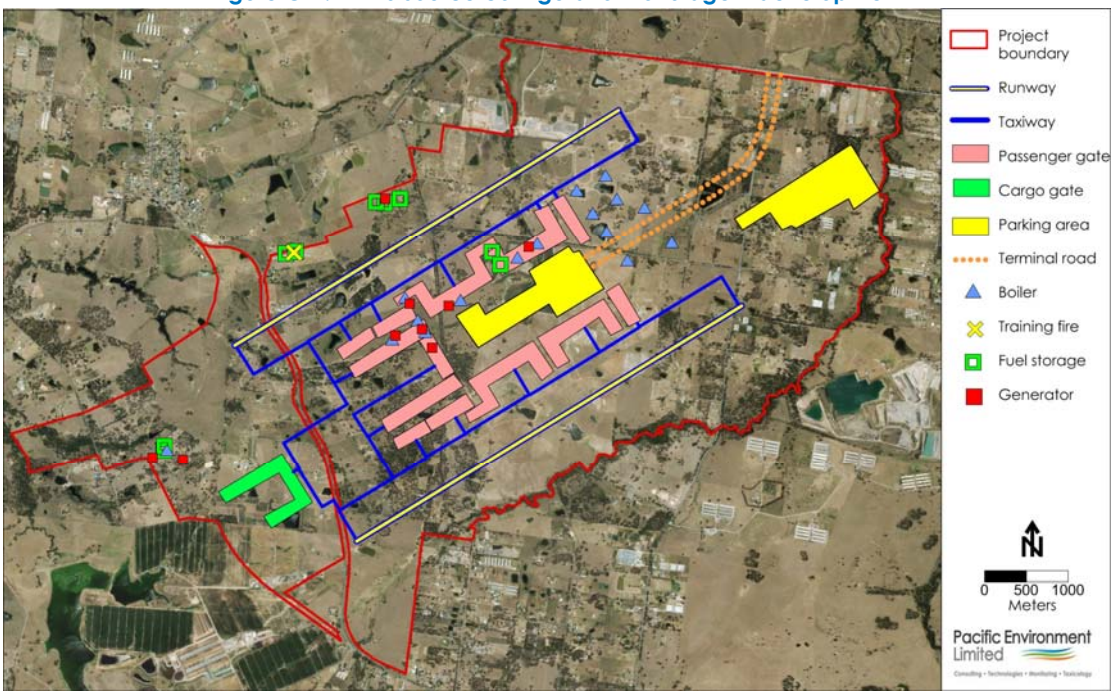


Figure C-2: EDMS source configuration for longer term development

C.2 AIRCRAFT MAIN ENGINES AND APUS

C.2.1 Description

The operation of aircraft is one of the most important sources of air pollution at airports. Aircraft are equipped with main engines for propulsion and on-board APUs that provide electrical power when the aircraft is taxiing or parked at a gate. These sources are described in more detail below.

C.2.1.1 Main engines

Aircraft main engines are generally classified as either gas turbine turbofans/turbojets, turboprops, or internal combustion piston engines. Turbofans/turbojets and turboprops are fuelled with aviation kerosene (jet fuel). Piston engines are fuelled with aviation gasoline (AVGAS).

Emissions from main engines vary according to the operational mode. The landing/take-off (LTO) cycle represents a useful way of incorporating all normal flight and ground operation activities, including descent/approach from a reference height above ground, touchdown, landing run, taxi in, idle and shut-down, start-up and idle, checkout, taxi out, take-off and climb-out to the reference height **(DEWHA, 2008)**. All flight and ground operations in the LTO cycle are grouped into four standard modes for which emission rate data are readily available. These modes are:

- The *approach* mode, for which emissions are estimated from a height of 1,000 m to ground level.
- The *taxi/idle* mode, which applies to both incoming and outgoing aircraft during taxiing and idling operations.
- The *take-off* mode, which is defined as the period between commencement of acceleration on the runway and the aircraft reaching a height of 200 m, during which time the engine is operated at full throttle and fuel usage is at a maximum for any given engine.
- The *climb-out* mode, for which emissions are calculated for the period between 200 and 1,000 m above ground level.

In each of the modes the main engines operate at different power settings. The power settings determine the rate at which fuel is burned which, in turn, determines the quantity and nature of emissions released into the atmosphere.

ICAO publishes emission factors for the operational modes listed above, expressed in grams of pollutant per kilogram of fuel used during the time-in-mode. For estimating emissions over the complete LTO cycle the amount of time each aircraft spends in each operational mode is therefore required. Emission factors are also expressed in grams of pollutant for the entire LTO cycle. Engine manufacturers calculate this value, based on default LTO times-in-mode, as part of the engine certification process.

C.2.1.2 Auxiliary power units (APUs)

An APU is a small turbine engine coupled to an electrical generator that generates electricity and compressed air to operate the aircraft's instruments, lights, ventilation and other equipment while the main aircraft engines are shut down. It is also used to provide power for starting the main aircraft engines. APUs are usually mounted in the tail cone of the aircraft and run on aviation kerosene (jet fuel) fed from the main fuel tanks. Although the use of APUs on jet aircraft is almost universal, some turboprops and business jets do not have APUs **(DEWHA, 2008)**.

DEWHA (2008) note that emissions from APUs are also usually expressed in terms of specific modes of operation, such as: 'idle', '400 Hz' (provides electricity when an aircraft is on the ground and in operation), 'PCA' (provides pre-conditioned air during pre- or post-flight activities), and 'bleed air' (bleed air for main engine start).

It is worth noting that APUs may also occasionally be used to provide power and preconditioned air during maintenance.

C.2.2 Approach in EDMS

C.2.2.1 Main engines

In EDMS the emissions from aircraft main engines are computed based on the engine specifications, taking into account aircraft performance characteristics and weather. Once emissions are calculated for one of the engines, EDMS multiplies the single engine results with the number of engines of the aircraft to compute the emissions of the aircraft.

EDMS utilises the latest aircraft engine emission factors from the ICAO Engine Exhaust Emissions Data Bank. It is worth noting that EDMS actually uses six operational modes, due a formal separation of 'taxi in' and 'taxi out', and the inclusion of a 'start-up' mode at the gate (only for aircraft with ICAO certified engines). In the absence of specific information on time in mode for the airport, the ICAO default values in EDMS were used in this study.

Each aircraft activity is expressed as an arrival or a departure, with each type consisting of different modes of operation. An arrival consists of the approach and taxi-in modes. A departure consists of the start-up, taxi-out, take-off and climb-out modes. An LTO cycle consists of an arrival and a departure, and therefore consists of one of each of the six modes of operation.

EDMS calculates the amount of emissions (up to a height of 915 m) released in the airborne segments and approach ground roll using the aircraft performance module, which dynamically models the flight of the aircraft, based a flight profile. Operational information for aircraft can be entered by specifying a *schedule of operations*. This provides a precise and accurate modelling of aircraft performance by taking into account the aircraft type, engine, weight, approach angle to be flown (for arrivals), elevation and weather. Using hourly meteorological weather data, variations in the thrust used (and emissions released) for the same aircraft can be observed at different times of the day and at different airports due to the changing weather conditions. For the EDMS Taxi In and Taxi Out modes of operation, the taxi times are generated by the sequencing model. The default approach and climb out times in mode of both system aircraft using ICAO times in mode and user-created aircraft are based on a mixing height of 3,000 feet but are adjusted to reflect the user-specified local mixing height. As noted earlier, for aircraft sequencing there is a need to define the airport gates, the taxiways, the runways and the taxipaths (how the taxiways and runways are used).

C.2.2.2 APUs

Emissions are generated by an APU while an aircraft is parked at a gate. The emission calculations for APUs are similar to those for an aircraft main engine operating at one power setting. The methodology for calculating emissions from APUs is adapted from the USEPA *Procedures for Emission Inventory Preparation, Volume IV*[i]. APU emissions generated per LTO cycle are the product of the emission factor and operating time, multiplied by the number of applicable aircraft LTO cycles. APU emissions for arrivals and departures are computed in the same way. For the purpose of emissions calculations, APUs are assigned to the same category as GSE. External APUs used by an aircraft fall into the category of ground support equipment. In the absence of an APU or applicable GSE, a combination of 400 Hz electric power and preconditioned air (PCA) can be supplied to the aircraft using a fixed system at each gate to allow for normal operation. Fixed systems usually generate little or no emissions at the airport and are not included in EDMS.

[i] www.epa.gov/otaq/invntory.htm.

C.2.3 Definition of input data for the airport

C.2.3.1 Main engines

The parameters required to be input to aircraft schedule were:

- date and time of movement (1-minute);
- type of flight (passenger or freight);
- type of operation (arrival or departure);
- aircraft type;
- engine type;
- gate number (to simplify the calculation the gates were grouped); and
- runway allocation.

Aircraft schedules

The projected annual ATMs of 63,302 during the Stage 1 development and 369,952during the longer term development were used as the basis for the development of the aircraft schedule for these two investigation scenarios.

A 'worst case' daily synthetic schedule was supplied by L.E.K. Consulting. These data included information on aircraft use (passenger or freight), aircraft family, operation type and operation time (to the nearest15 minutes) In accordance with the feasibility design report **(DIRD, 2015)**, this worst case day was chosen to represent October 17 2013, KSA's busiest day for 2013. The projected ATMs were combined with the monthly, daily and hourly weighting factors presented in **DIRD (2005)** to develop an annual schedule of aircraft movements to be used as the basis for the calculation of aircraft emissions. The annual profile of the daily ATMs for Stage 1 and the longer term development are shown in **Figure C-3**.

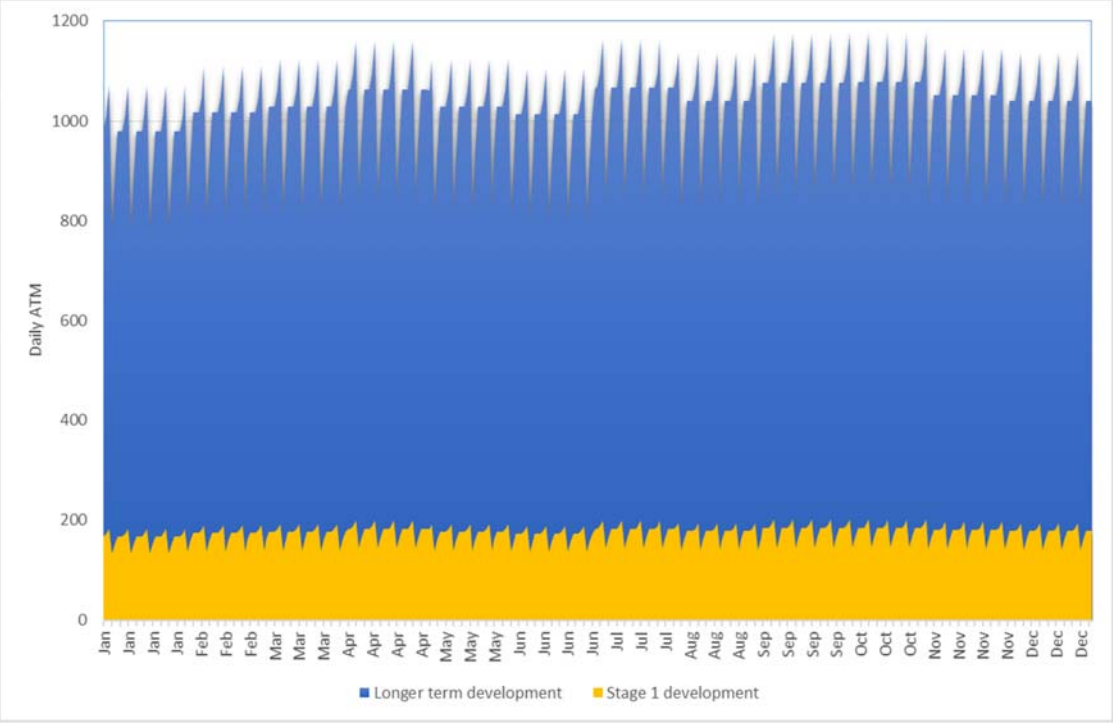


Figure C-3: Annual profile of daily ATM for Stage 1 and longer term development

As only aircraft family was provided as part of the synthetic schedule the default range of aircraft and engine combinations in EDMS were adopted. The projected ATMs by aircraft family are provided in **Table C-1**.

Table C-1: Annual movements by aircraft type for Stage 1 and Ultimate scenarios

Row Labels	Aircraft name	2030	2063
A320-2	Airbus A320-200 Series	33,357	128,386
A330-2	Airbus A330-200 Series	689	n/a [(a)]
A330-2F	Airbus A330-200 Series Freighter	632	583
A330-3	Airbus A330-300 Series	2,598	48,309
A350-8	Airbus A350-800 Series	1,300	26,809
A350-9	Airbus A350-900 series	1,357	26,711
A380-8	Airbus A380-800 Series	n/a [(a)]	2,682
B737-3F	Boeing 737-300 Series Freighter	518	6,194
B737-7	Boeing 737-700 Series	2,949	n/a [(a)]
B737-8	Boeing 737-800 Series	2,954	n/a [(a)]
B737-8-BBJ2	Boeing Business Jet II	1,446	n/a [(a)]
B737-9	Boeing 737-900 Series	1,923	66,397
B747-3F	Boeing 747-300 Series Freighter	502	2,192
B747-4F	Boeing 747-400 Freighter	1,575	8,678
B747-8I	Boeing 747-8	n/a [(a)]	670
B767-2F	Boeing 767-200 Series Freighter	665	1,868
B767-3F	Boeing 767-300 ER Freighter	352	992
B777-2	Boeing 777-200 Series	234	n/a [(a)]
B777-2ER	Boeing 777-200-ER	425	n/a [(a)]
B777-2LR	Boeing 777-200-LR	150	n/a [(a)]
B777-3	Boeing 777-300 Series	64	n/a [(a)]
B777-3ER	Boeing 777-300 ER	206	27,603
B787-8	Boeing 787-8 Dreamliner	203	5,867
BAE146-200	BAE 146-200	1,303	4,581
BAE146-300	BAE 146-300	1,275	4,708
DHC8Q-3	Bombardier de Havilland Dash 8 Q300	2,068	1,674
DHC8Q-4	Bombardier de Havilland Dash 8 Q400	665	1,627
SAAB340-A	Saab 340-A	3,892	3,421
Total		**63,302**	**369,952**

Notes: (a) Not included in model scenario

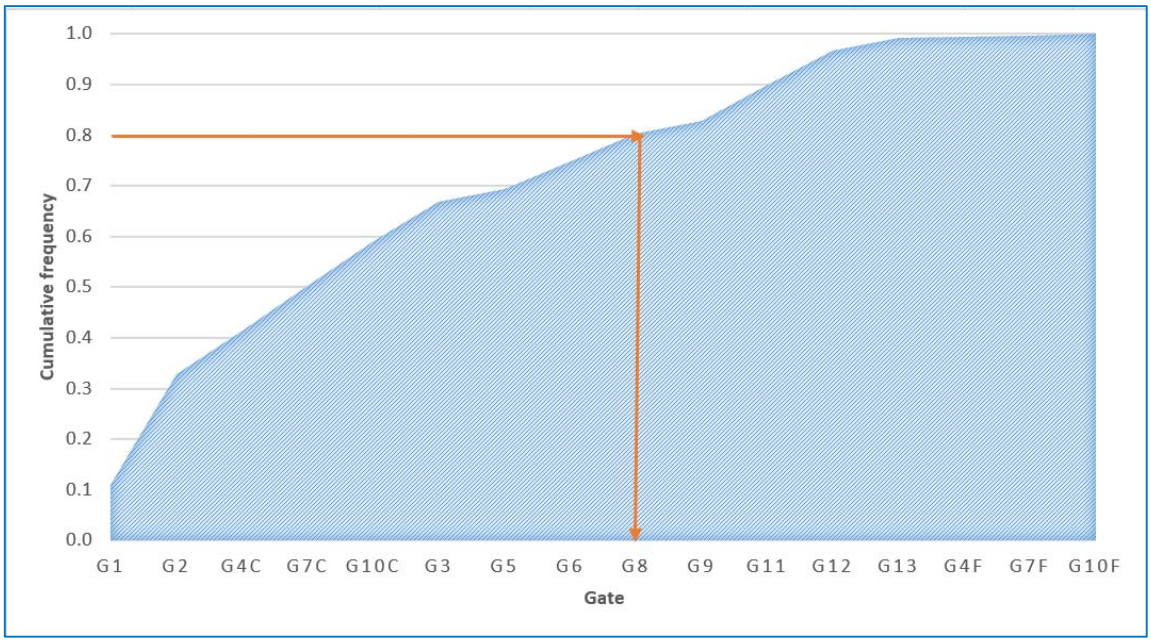
Gate allocation

The gate allocation was not available and therefore was based on the aircraft code (size of the aircraft) and capacity of each gate to accommodate that particular aircraft. This was relatively straightforward for the Stage 1 development given the grouping of available gates by aircraft code (i.e. Gate group 1 for 'C code' or smaller, 'E Code' for larger aircraft and 'Cargo').

The gate allocations are shown in **Figure C-1** and **Figure C-2** for the Stage 1 development and longer term development scenarios, respectively.

However, for the longer term development the gate arrangement is more complex. A probabilistic approach was used to determine the gate and subsequent taxipath based on aircraft code. For each aircraft movement a random number (between 0 and 1) was generated, and the value of the random number was used to identify the gate using the cumulative frequency. This approach is explained graphically in **Figure C-4**.

Figure C-4: Identification of gate based on probability



Runway allocation

During the Stage 1 development operation there is a single runway comprising two runway combinations '5L' and '23R'. For the longer term development this increases to four, with the addition of the southern runway and now includes '5R' and '23L'. The location of the runways can be seen in the site layout shown in **Figure C-1** and **Figure C-2** for each of the respective scenarios.

The runway allocation was not contained in the information provided by LEK Consulting. Therefore the following assumptions were made:

- Stage 1 development: 50 per cent of ATMs were allocated to each runway combination; and
- Longer term development: 50 per cent of ATMs were allocated to each runway. This was then further split to assume 50 per cent of ATMs on each runway will use each runway combination.

It is acknowledged that in reality the runway combinations are a function of the prevailing weather conditions and gate availability. Given the uncertainty in predicting future events, the approach adopted is considered a reasonable approach and has been adopted for similar airports, such as in the local air quality modelling for KSA **(Pacific Environment, 2014)**.

Flight profiles and time in mode

Flight profiles based on the performance of aircraft-engine combinations were used to determine times in mode within EDMS. Take-off, climb-out, approach, and landing roll times were calculated by the

EDMS performance module using aircraft weight (EDMS default values), the approach angle and the mixing height.

C.2.3.2 APUs

The EDMS defaults were used for both allocating APUs to aircraft and for the operational time for APUs during arrivals and departures. For the user-defined aircraft, the default APUs for the representative aircraft types mentioned above were used.

The default value for operational time was 13 minutes (for both arrivals and departures).

C.3 GROUND SUPPORT EQUIPMENT

C.3.1 Description

Upon arrival at a gate, aircraft are serviced by various airside vehicles and mobile plant, collectively known as ground support equipment (GSE). GSE are necessary to handle the aircraft during the turnaround at the stand. Examples of GSE include:

- Aircraft push-back tugs
- Mobile generators to provide electricity
- Air conditioning units
- Conveyer belts for loading and unloading baggage
- Baggage tugs
- Powered passenger stairs
- Fork lifts
- Tractors
- Cargo tractors and loaders
- Hydrant trucks for refuelling
- Catering trucks
- Lavatory trucks

The extent of GSE activity is generally dependent on the size and usage of the aircraft, ranging from a wide range of equipment in service for extended periods for large passenger aircraft embarking on international flights to limited GSE activity for small aircraft used for local business flights **(DEWHA, 2008)**.

Emissions from GSE are dependent on fuel type, engine size, load factor, technology, age (or deterioration factor) and emission reduction devices in place. GSE are generally powered by internal combustion engines of various kinds, although other technologies are sometimes used. Several of the GSE are non-road vehicles that are specifically designed to provide the services required for aircraft (*e.g.* cargo loaders, baggage belts, aircraft tugs). GSE are generally designed for low-speed, high-torque functions, and are built to be easily manoeuvrable within the confined environments surrounding aircraft **(DEWHA, 2008)**.

C.3.2 Approach in EDMS

GSE can be modelled in EDMS both by assignment to an aircraft and by population. GSE that are assigned to an aircraft will have their operations depend on the activity of that aircraft. GSE that are modelled as a population operate independently from aircraft activity. The GSE emission factors used by EDMS are derived from the USEPA's NONROAD2005 model and are based on the following variables: fuel, brake horsepower and load factor. In addition, a deterioration factor is applied based on the age of the engine. GSE emission factors are given in grams per horsepower-hour. EDMS allows users to select the EPA-derived national fleet average age for a particular vehicle type, or to specify the exact age of an individual piece of equipment.

GSE that are assigned to an aircraft are given times (minutes per arrival, minutes per departure) based upon the type of service. For example, a fuel truck servicing a large commercial aircraft will have a different operating time than the same fuel truck servicing a commuter aircraft. Tugs are generally used

to move commercial aircraft away from the gates, but are typically not used by general aviation (GA) aircraft.

As system aircraft are added to the study, default GSE assignments are made for each newly added aircraft. Default assumptions are used in EDMS, but the user also has the flexibility to add and remove GSE to and from aircraft and modify the operating times as well as other parameters for assigned GSE. These default assignments are based upon several categories of aircraft types (e.g., wide body jets, cargo planes, commuter aircraft, general aviation, military jets, military transports, business jets, etc.).

No data on the proposed GSE for the airport were available for the air quality assessment. Consequently the default approach in EDMS was used, whereby EDMS associated default GSE to each aircraft LTO and calculates emissions accordingly. The default values included operational time, power and load factor.

The default allocation of GSE in EDMS was used for the Stage 1 development and the longer term development. The unit emission factors for GSE are linked to the study year, and take into account future improvements in technology.

C.4 PARKING FACILITIES

C.4.1 Description

In EDMS it is assumed that airport parking facilities generate emissions due to on-road vehicles operations and vehicle idling. The location of the carpark facilities is shown in **Figure C-1** and **Figure C-2** for each scenario.

Several airport parking facilities were included in the study:

- Stage 1 development (up to 12,500 spaces):
  - A multi-level carpark comprising 4 storeys
  - 3 surface carparks
- Longer term development (up to 70,000 spaces):
  - A multi-level carpark comprising 4 storeys
  - One surface carpark

C.4.2 Approach in EDMS

Exhaust emissions from landside road traffic in parking facilities are accounted for in EDMS through the use of the distance travelled in the facility, the speed and the idle time. Specific vehicle categories and emission factors can be defined. EDMS does not take into account so-called 'cold-start'[k] exhaust emissions.

C.4.2.1 Emissions inputs

Emissions from a given car park were calculated in EDMS for vehicles moving and idling, and were defined in terms of the following:

- The number of vehicle movements.
- The vehicle speed.
- The distance travelled (the average distance a vehicle travels between entry and exit).

[k] Cold-start emissions occur during the period following an engine start. Emissions are elevated during this period as the engine and exhaust-after-treatment system are not at their full operational temperatures.

- The idle duration (the time with the engine at idle between entry and exit).

The data used for each of these parameters are summarised for each car park in **Table C-2**. The projected vehicle number to use the parking facilities were calculated as art of the *Traffic Assessment* **(GHD, 2015)**. The distribution of the total vehicle number across the four carparks was based on the area of the car park as provided in the *Airport Plan* **(DIRD, 2015)**.

The speed and distance were used to determine the moving emission factors. The moving emissions and idle emissions were then combined. The emission factors were generated within EDMS using the USEPA's MOBILE 6.2 model[I].

Table C-2: Input data for parking facilities (Stage 1 development)

Parameter	Stage 1 development				Longer term development	
	Car park 1	Car park 2	Car park 3	Car park 4	Car park 1	Car park 2
Number of vehicle movements per year[(a)]	6,544,625	2,825,795	3,472,676	3,038,402	45,381,153	11,208,885
Average speed of vehicles in parking facility (km/h)	16	16	16	16	16	16
Average distance travelled in car park (m)	250[(a)]	250[(a)]	250[(a)]	250[(a)]	250[(a)]	250[(a)]
Average vehicle idle time (minutes)	1.5[(a)]	1.5[(a)]	1.5[(a)]	1.5[(a)]	1.5[(a)]	1.5[(a)]

(a) EDMS default.

Emissions are also a function of vehicle type, fuel type and year of manufacture. However, the use of a custom vehicle fleet in EDMS requires a significant amount of input data, as each vehicle type and model year must be defined separately (each as a separate parking facility). Moreover, emission factors for specific vehicle categories are not available in EDMS for years beyond 2011. Therefore, whilst it could have been assumed that most vehicles in the airport car parks would have been cars and light commercial vehicles, this assumption would have complicated the modelling disproportionately. The default vehicle mix in EDMS was therefore used for simplicity. This had the additional advantage of automatically adjusting the fleet emissions for the modelled year. The default traffic mix was the US national average fleet of vehicles for the year being modelled, and changed automatically with the study year. The default traffic mix would have included both heavy-duty and light-duty vehicles, and would therefore not have been fully representative of the vehicles using the car parks at the airport. However, the impacts of this assumption in relation to overall emissions from the airport would have been negligible.

C.4.2.2 Dispersion parameters

The parking facility height is specified in EDMS to represent the height at which emissions are released. Facilities with multiple parking levels are modelled using stacked area sources. The dispersion parameters for the parking facilities at the airport are given in **Table C-3**.

[I] MOBILE 6 is a USPEA model for estimating emissions from road vehicles. It is worth noting that t has now been replaced by MOVES as USEPA's official model for estimating emissions.

Table C-3: Dispersion parameters for parking facilities

Parking facility	Number of levels	Release height (m)
Stage 1 development		
Car park 1	4	10.5
Car park 2	1	1.5
Car park 3	1	1.5
Car park 4	1	1.5
Longer term development		
Car park 1	4	10.5
Car park 2	1	1.5

C.5 ROAD TRAFFIC

C.5.1 Description

In EDMS it is assumed that roadways generate emissions due to on-road vehicles operations and vehicle idling travelling within and outside of the project boundary.

In total, 421 roadway links were included in the study:

- The airport terminal roadways; and
- Roadways outside of the airport study boundary, extending as far north as the M4 and as far east as the M7. Future emissions from the proposed M12 roadways were also included.

C.5.2 Approach in EDMS

Exhaust emissions from landside road traffic are calculated in EDMS based on the roadway length, the volume of the traffic, the traffic mix, and the average speed. Either default or user-defined emission factors can be used. The default emission factors are calculated using the MOBILE 6.2 algorithms in conjunction with a default traffic mix (the US national average fleet) and a user-defined speed.

C.5.3 Definition of input data

Overview

EDMS requires the total annual traffic volume on each road link. The model then breaks this annual value down to determine the traffic volume in each hour of the year based on operational profiles for (i) hour of the day, (ii) day of the week and (iii) month of the year. The values in the operational profiles are all normalised to the highest value (taken to be 1).

EDMS also requires an emission factor (g/vkm) for each pollutant. For road traffic we used NSW-specific emission factors and a local traffic mix, rather than the default US values.

The derivation of total annual traffic, volume, the operational profiles, and the emission factors is described below.

Annual traffic volume

Traffic model data

The basic traffic data used in the study were obtained by GHD. The road links that were defined by GHD are shown in **Figure C-5**.

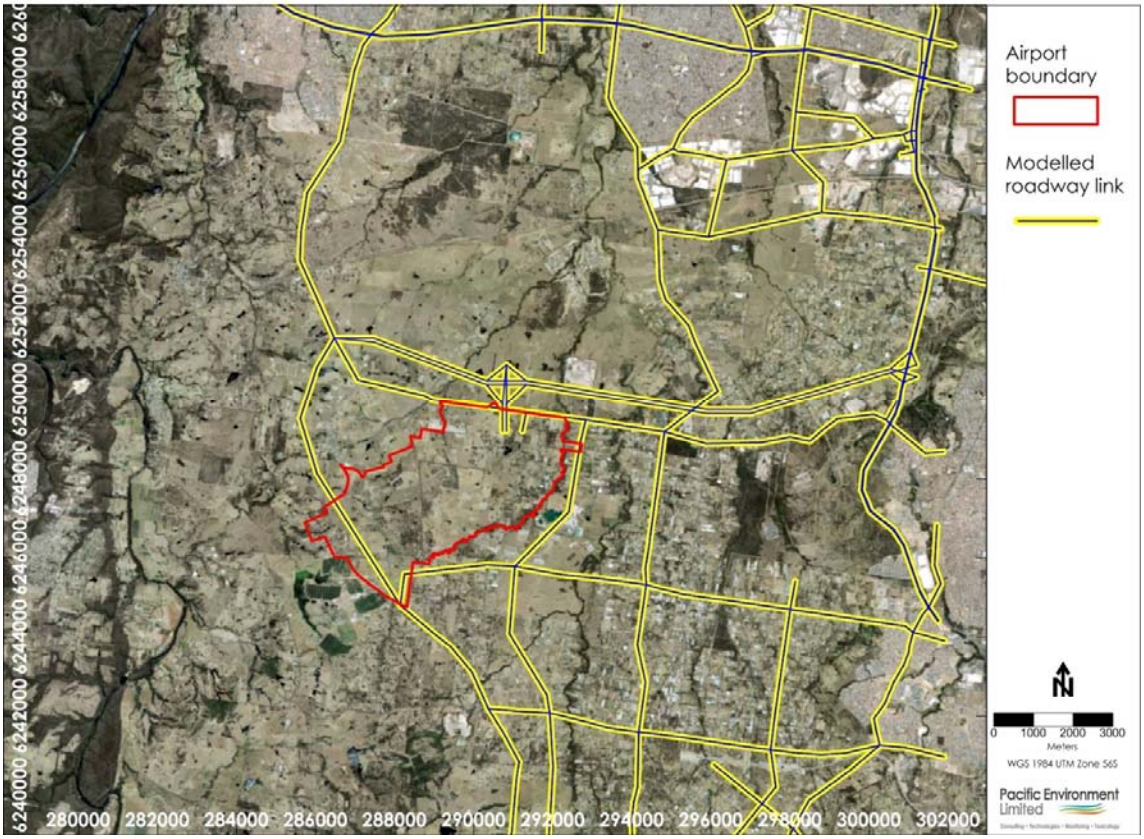


Figure C-5: Modelled road links

Traffic data were provided to Pacific Environment for the following conditions:

- Stage 1 development;
- Longer term development (with rail network); and
- Longer term development (without rail network).

As it is not possible for the longer term development to achieve the projected passenger numbers without the rail network the traffic scenario that does not include the rail network was disregarded.

The traffic model output included the following information:

- Total traffic volume for the following periods of an average weekday:
  - AM peak (7:00 am to 9:00 am);
  - In between peaks (9:00 am to 3:00 pm);
  - PM peak (3:00 pm to 6:00 pm);
  - Evening (6:00 pm to 7:00 am);
- Traffic speed for the above periods; and
- Numbers of cars, light duty vehicles, rigid vehicles and articulated trucks for the above periods.

Operational profiles – hour of day

Hour traffic volumes for each road link and each hour of the day were derived as noted above. For each road link the hourly profiles were normalised to the highest value (the format required by EDMS).

However, this resulted in many different profiles (421 links and 2 scenarios). This was too much information to enter into EDMS and representative profiles were identified based on the hourly traffic data provided. Seven traffic profiles were developed for Stage 1 development and five for the longer term development. These profiles are shown in **Figure C-5**. As more detailed information was available for the airport terminal traffic an additional profile for each scenario was developed. The hourly profiles for the terminal traffic are shown in **Figure C-6**. In EDMS one of the three profile types was allocated to each road link.

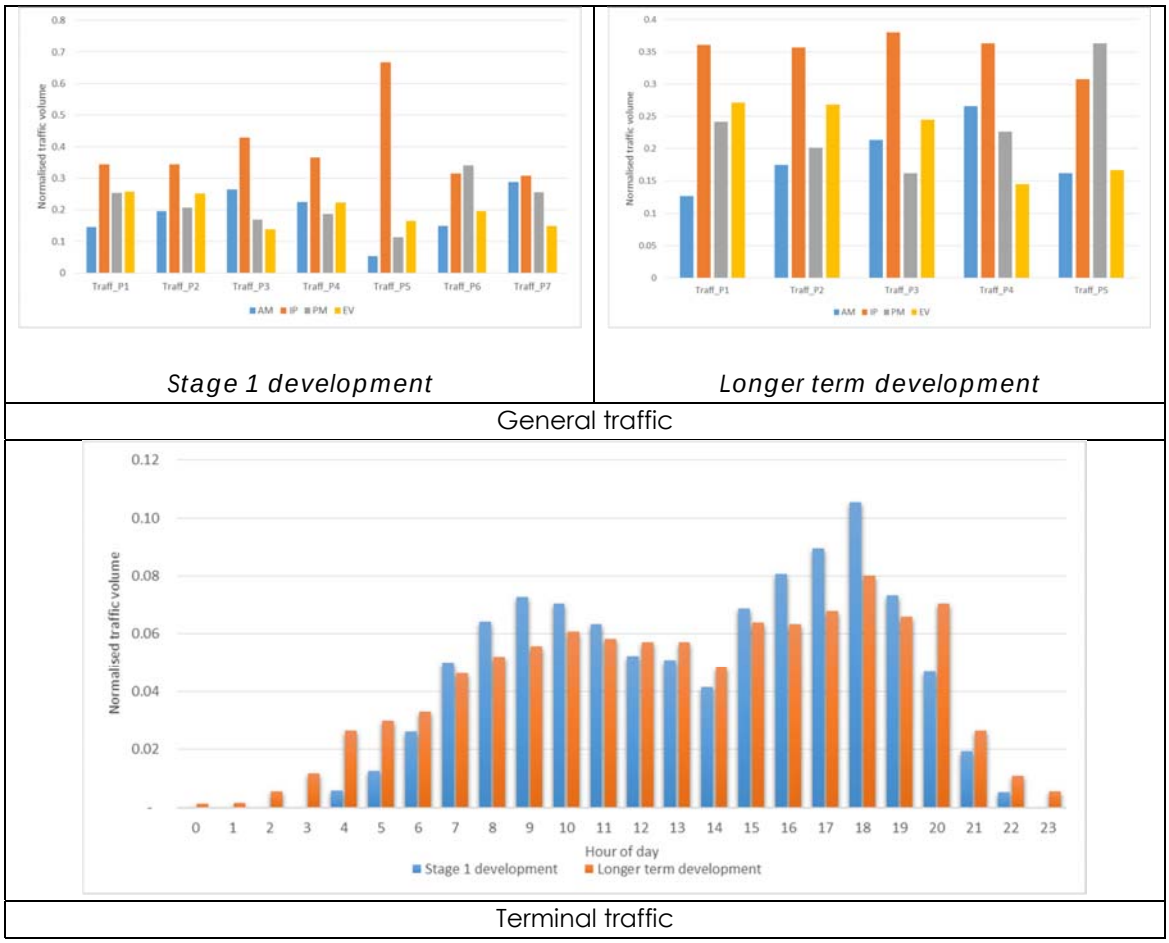


Figure C-6: Operational profile for roads – hour of day

Speed

Average hourly traffic speeds during the AM and PM peak periods were provided by the traffic model. For the terminal traffic it was assume that vehicles would travel at 20 km/hr.

Emission factors

'Hot running'[m] emissions from the road traffic were calculated using the emission factors developed by NSW Environment Protection Authority (EPA) for the latest emissions inventory for the Greater Metropolitan Region (GMR) **(NSW EPA, 2012)**. The calculation involved the use of base 'composite'

[m] Hot running emissions are those that are produced once a vehicle's engine and exhaust emission-control system have reached their full operational temperatures.

emission factors for various vehicle types (CP, CD, LDCP, LDCD, HDCP, RT, AT, BusD and MC)[n], with the emission factor for each vehicle type taking into account vehicle-km travelled (VKT) by age and the associated emission factors by sub-type (such as emission standard). Five road types (residential, arterial, commercial arterial, commercial highway, highway/freeway) are specified in the emissions inventory. In the development of the emission factors, EPA has taken various real-world effects into consideration, including the deterioration in emissions performance with mileage, the effects of tampering or failures in emission-control systems, and the use of ethanol in petrol. For each case, the base emission factor is defined for a VKT-weighted average speed (the base speed) associated with the corresponding road type. Correction factors – in the form of 6th-order polynomial functions - are then applied to the base emission factors taking into account the actual speed on a road. It was assumed that all roads in the study were in the 'arterial'[o] category.

The emission factors from the NSW GMR inventory were only available for specific years (2008, 2011, 2016, 2021, etc.). An interpolation routine was therefore developed to determine emission factors for the nominal scenario years 2030 (Stage 1 development) and 2060 (longer term development).

Hot running emissions were calculated for CO, NO_X, PM_{10}, $PM_{2.5}$, hydrocarbons (HC)[p] and SO_2. Emissions of CO_2 were also calculated, but these were only used to estimate fuel consumption which was used, in turn to estimate SO_2 emissions based on fuel sulphur content (taken to be 10 ppm). Neither cold-start emissions nor evaporative emissions were estimated as part of the assessment. The inclusion of these would have complicated the assessment considerably, and would not have had a large impact on the results.

For each road link and pollutant the emissions were calculated for each hour of the typical weekday 24-hour period, and then an average fleet-weighted emission factor (converted to grams per vehicle-mile for input into EDMS) was determined.

Dispersion parameters

It was assumed that the width of each road was 20m.

C.6 STATIONARY SOURCES – AIRCRAFT ENGINE TESTS

C.6.1 Description

All aircraft returning to service after maintenance must undergo an engine test. Engine testing may involve the operation of engines without their removal from the aircraft (known as 'ground runs') or the use of dedicated test cells.

When testing a jet engine in a test cell, the engine is removed from the aircraft and placed in a stand. Emissions from the engine are typically directed through a stack. Test cells are typically used when a jet engine is down for overhaul or major maintenance.

Engine ground running involves the running of aircraft engines while they are attached to the aircraft. An engine run may also be carried out if an engine has been in storage for a long period to ensure

[n] CP = petrol passenger vehicles; CD = diesel passenger vehicles; LDCP = light-duty commercial petrol vehicles (<=3500 kg); LDCD = light-duty commercial diesel vehicles (<=3500 kg); HDCP = heavy-duty commercial petrol vehicles (>3500kg); RT = rigid trucks (3.5-25 tonnes, diesel only); AT = articulated trucks (> 25 tonnes, diesel only); BusD = heavy public transport buses (diesel only); MC = motorcycles.
[o] Roads that distribute traffic within residential, commercial and industrial areas. Speed limit 50-70 km/h, 1-2 lanes. Regular intersections, mostly uncontrolled. Lower intersection delays than residential roads, but significant congestion impact at high volume:capacity ratios.
[p] Assumed to be equivalent to volatile organic compounds (VOCs).

engine deterioration has not occurred. The testing of engines without their removal from the aircraft may involve the entire aircraft being placed into a building that serves as the test cell. Ground runs are usually conducted at idle thrust, with some excursions to medium or high power (take off) thrust should testing require it. Testing at medium and high power can generally only be sustained for a few minutes without causing potential damage or failure of the engine **(Holmes, air Sciences, 2008)**.

C.6.2 Approach in EDMS

EDMS calculates emissions for engine tests based on the engine model and the time spent at 7 per cent, 30 per cent, 85 per cent and 100 per cent of the rated power.

C.6.3 Definition of input data

No information on engine testing was available for this study. Therefore engine testing was pro-rated based on the calculated emissions information published in the *Sydney Airport Master Plan* **(SACL, 2014**). The total number of aircraft tests was approximated to be 817 during Stage 1 operations and 4,796 during longer term operations.

Dispersion parameters

It was assumed that all aircraft testing was undertaken within the immediate vicinity of the aircraft maintenance building.

C.7 STATIONARY SOURCES - BOILER/SPACE HEATERS

C.7.1 Description

Facilities that produce energy for airport infrastructure - such as boiler houses and heating/cooling plants - are a source of emissions through fuel combustion.

C.7.2 Approach in EDMS

EDMS calculates emissions for stationary sources from an internal database for boilers/space heaters.

C.7.3 Definition of input data

No information on boiler usage was available. It was assumed that all boilers at the airport will use natural gas. The annual consumption of natural gas by the airport is 57,000 Gj during the proposed Stage 1 and 449,000 Gj during the longer term operations. It was assumed that each building would include at least one boiler. It was assumed that there would be 16 boilers during Stage 1 and 19 during the longer term development. Emissions from the total gas consumption were evenly split across assumed number of boilers.

Dispersion parameters

Table C-4 shows the dispersion parameters used for boilers (treated as point sources).

Table C-4: Dispersion parameters for boilers

Source	Source type	Relative height (m)	Diameter (m)	Gas velocity (m/s)	Temperature
Boilers	Point	20	0.1	15	400 F

C.8 STATIONARY SOURCES - EMERGENCY GENERATORS

C.8.1 Description

Generators are used for emergency power generation for buildings or runway lights during power outages.

C.8.2 Approach in EDMS

EDMS calculates emissions for stationary sources from an internal database for emergency generators.

C.8.3 Definition of input data

No information on the use of generators at the airport was available for this study. Therefore it was assumed that each building would include an emergency generator and would operate for 1 hour per month as part of routine maintenance. Each emergency generator was assumed to use 233L per hour of diesel fuel.

Dispersion parameters

An emergency generator was located at each building. **Table C-5** shows the dispersion parameters used for generators.

Table C-5: Dispersion parameters for generators

Source	Source type	Relative height (m)	Diameter (m)	Gas velocity (m/s)	Temperature
Generators	Point	5	0.1	15	400 F

C.9 STATIONARY SOURCES - FUEL TANKS

C.9.1 Description

Evaporation from fuel storage tanks, trucks and pipelines at airports is a source of VOCs, including specific air toxics such as benzene, toluene and xylenes. Emissions occur as a result of tank standing losses and working losses. Standing loss is the expulsion of vapour from a tank through vapour expansion and contraction resulting from changes in temperature and barometric pressure. This loss occurs without any liquid level change in the tank. The combined loss from filling and emptying is called working loss. Evaporation during filling operations is a result of an increase in the liquid level in the tank. As the liquid level increases, the pressure inside the tank exceeds the relief pressure and vapours are expelled from the tank. Evaporative loss during emptying occurs when air drawn into the tank during liquid removal becomes saturated with organic vapour and expands, thus exceeding the capacity of the vapour space **(USEPA, 1995)**.

At major airports, fuel companies typically operate systems that involve the reticulation of aviation fuel[q] via underground pipelines from a so-called 'Joint User Hydrant Installation' (JUHI). Aviation fuel is distributed from the JUHI storage facility to apron hydrant outlets located adjacent to aircraft gates.

[q] Commonly known as AVTUR, Aviation Jet Fuel A-1, or Aviation kerosene.

Into-plane dispensing is undertaken directly by the fuel companies. Specialist hydrant refuelling vehicles are used for this task. Bulk tanker vehicles are used for the fuelling of regional, general aviation (GA) aircraft and helicopters where hydrant access is not available **(SACL, 2009)**.

The primary storage of jet fuel will be at the fuel farm located to the north of the site boundary (see Error! Reference source not found.). Fuel will be distributed via a purpose built underground pipeline grid served from the on-site fuel farm. There will also be a number of diesel and petroleum fuel storage tanks located across the airport, such as at the ARFFs and airport maintenance areas.

C.9.2 Approach in EDMS

EDMS calculates emissions for stationary sources from an internal database for fuel tanks.

C.9.3 Definition of input data

EDMS uses a simplified version of the USEPA TANKS software to calculate VOC emissions from fuel tanks. Information on fuel throughput was only available for Jet-A1. The diesel and petroleum fuel throughputs were based on the fuel consumptions rates of the on-site GSE for each investigation scenario. Details of the airport fuel tanks are presented in **Error! Reference source not found. C-6**.

Table C-6: Fuel tanks

Fuel tank	Tank type	Stage 1 fuel throughput (KL)	Longer term throughput (KL)
Jet fuel			
Fuel farm	Horizontal fixed roof	985,500	8,030,000
ARFF1	Horizontal fixed roof	5,682	16,687
ARFF2	Horizontal fixed roof	n/a	16,687
Diesel			
Fuel farm	Horizontal fixed roof	3,872	7,570
Refueler stand and GSE storage	Horizontal fixed roof	726	1,419
Aircraft maintenance	Horizontal fixed roof	121	237
ARFF	Horizontal fixed roof	121	237
Petroleum			
Fuel farm	Horizontal fixed roof	0	10,327
Refueler stand and GSE storage	Horizontal fixed roof	0	2,259
Aircraft maintenance	Horizontal fixed roof	0	323

Dispersion parameters

The locations of each fuel tank is shown in Error! Reference source not found. and Error! Reference source not found.. The JUHI storage facility is located at the northern end of the airport. **Table C-7** shows the dispersion parameters used for fuel tanks.

Table C-7: Dispersion parameters for fuel tanks

Source	Source type	Relative height (m)	Diameter (m)	Gas velocity (m/s)	Temperature

Fuel tanks	Volume	20	1	15	Ambient

C.10 STATIONARY SOURCES - SURFACE COATING/PAINTING

C.10.1 Description

Airport maintenance facilities at most large airports are typically operated by commercial airlines or other services that perform scheduled aircraft inspections and repairs on the aircraft fuselage, engines and other apparatus. A variety of surface treatment, coating and painting operations may also occur. Volatile organic compounds (VOCs) are emitted to the atmosphere during surface treating, coating and painting operations mainly as a result of evaporation and/or over-spray of the materials used **(DEWHA, 2008)**.

C.10.2 Approach in EDMS

EDMS calculates emissions for stationary sources from an internal database for surface coating/painting.

C.10.3 Definition of input data

Information on paints and solvents at the airport were not available for this study. Therefore paint and solvent usage was pro-rated based on the calculated emissions information published in the Sydney Airport Master Plan **(SACL, 2014)**. The total volume of paints and solvents was approximated to be 16.1 kl during Stage 1 operations and 94.3 kl during longer term operations.

Dispersion parameters

Table C-8 shows the dispersion parameters used for stationary sources (all sources were treated as point sources).

Table C-8: Dispersion parameters for surface coating/painting

Source	Source type	Relative height (m)	Diameter (m)	Gas velocity (m/s)	Temperature
Surface coating/painting	Volume	20	1	15	Ambient

C.11 TRAINING FIRES

C.11.1 Description

Airservices Australia is responsible for the provision of safe and environmentally sound air traffic management and related services to aircraft operators in Australia under the *Air Services Act 1995*. This responsibility includes the provision of Aviation Rescue and Fire Fighting (ARFF) services at major airports. Regular training activities for fire rescue are undertaken to ensure firefighting crews are fully prepared. Fire training facilities are distinguished by the type of fuel burned in the simulations. Internationally, the most commonly used fuels are propane, AVTUR (kerosene), diesel and petrol. Airservices Australia currently primarily uses AVTUR for aircraft fire simulations, and burn times are generally limited to less than three minutes. The air pollutants generated from the burning training fires include PM_{10}, $PM_{2.5}$, NO_X, SO_2, CO and VOCs. Pollution-control systems are generally in place to separate effluent residue from the firefighting activity from the unburned fuel which is captured and reused **(DEWHA, 2008)**.

C.11.2 Approach in EDMS

EDMS calculates emissions from training fires based on an internal database. Input information includes the fuel type and annual number of training fires completed annually.

EDMS does not contain emission factors for Jet A-1 fuel. However, it does contain emission factors for JP-8, which is the military equivalent of Jet A-1[r]. It was therefore assumed that the JP-8 emission factors would be representative of Jet A-1. There are also no emission factors in EDMS for the open burning of petrol. In this case the EDMS emission factors for JP-4 fuel were used (JP-4 is a 50-50 kerosene-petrol blend).

C.11.3 Definition of input data

Information on training fires at the airport were not available for this study. Therefore the volume of fuel consumed by the airport was pro-rated based on the calculated emissions information published in the *Sydney Airport Master Plan* **(SACL, 2014)**. The total volume of fuel consumed during training fires was calculated to be 5,682 L during Stage 1 operations and 33,373 L during the longer term operations.

Dispersion parameters

There is one allocated training fire area located at ARFF1 (northern end of airport site). For air pollutant dispersion, training fires were treated a point sources and the default parameters in EDMS for were used. The dispersion parameters for training fires are shown in **Table C-9**.

Table C-9: Dispersion parameters for training fires

Source	Source type	Relative height (m)	Diameter (m)	Gas velocity (m/s)	Temperature
Training fires	Point	4	5	10	204°C

C.12 WASTE WATER TREATMENT PLANT

C.12.1 Definition of input data

It was assumed the waste water treatment plant was an 'extended aeration plant'. Data was drawn from Haas & Lant (2009) in order to find an approximate GHG emission. This treatment plant was assumed to have 100% throughput of potable water (3.5ML/day) and recycled water (1.8ML/day) for 2030.

[r] http://www.csgnetwork.com/jetfuel.html

Appendix D DISPERSION MODEL INPUTS

D.1 DISPERSION MODEL

D.1.1 AERMOD technical overview

AERMOD is a steady-state plume model that assumes a Gaussian concentration distribution in both the horizontal and vertical directions in the stable boundary layer. In the convective boundary layer, dispersion is Gaussian in the horizontal direction, with the vertical direction being modelled by a bi-Gaussian probability density function **(CSSI, 2013)**. Whilst all mathematical models of airborne pollutant dispersion are simplifications of reality, for most practical purposes steady-state models such as AERMOD provide useful and adequate indications of ground level concentrations.

AERMOD is capable of simulating the effects of multiple sources. For dispersion modelling purposes each source is assigned one of three categories.

- Point sources, which cover stationary sources such as power plant and training fires. Point source emission rates are generally given in grams per second (g/s).
- Area sources, which are defined as an area with a uniform rate of emission. Aircraft movements and on-road vehicle operations are considered to be a series of area sources, since their movement along a path approximates a line of continuous emissions. Parking facilities are also categorised as area sources. In the case of a multi-level parking facility, area sources are stacked at a defined increment to characterise the structure. Area source emission rates are generally given in grams per second per square metre ($g/s/m^2$).
- Volume sources. The activity at gates are considered to be volume sources when the emissions from start-up, GSE and APUs are estimated to originate from a single point of discharge, and area sources when multiple points are used to model the gate. The latter case is typically used when a terminal or part of a terminal is represented as an EDMS gate.

The effects of these different sources can be integrated in AERMOD over a long time period or evaluated for short-term maximum impacts (as short as one hour[s]). Calculations are performed at receptor points, which may number from one up to many hundreds, depending on requirements and program limitations.

D.1.2 Meteorological data and land use

The Bureau of Meteorology's (BoM) operates an Automatic Weather Station (AWS) at Badgerys Creek. The Badgerys Creek AWS collects hourly readings of wind speed, wind direction, temperature, relative humidity, precipitation and sea level pressure. Cloud amount and ceiling height is not recorded at Badgerys Creek and therefore the readings from the next closest station that measures cloud data at Camden Airport were used for this assessment.

Data were obtained from the Badgerys Creek AWS for the years between 2010 and 2014. The data were used both to illustrate the meteorological conditions at the site, and to determine an appropriate meteorological year for dispersion modelling.

A review of the local meteorology between 2010 and 2014 is provided in **Section** Error! Reference source not found..

When choosing a representative meteorological year for dispersion modelling, all six full years (2010 to 2014) were analysed. All years are similar in pattern, percentage of calms and average wind speed. The use of the most recently available full year of data in 2014 was therefore considered to be suitable for the dispersion modelling.

[s] Whilst AERMOD operates on a one-hour time base, for calculating emissions EDMS uses 15-minute intervals to provide a better representation of aircraft movements.

D.1.2.1 Data processing

The basic meteorological parameters required for input to AERMOD are:

- Air temperature;
- Wind speed;
- Wind direction;
- Surface characteristics (i.e. roughness);
- Stability characteristics (i.e. Monin-Obukhov Length); and
- Mixing height.

Air temperature is important in determining the buoyancy of (heated) plumes emitted into the atmosphere. Buoyancy affects the extent of plume rise, with more buoyant plumes tending to rise higher above the ground, thus reducing the ground level impact. Wind speed has two main effects on plume dispersion. Firstly, it influences the initial dilution of the plume as it leaves the source. Greater wind speeds result in greater plume dilution - plume concentration is inversely proportional to the wind speed. Secondly, wind speed affects plume rise, with higher wind speeds reducing its extent. Wind direction affects the direction in which the plume travels. Only points downwind and within the lateral bounds of the plume are affected at any given time. The atmospheric stability is related to the degree of turbulence or mixing in the region of the atmosphere relevant to plume dispersion. The degree of mixing affects the rate of plume dilution by determining the rate of lateral and vertical spread of the plume. Traditionally, stability class has been defined under the Pasquill-Gifford scheme through designation of a letter from A to F, ranging from highly unstable to strongly stable. Unstable conditions are associated with strong turbulence and mixing, and are most strongly developed on sunny days with light winds. Strongly stable conditions are associated with very limited plume mixing and are most developed on calm clear nights and into the early hours after sunrise. Such conditions are common during winter. Neutral stability conditions, between stable and unstable and designated class D, occur most often during windy and/or cloudy weather. AERMOD uses a continuous representation of stability through the Monin-Obukhov length.

However, the above meteorological data requirements cannot be directly met through the observations. The data were therefore run through a pre-processor to ensure that they were in the correct format for use in AERMOD. The meteorological parameters used in the dispersion analysis were generated using AERMET, a USEPA-approved meteorological processor **(USEPA, 2004b).**

In applying the AERMET meteorological processor to prepare the meteorological data for the AERMOD model appropriate values for three surface characteristics needed to be determined:

- Surface roughness length;
- Albedo; and
- Bowen ratio.

The surface roughness length is related to the height of obstacles to the wind flow and is, in principle, the height at which the mean horizontal wind speed is zero based on a logarithmic profile. The surface roughness length influences the surface shear stress and is an important factor in determining the magnitude of mechanical turbulence and the stability of the boundary layer.

The albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption. The daytime Bowen ratio, an indicator of surface moisture, is the ratio of sensible heat flux to latent heat flux and is used for determining planetary boundary layer parameters for convective conditions driven by the surface sensible heat flux.

Aerial photographs were used to inform the designation of land use and associated effective surface roughness on a sector-by-sector basis around the airport site. Values of Bowen ratio and albedo were determined using land use type over a greater domain again centred over the Badgerys Creek AWS as recommended **(USEPA, 2004b).** Reference was made to the AERMET user's guide **(USEPA, 2004b)** in

assigning surface roughness, Bowen ratio and albedo values to designated land cover categories. The designated land use types are shown in **Figure D-3**.

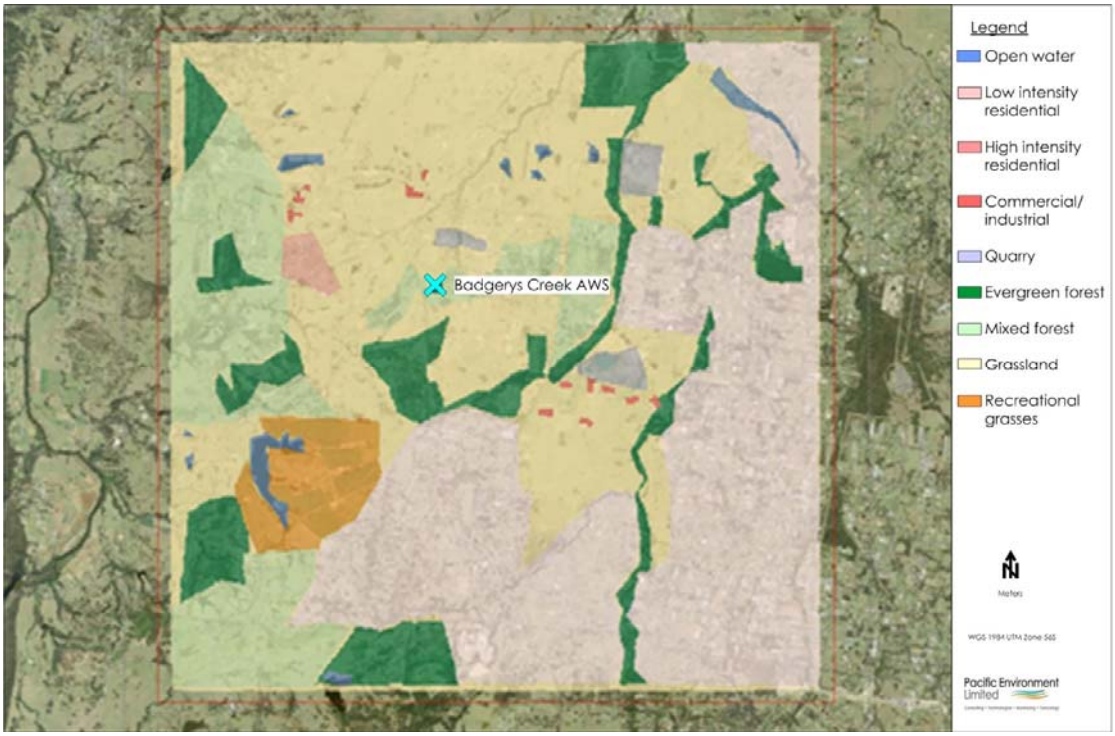


Figure D-3: Summary of Land-use Characteristics adopted within AERMET

AERMET calculates planetary boundary layer parameters, including: friction velocity, Monin-Obukhov length, convective velocity scale, temperature scale, mixing height and surface heat flux. These parameters are used, in conjunction with measurements, to calculate vertical profiles of wind speed, lateral and vertical turbulent fluctuations, potential temperature gradient and potential temperature.

The surface data and profile files from AERMET was used for input into AERMOD **(USEPA, 2004b)**. The profile file was generated using the upper air estimator tool as no hourly observational upper air data were available for the site.

D.1.3 Atmospheric Stability

An important aspect of pollutant dispersion is the level of turbulence in the lowest 1 km or so of the atmosphere, known as the planetary boundary layer (PBL). The EDMS default value of 3,000 feet was used in this study. Turbulence controls how effectively a plume is diffused into the surrounding air and hence diluted. It acts by increasing the cross-sectional area of the plume due to random motions. With stronger turbulence, the rate of plume diffusion increases. Weak turbulence limits diffusion and contributes to high plume concentrations downwind of a source.

Turbulence is generated by both thermal and mechanical effects to varying degrees. Thermally driven turbulence occurs when the surface is being heated, in turn transferring heat to the air above by convection. Mechanical turbulence is caused by the frictional effects of wind moving over the earth's surface, and depends on the roughness of the surface as well as the flow characteristics.

Turbulence in the boundary layer is influenced by the vertical temperature gradient, which is one of several indicators of stability. Plume models use indicators of atmospheric stability in conjunction with other meteorological data to estimate the dispersion conditions in the atmosphere.

Stability can be described across a spectrum ranging from highly unstable through neutral to highly stable. A highly unstable boundary layer is characterised by strong surface heating and relatively light winds, leading to intense convective turbulence and enhanced plume diffusion. At the other extreme, very stable conditions are often associated with strong temperature inversions and light winds, which commonly occur under clear skies at night and in the early morning. Under these conditions plumes can remain relatively undiluted for considerable distances downwind. Neutral conditions are linked to windy and/or cloudy weather, and short periods around sunset and sunrise, when surface rates of heating or cooling are very low.

The stability of the atmosphere plays a large role in determining the dispersion of a plume and it is important to have it correctly represented in dispersion models. Current air quality dispersion models (such as AERMOD and CALPUFF) use the Monin-Obukhov Similarity Theory (MOST) to characterise turbulence and other processes in the PBL. One of the measures of the PBL is the Monin-Obukhov length (L), which approximates the height at which turbulence is generated equally by thermal and mechanical effects (**Seinfeld and Pandis 2006**). It is a measure of the relative importance of mechanical and thermal forcing on atmospheric turbulence.

Because values of L diverge to + and - infinity as stability approaches neutral from the stable and unstable sides, respectively, it is often more convenient to use the inverse of L (i.e., 1/L) when describing stability.

Figure D-2 shows the hourly averaged 1/L for the Project site computed from all data in the AERMET surface file. Based on **Table D-1** this plot indicates that the PBL is stable overnight and becomes unstable as radiation from the sun heats the surface layer of the atmosphere and drives convection. The changes from positive to negative occur at the shifts between day and night. This indicates that the diurnal patterns of stability are realistic.

Table D-1: Inverse of the Monin-Obukhov length L with respect to Atmospheric stability

1/L	Atmospheric Stability
Negative	Unstable
Zero	Neutral
Positive	Stable

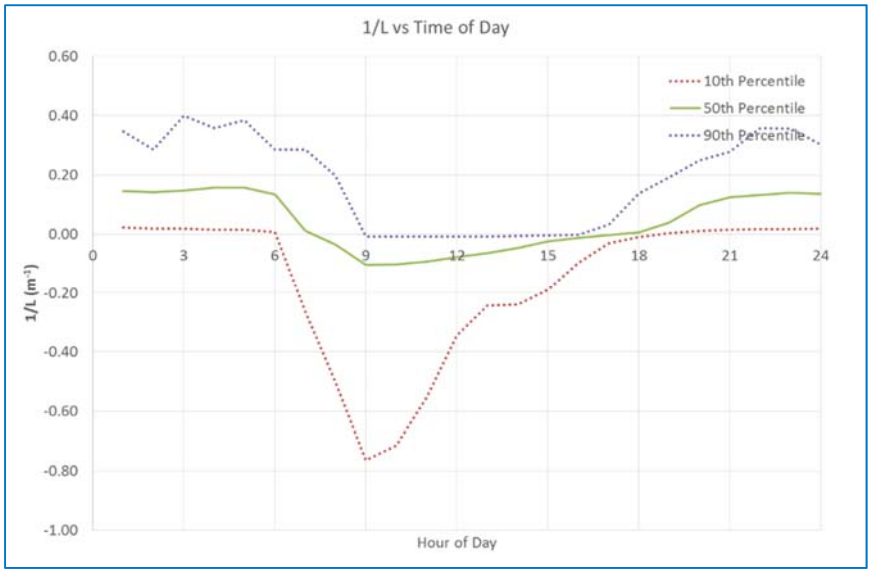


Figure D-2: Annual statistics of 1/L by hour of the day

Figure D-3 shows the variations in stability over the year by hour of the day, with reference to the widely known Pasquill-Gifford classes of stability. The relationship between L and stability classes is based on values derived by **Golder (1972)** set out in **NSW DEC (2005).** Note that the reference to stability categories here is only for convenience in describing stability. The model uses calculated values of L across a continuum.

Figure D-3 shows that stable and very stable conditions occur for about 50 per cent of the time, which is typical for inland locations that regularly experience temperature inversions at night. Atmospheric instability increases during the day and reaches a peak around noon as solar-driven convective energy peaks. A stable atmosphere is prevalent during the night. These profiles indicate that pollutant dispersion is most effective during the daytime and least effective at night.

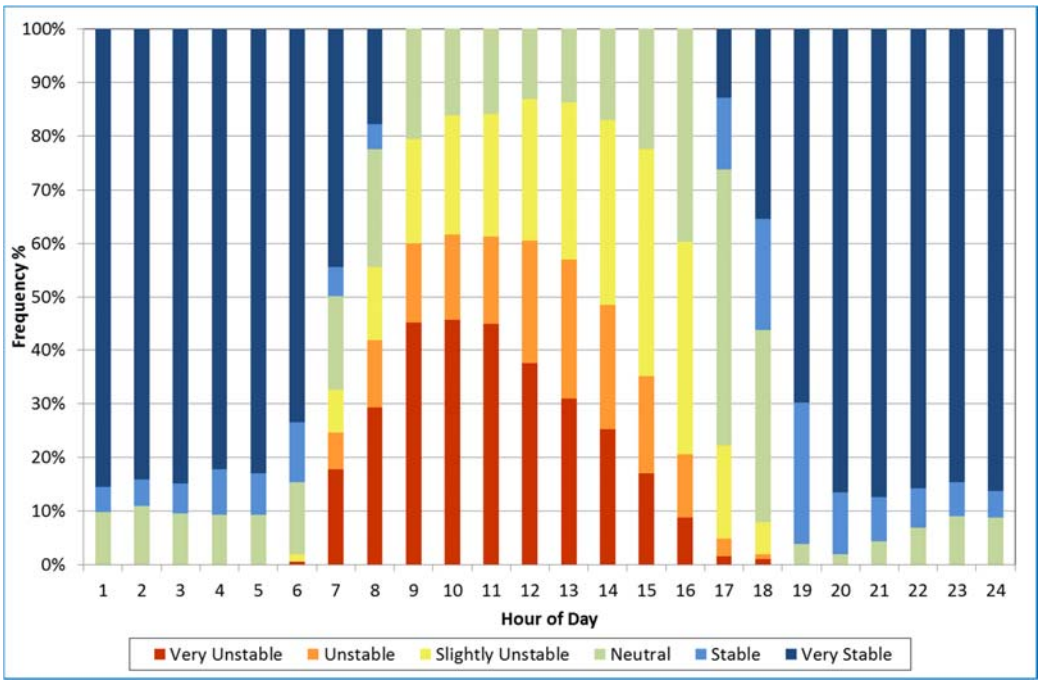


Figure D-3 Annual distribution of stability type by hour of the day

D.1.4 Meteorological data input for EDMS

EMDS requires that the same year of meteorological data is used as the year of emissions being modelled. For this reason the AERMET compiled for 2014 was modified to reflect the years 2030 and 2063.

D.1.5 Buildings

In AERMOD buildings affect plumes from point source by acting as obstacles, and can therefore have a significant impact on concentrations resulting from stationary source emissions. Buildings have no effect on the concentrations estimated from volume and area sources such as aircraft, APU, GSE, roadways, and parking facilities. The buildings included in EDMS are shown in **Figure C-1** and **Figure C-2** for the Stage 1 and longer term development, respectively. The height of the each building is provided in **Table D-2**

Table D2: Building height data for airport

No.	Building Facility	Height Above Ground (m)
1	Terminal Headhouse	25
2	Terminal Concourse	15
3	Air Traffic Control Tower	120
4	Multi-story Car Park (4-levels)	15
5	Freighter	20
6	Aircraft Maintenance Hangar (Code F)	35
7	Aircraft Engine Run-up (Code F)	35
8	Corporate Aviation Hangars	20
9	ARFFS Station (north)	5
10	ARFFS Station (south)	5
11	Fuel Farm Tanks	20
12	Catering	15
13	Waste water treatment plant	10
14	Rental Car	5
15	Airport Maintenance (north)	10
16	Airport Maintenance (south)	10
17	Train Station (elevated)	10
18	Commercial Development Area	Various
19	Taxi/Bus Staging	5

Appendix E SENSITIVE RECEPTORS

Table E1: Sensitive receptor information

ID	Receptor location	Type	ID	Receptor location	Type
R1	Bringelly	Residential	R75	Trinity Catholic Primary School	Community
R2	Luddenham	Residential	R76	Bringelly Public School	Community
R3	Greendale, Greendale Road	Residential	R78	Mulgoa Public School	Community
R4	Kemps Creek	Residential	R79	Rossmore Public School	Community
R6	Mulgoa	Residential	R80	Wallacia Public School	Community
R7	Wallacia	Residential	R82	Bellfield College - Junior Campus	Community
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	Residential	R84	Bringelly Park	Community
R14	Lawson Road, Badgerys Creek	Residential	R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	Community
R15	Mersey Rd, Greendale	Residential	R86	Blaxland Crossing Reserve	Community
R17	Luddenham Road	Residential	R87	Bill Anderson Reserve	Community
R18	Cnr Adams & Elizabeth Drive	Residential	R88	Kemps Creek Nature Reserve	Community
R19	Cnr Adams & Anton Road	Residential	R91	Western Sydney Parklands	Community
R21	Cnr Willowdene Ave and Vicar Park Lane	Residential	R93	Rossmore Grange	Community
R22	Rossmore, Victor Ave	Residential	R94	Freeburn Park	Community
R23	Wallacia, Greendale Rd	Residential	R95	Overett Reserve	Community
R24	Badgerys Creek 1 NE	On-site	R97	Mulgoa Park	Community
R25	Badgerys Creek 2 SW	On-site	R98	Wallacia Bowling and Recreation Club	Community
R27	Greendale, Dwyer Rd	Residential	R99	Hubertus Country Club	Community
R30	Rossmore residential	Residential	R100	Sugarloaf Cobbitty Equestrian Club	Community
R31	Mt Vernon residential	Residential	R102	Panthers Wallacia	Community
R34	Emmaus Residential Aged Care	Community	R103	Twin Creeks Golf and Country Club	Community
R35	Mamre After School and Vacation Care	Community	R104	Sydney International Shooting Centre	Community
R36	Head Start After School Care	Community	R108	Luddenham Showground	Community
R37	Schoolies at Mulgoa	Community	R109	Kemps Creek Sporting and Bowling Club	Community
R38	Do-re-mi Day Care Centre	Community	R110	St James Luddenham	Community
R39	Little Amigos Austral Early Learning Centre	Community	R111	Lin Ying temple	Community
R40	Little Smarties Childcare Centre	Community	R112	Vat Ketanak Khmer Kampuchea Krom	Community
R41	The Grove Academy	Community	R114	Anglican Church Sydney Diocese	Community
R42	Horsley Kids	Community	R115	Anglican Parish of Mulgoa	Community
R44	Bringelly Child Care Centre	Community	R117	Bringelly Vineyard Church	Community
R46	Clementson Drive Early Educational Centre	Community	R118	Free Church of Tonga	Community
R48	Kids Korner West Hoxton Early Learning Centre	Community	R120	Our Lady Queen of Peace	Community
R49	Luddenham Child Care Centre	Community	R122	St Anthony	Community
R52	The Frogs Lodge	Community	R123	St Marys Church	Community
R53	Rossmore Community Preschool	Community	R124	Wallacia Christian Church	Community
R54	Mulgoa Preschool	Community	R126	St Francis Xavier Church	Community
R55	Jillys Educational Childcare Centre	Community	R127	Luddenham Uniting Church	Community
R57	Wallacia Progress Hall	Community	R130	Hopewood Health Retreat	Community
R59	Bringelly Community Centre	Community	R131	Science of the Soul Study Centre	Community

R63	Luddenham Progress Hall	Community	R132	Bringelly shops	Community
R64	Mulgoa Hall	Community	R134	Kemps Creek shops	Community
R65	Emmaus Catholic College	Community	R135	Luddenham shops	Community
R66	University of Sydney Farms	Community	R136	Mulgoa shops	Community
R68	Christadelphian Heritage College Sydney	Community	R137	Rossmore shops	Community
R69	Mamre Anglican School	Community	R138	Wallacia Shops	Community
R72	Irfan College	Community	R140	Holy Family Catholic Primary and Church	Community
R73	Luddenham Public School	Community	R141	Edmund Rice Retreat and Conference Centre	Community
R74	Kemps Creek Public School	Community			

Appendix F TABULATED RESULTS AND CONTOUR PLOTS DURING OPERATIONS

F.1 STAGE 1 DEVELOPMENT

F.1.1 Nitrogen dioxide

Table F1: Predicted NO_2 concentrations during Stage 1 development

Receptor	Receptor location	Airport (µg/m³)		Cumulative (µg/m³)	
		1-hour	Annual	1-hour	Annual
AEPR ambient objective / NSW EPA Criterion		*n/a*	*n/a*	*320*	*62*
R1	Bringelly	84	11	139	18
R2	Luddenham	91	13	91	15
R3	Greendale, Greendale Road	194	12	227	14
R4	Kemps Creek	76	11	160	25
R6	Mulgoa	84	12	90	14
R7	Wallacia	90	11	92	13
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	86	13	105	19
R14	Lawson Road, Badgerys Creek	147	13	160	22
R15	Mersey Rd, Greendale	130	13	138	17
R17	Luddenham Road	96	13	115	18
R18	Cnr Adams & Elizabeth Drive	107	17	110	22
R19	Cnr Adams & Anton Road	111	19	121	23
R21	Cnr Willowdene Ave and Vicar Park Lane	171	13	179	16
R22	Rossmore, Victor Ave	68	11	145	17
R23	Wallacia, Greendale Rd	87	11	101	13
R24	Badgerys Creek 1 NE	166	18	169	25
R25	Badgerys Creek 2 SW	104	12	108	16
R27	Greendale, Dwyer Rd	80	11	86	12
R30	Rossmore residential	66	11	131	20
R31	Mt Vernon residential	142	12	143	19
R34	Emmaus Residential Aged Care	85	12	138	21
R35	Mamre After School and Vacation Care	97	12	121	21
R36	Head Start After School Care	75	11	98	16
R37	Schoolies at Mulgoa	95	13	98	16
R38	Do-re-mi Day Care Centre	108	11	155	22
R39	Little Amigos Austral Early Learning Centre	82	11	148	17
R40	Little Smarties Childcare Centre	93	12	109	21
R41	The Grove Academy	72	11	127	17
R42	Horsley Kids	67	11	127	17
R44	Bringelly Child Care Centre	97	11	103	14
R46	Clementson Drive Early Educational Centre	77	11	146	17
R48	Kids Korner West Hoxton Early Learning Centre	69	11	91	14
R49	Luddenham Child Care Centre	89	12	188	18
R52	The Frogs Lodge	70	11	126	18
R53	Rossmore Community Preschool	65	11	99	14

Receptor	Receptor location	Airport (µg/m³)		Cumulative (µg/m³)	
		1-hour	Annual	1-hour	Annual
AEPR ambient objective / NSW EPA Criterion		*n/a*	*n/a*	*320*	*62*
R54	Mulgoa Preschool	84	11	122	16
R55	Jillys Educational Childcare Centre	80	11	122	16
R57	Wallacia Progress Hall	77	11	85	13
R59	Bringelly Community Centre	93	11	88	13
R63	Luddenham Progress Hall	83	12	88	13
R64	Mulgoa Hall	86	12	94	14
R65	Emmaus Catholic College	87	12	127	21
R66	University of Sydney Farms	114	11	158	19
R68	Christadelphian Heritage College Sydney	104	11	158	19
R69	Mamre Anglican School	96	12	116	21
R72	Irfan College	67	10	231	33
R73	Luddenham Public School	90	13	93	15
R74	Kemps Creek Public School	111	11	142	18
R75	Trinity Catholic Primary School	96	12	151	21
R76	Bringelly Public School	85	11	151	21
R78	Mulgoa Public School	85	11	101	21
R79	Rossmore Public School	68	11	92	13
R80	Wallacia Public School	90	11	92	13
R82	Bellfield College - Junior Campus	69	11	103	17
R84	Bringelly Park	96	11	153	12
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	121	11	91	13
R86	Blaxland Crossing Reserve	89	11	91	13
R87	Bill Anderson Reserve	75	11	158	21
R88	Kemps Creek Nature Reserve	68	11	80	12
R91	Western Sydney Parklands	93	11	146	21
R93	Rossmore Grange	71	11	138	16
R94	Freeburn Park	91	13	94	15
R95	Overett Reserve	83	12	126	19
R97	Mulgoa Park	86	12	95	14
R98	Wallacia Bowling and Recreation Club	77	11	87	13
R99	Hubertus Country Club	113	19	103	13
R100	Sugarloaf Cobbitty Equestrian Club	95	11	103	13
R102	Panthers Wallacia	87	12	119	18
R103	Twin Creeks Golf and Country Club	80	12	119	18
R104	Sydney International Shooting Centre	110	11	**305**	34
R108	Luddenham Showground	83	12	91	15
R109	Kemps Creek Sporting and Bowling Club	80	11	188	25
R110	St James Luddenham	104	13	143	19
R111	Lin Ying temple	88	11	125	16

Receptor	Receptor location	Airport (µg/m³)		Cumulative (µg/m³)	
		1-hour	Annual	1-hour	Annual
AEPR ambient objective / NSW EPA Criterion		*n/a*	*n/a*	*320*	*62*
R112	Vat Ketanak Khmer Kampuchea Krom	68	11	125	16
R114	Anglican Church Sydney Diocese	68	11	102	16
R115	Anglican Parish of Mulgoa	86	11	101	14
R117	Bringelly Vineyard Church	89	11	135	19
R118	Free Church of Tonga	105	12	241	35
R120	Our Lady Queen of Peace	71	11	165	20
R122	St Anthony	78	11	91	13
R123	St Marys Church	85	12	91	13
R124	Wallacia Christian Church	89	11	60	10
R126	St Francis Xavier Church	103	11	88	13
R127	Luddenham Uniting Church	83	11	54	10
R130	Hopewood Health Retreat	78	11	86	13
R131	Science of the Soul Study Centre	79	11	160	25
R132	Bringelly shops	83	11	104	18
R134	Kemps Creek shops	72	11	158	22
R135	Luddenham shops	111	14	89	14
R136	Mulgoa shops	83	12	89	14
R137	Rossmore shops	67	11	112	21
R138	Wallacia Shops	88	11	64	10
R140	Holy Family Catholic Primary and Church	108	14	117	13
R141	Edmund Rice Retreat and Conference Centre	114	11	117	13

Figure F1: NO_2 1-hour Contour Plot during Stage 1 development -Cumulative

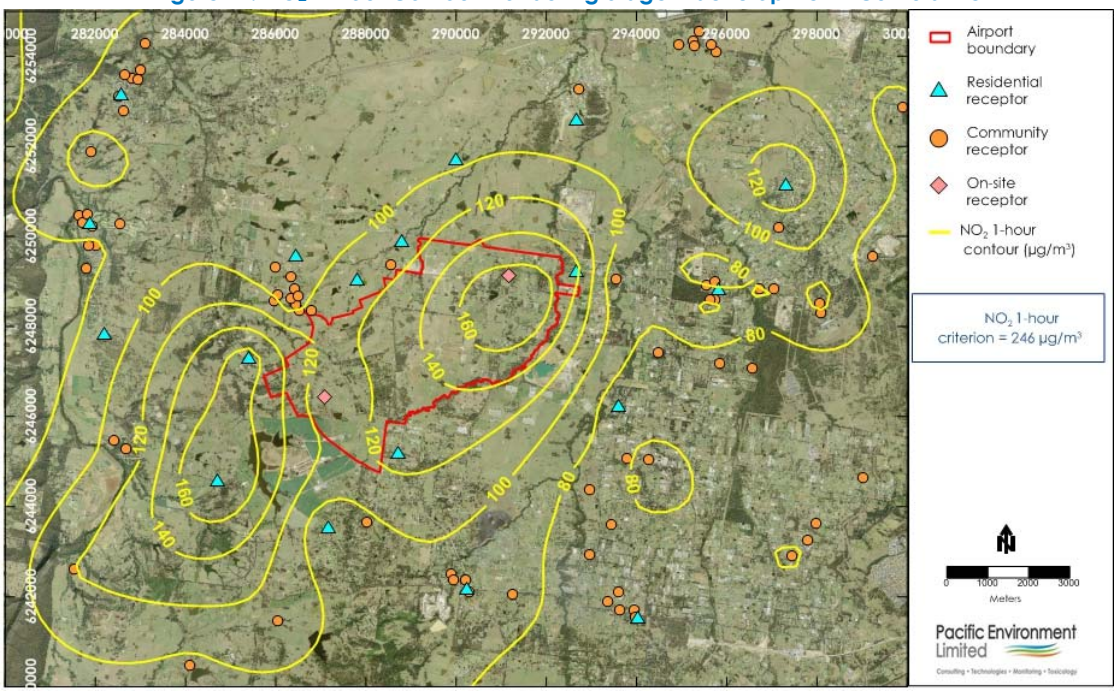
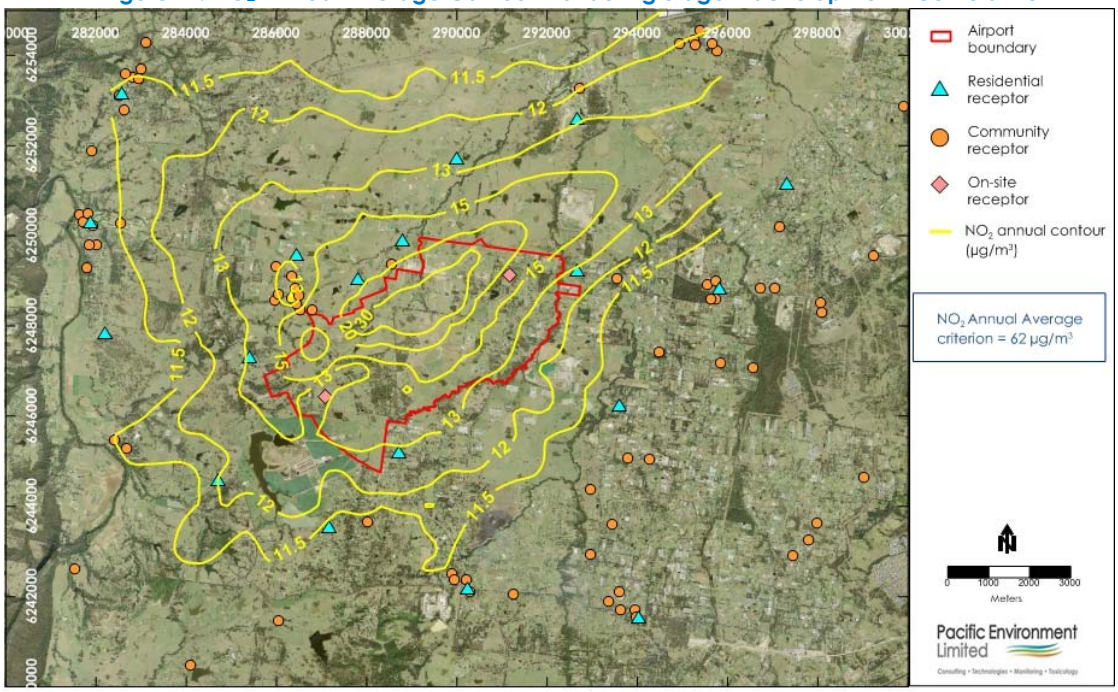


Figure F2: NO_2 Annual Average Contour Plot during Stage 1 development -Cumulative



F.1.2 Particulate matter PM_{10}

Table F2: Predicted incremental and cumulative PM_{10} concentrations during Stage 1 development.

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual

AEPR ambient objective / NSW EPA Criterion		n/a	n/a	n/a	n/a	50	30
R1	Bringelly	0.5	<0.1	7.8	1.1	44	18
R2	Luddenham	0.5	<0.1	2	0.3	43	17
R3	Greendale, Greendale Road	1.0	<0.1	3.3	0.2	43	17
R4	Kemps Creek	0.6	<0.1	15.8	1.7	46	19
R6	Mulgoa	0.5	<0.1	1.9	0.2	43	17
R7	Wallacia	0.4	<0.1	2	0.2	43	17
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.6	<0.1	3.8	0.6	44	18
R14	Lawson Road, Badgerys Creek	1.5	0.1	7.1	1.1	44	18
R15	Mersey Rd, Greendale	1.1	0.1	2.5	0.5	44	18
R17	Luddenham Road	0.7	<0.1	3.5	0.6	43	18
R18	Cnr Adams & Elizabeth Drive	0.7	0.1	3.7	0.7	44	18
R19	Cnr Adams & Anton Road	2.0	0.2	3	0.6	44	18
R21	Cnr Willowdene Ave and Vicar Park Lane	0.9	<0.1	3.3	0.4	43	17
R22	Rossmore, Victor Ave	0.9	<0.1	4.5	0.6	44	18
R23	Wallacia, Greendale Rd	0.6	<0.1	3	0.2	43	17
R24	Badgerys Creek 1 NE	4.1	0.4	6	1.2	44	18
R25	Badgerys Creek 2 SW	0.6	<0.1	2.8	0.6	43	18
R27	Greendale, Dwyer Rd	0.1	<0.1	1.7	0.2	43	17
R30	Rossmore residential	0.3	<0.1	7.5	1.4	45	18
R31	Mt Vernon residential	0.9	<0.1	5.6	0.6	43	18
R34	Emmaus Residential Aged Care	0.4	<0.1	5.1	1	44	18
R35	Mamre After School and Vacation Care	0.3	<0.1	4.3	0.9	44	18
R36	Head Start After School Care	0.3	<0.1	11	1.8	48	19
R37	Schoolies at Mulgoa	0.8	<0.1	2	0.4	43	17
R38	Do-re-mi Day Care Centre	0.8	<0.1	5.8	1	44	18
R39	Little Amigos Austral Early Learning Centre	1.2	<0.1	5.3	0.7	44	18
R40	Little Smarties Childcare Centre	0.4	<0.1	5.5	0.9	44	18
R41	The Grove Academy	0.4	<0.1	4.6	0.7	44	18
R42	Horsley Kids	0.3	<0.1	2.6	0.5	43	17
R44	Bringelly Child Care Centre	0.6	<0.1	2	0.3	43	17
R46	Clementson Drive Early Educational Centre	1.4	<0.1	6.5	0.6	44	18
R48	Kids Korner West Hoxton Early Learning Centre	0.2	<0.1	6.7	0.7	44	18
R49	Luddenham Child Care Centre	0.5	<0.1	1.9	0.3	43	17
R52	The Frogs Lodge	0.6	<0.1	4.6	0.8	45	18
R53	Rossmore Community Preschool	0.3	<0.1	5.4	1.1	44	18
R54	Mulgoa Preschool	0.3	<0.1	1.5	0.2	43	17
R55	Jillys Educational Childcare Centre	0.6	<0.1	5	0.6	44	18

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
AEPR ambient objective / NSW EPA Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*50*	*30*
R57	Wallacia Progress Hall	0.4	<0.1	2.1	0.2	43	17
R59	Bringelly Community Centre	0.7	<0.1	4.7	0.8	44	18
R63	Luddenham Progress Hall	0.4	<0.1	1.6	0.2	43	17
R64	Mulgoa Hall	0.4	<0.1	1.4	0.2	43	17
R65	Emmaus Catholic College	0.3	<0.1	4.7	0.9	44	18
R66	University of Sydney Farms	0.3	<0.1	1.9	0.2	43	17
R68	Christadelphian Heritage College Sydney	0.9	<0.1	6.7	0.9	44	18
R69	Mamre Anglican School	0.3	<0.1	4.2	0.9	44	18
R72	Irfan College	0.3	<0.1	13.7	2.5	45	20
R73	Luddenham Public School	0.6	<0.1	1.9	0.3	43	17
R74	Kemps Creek Public School	1.0	<0.1	5.1	0.7	44	18
R75	Trinity Catholic Primary School	0.3	<0.1	4.3	0.9	44	18
R76	Bringelly Public School	0.6	<0.1	11.8	1.5	46	18
R78	Mulgoa Public School	0.4	<0.1	1.4	0.2	43	17
R79	Rossmore Public School	0.3	<0.1	5.1	1.6	44	19
R80	Wallacia Public School	0.3	<0.1	1.9	0.2	43	17
R82	Bellfield College - Junior Campus	0.4	<0.1	3.3	0.8	43	18
R84	Bringelly Park	0.7	<0.1	4.4	0.8	44	18
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	0.4	<0.1	2.2	0.2	43	17
R86	Blaxland Crossing Reserve	0.3	<0.1	1.8	0.2	43	17
R87	Bill Anderson Reserve	0.7	<0.1	6.7	1.2	44	18
R88	Kemps Creek Nature Reserve	0.3	<0.1	3.4	0.7	44	18
R91	Western Sydney Parklands	0.5	<0.1	5.7	0.9	44	18
R93	Rossmore Grange	0.6	<0.1	4.3	0.5	44	18
R94	Freeburn Park	0.7	<0.1	2.1	0.3	43	17
R95	Overett Reserve	0.9	<0.1	4.4	0.9	44	18
R97	Mulgoa Park	0.4	<0.1	1.3	0.2	43	17
R98	Wallacia Bowling and Recreation Club	0.4	<0.1	2.2	0.2	43	17
R99	Hubertus Country Club	1.8	0.2	3.4	0.6	44	18
R100	Sugarloaf Cobbitty Equestrian Club	0.4	<0.1	2.1	0.2	43	17
R102	Panthers Wallacia	0.3	<0.1	2.2	0.2	43	17
R103	Twin Creeks Golf and Country Club	0.3	<0.1	4.2	0.6	44	18
R104	Sydney International Shooting Centre	0.7	<0.1	7.3	1	44	18
R108	Luddenham Showground	0.4	<0.1	2	0.3	43	17
R109	Kemps Creek Sporting and Bowling Club	0.4	<0.1	11	1.7	46	19

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
AEPR ambient objective / NSW EPA Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*50*	*30*
R110	St James Luddenham	0.6	<0.1	1.8	0.3	43	17
R111	Lin Ying temple	1.6	<0.1	6.7	1	44	18
R112	Vat Ketanak Khmer Kampuchea Krom	0.4	<0.1	5.1	0.6	44	18
R114	Anglican Church Sydney Diocese	0.3	<0.1	3.2	0.7	43	18
R115	Anglican Parish of Mulgoa	0.2	<0.1	1.7	0.3	43	17
R117	Bringelly Vineyard Church	0.7	<0.1	5	1.1	45	18
R118	Free Church of Tonga	0.7	<0.1	3.1	0.2	43	17
R120	Our Lady Queen of Peace	0.4	<0.1	6.3	1.1	44	18
R122	St Anthony	0.8	<0.1	3.7	0.8	45	18
R123	St Marys Church	0.5	<0.1	2.1	0.2	43	17
R124	Wallacia Christian Church	0.4	<0.1	2	0.2	43	17
R126	St Francis Xavier Church	0.7	<0.1	3.2	0.2	43	17
R127	Luddenham Uniting Church	0.3	<0.1	1.5	0.2	43	17
R130	Hopewood Health Retreat	0.4	<0.1	2.5	0.2	43	17
R131	Science of the Soul Study Centre	0.4	<0.1	10.6	1.7	46	19
R132	Bringelly shops	0.5	<0.1	7.1	0.9	44	18
R134	Kemps Creek shops	0.7	<0.1	5.5	1.3	44	18
R135	Luddenham shops	0.7	<0.1	1.8	0.3	43	17
R136	Mulgoa shops	0.5	<0.1	2	0.2	43	17
R137	Rossmore shops	0.3	<0.1	5.8	1.5	44	18
R138	Wallacia Shops	0.4	<0.1	1.9	0.2	43	17
R140	Holy Family Catholic Primary and Church	0.7	<0.1	2.5	0.6	44	18
R141	Edmund Rice Retreat and Conference Centre	0.3	<0.1	1.6	0.2	43	17

Figure F3: PM_{10} 24-hour maximum Contour Plot during Stage 1 development - Airport

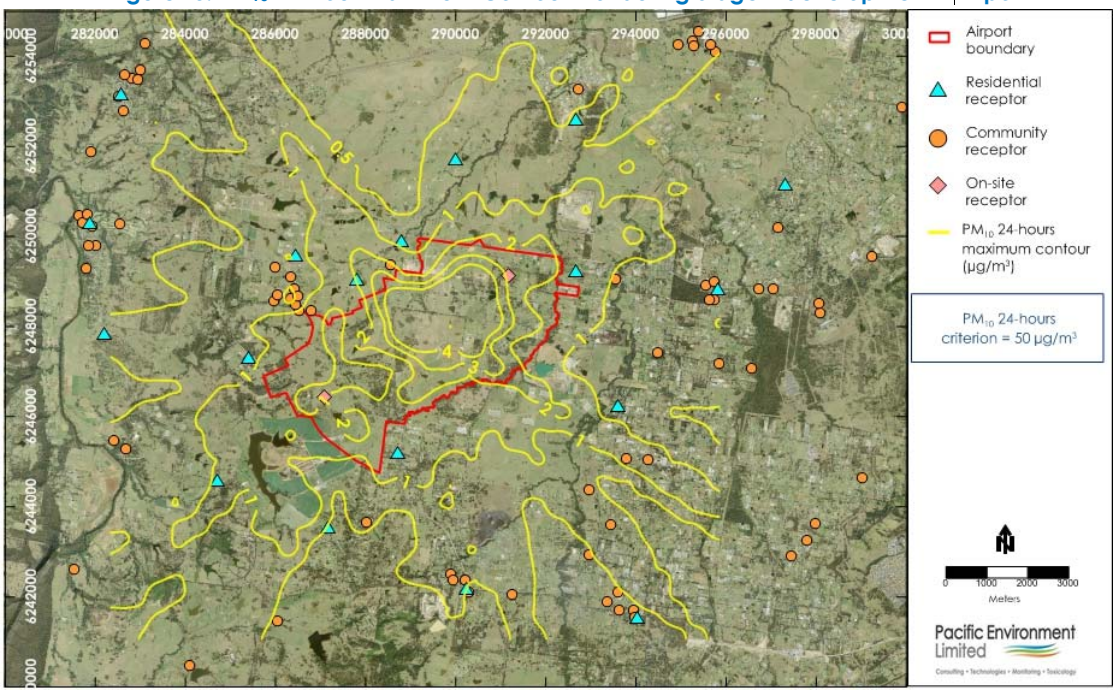


Figure F4: PM_{10} Annual Average Contour Plot during Stage 1 development - Airport

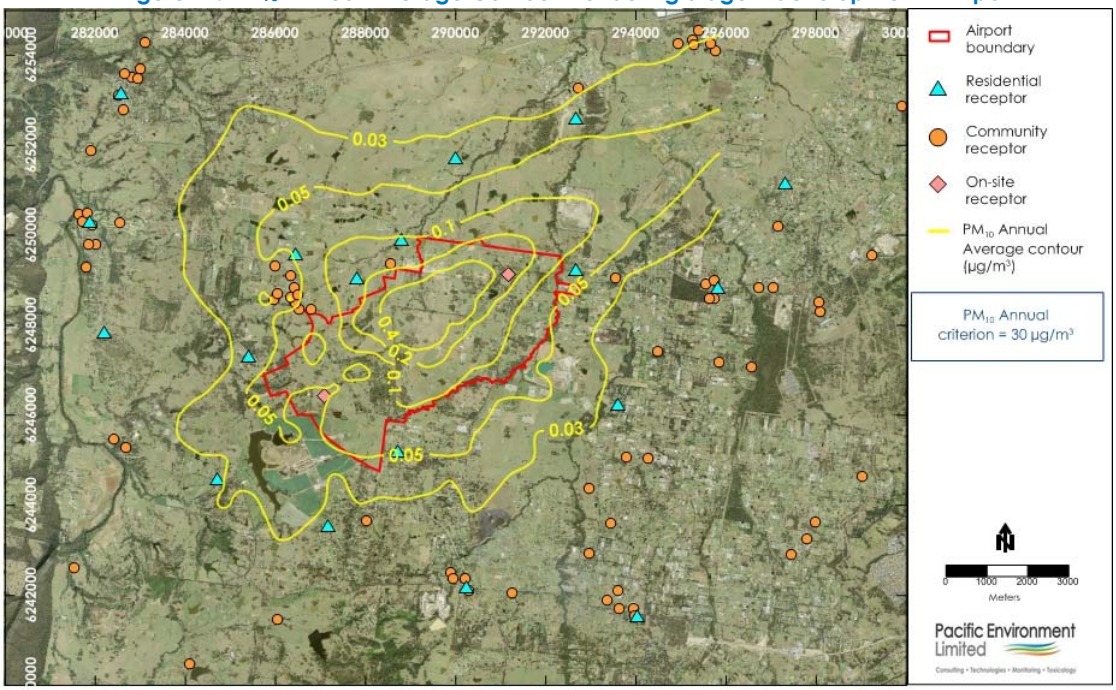


Figure F5: PM_{10} 24-hour maximum Contour Plot during Stage 1 development - Airport + external roadways

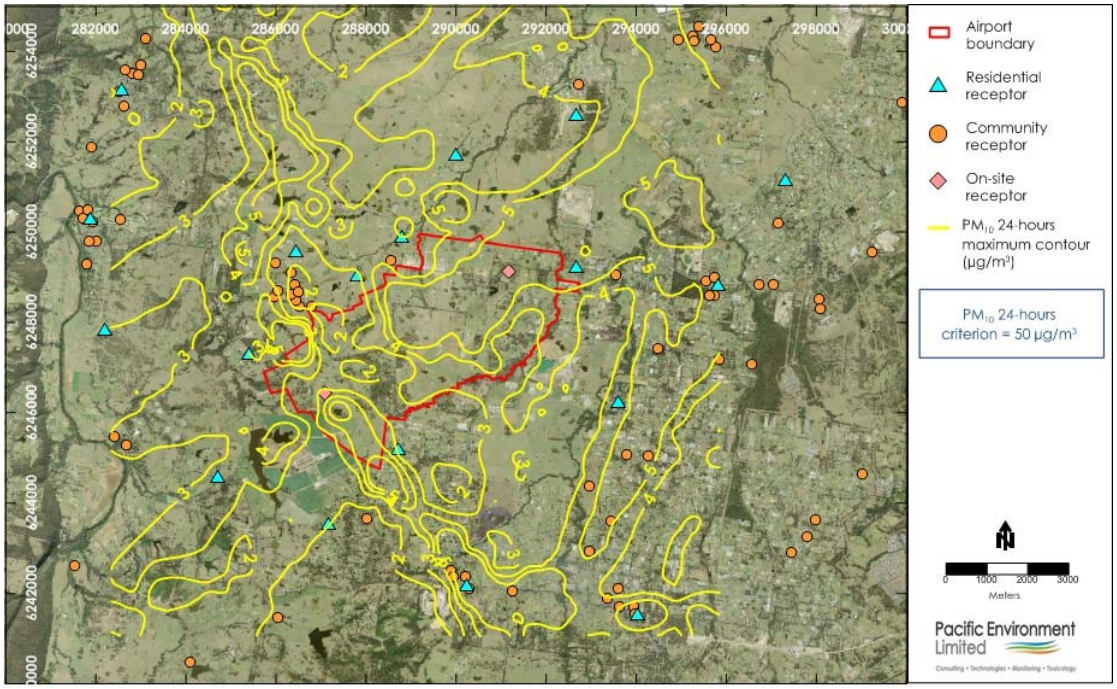


Figure F6: PM_{10} Annual Average Contour Plot during Stage 1 development - Airport + external

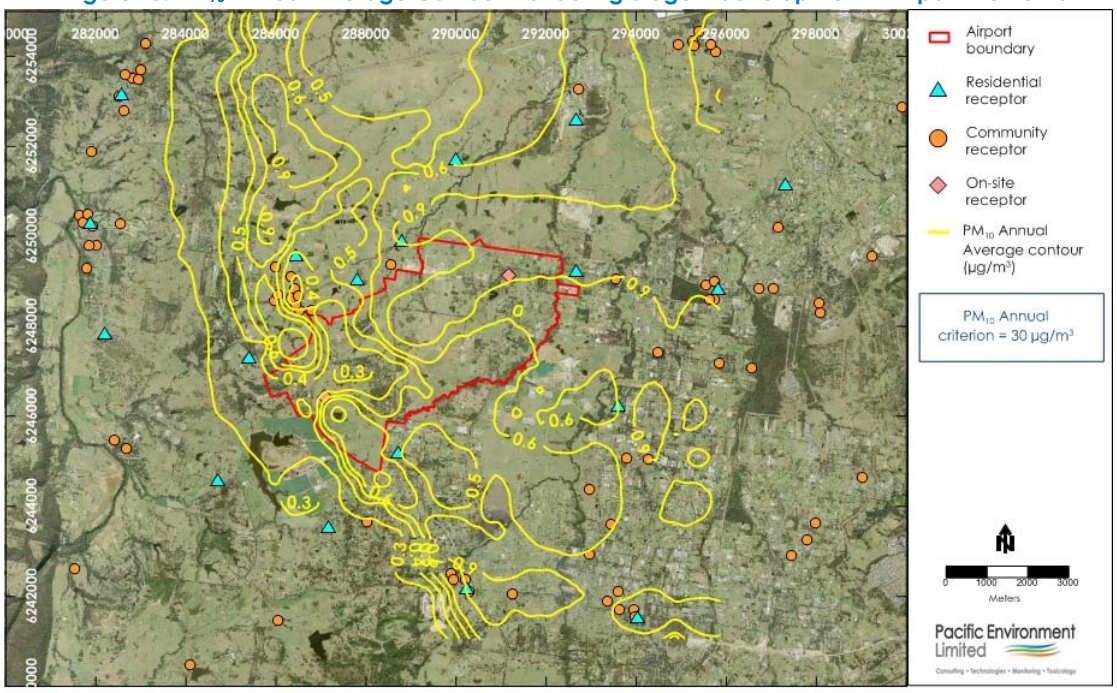


Figure F7: PM_{10} 24-hour maximum Contour Plot during Stage 1 development – Cumulative

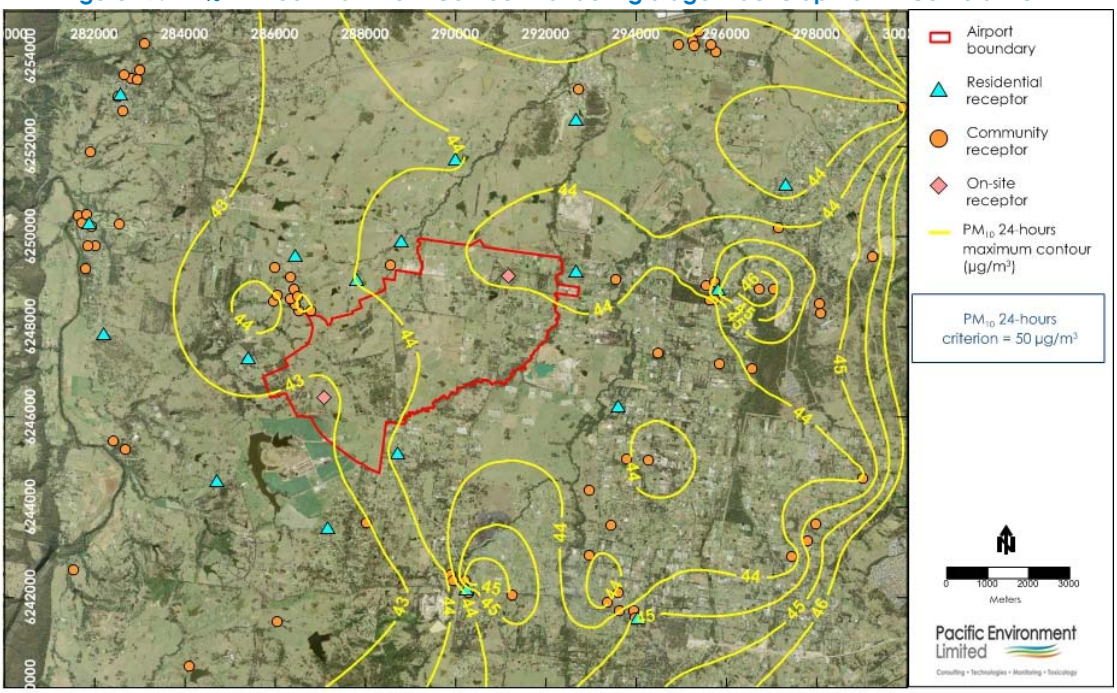
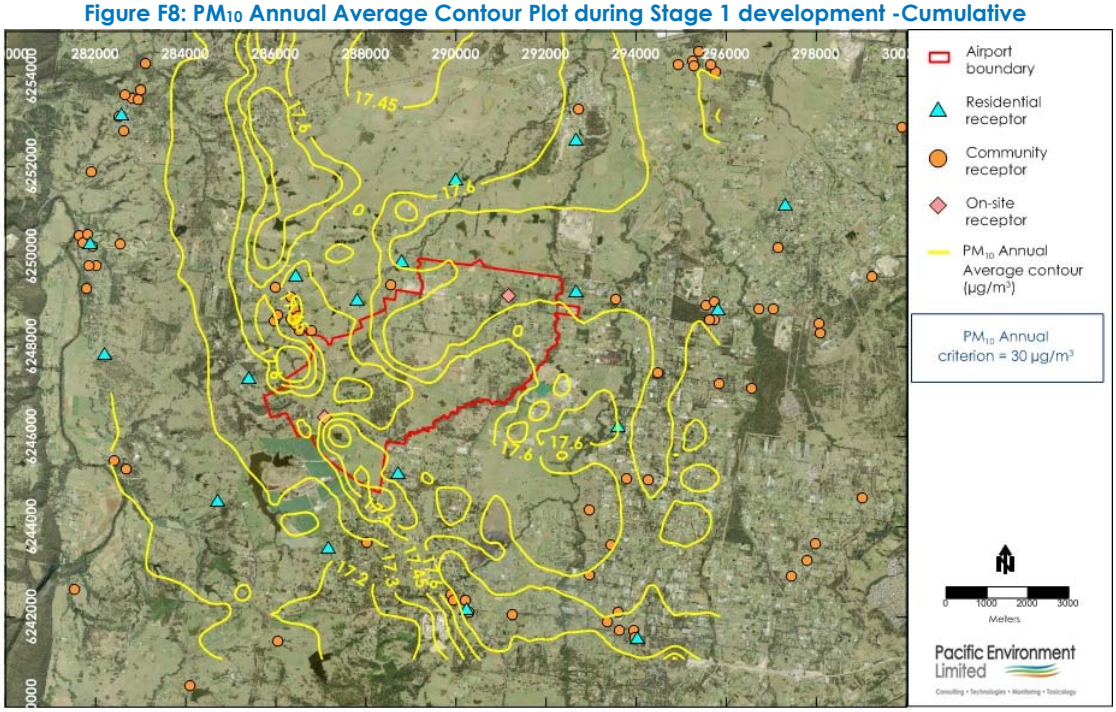


Figure F8: PM_{10} Annual Average Contour Plot during Stage 1 development -Cumulative



F.1.3 Particulate matter $PM_{2.5}$

Table F3: Predicted incremental and cumulative $PM_{2.5}$ concentrations during Stage 1 development

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual

NEPM-AAQ goal		n/a	n/a	n/a	n/a	25	8
R1	Bringelly	0.5	<0.1	3.6	0.5	14	8
R2	Luddenham	0.5	<0.1	1.0	0.2	14	7
R3	Greendale, Greendale Road	1.0	<0.1	2.0	0.1	13	7
R4	Kemps Creek	0.6	<0.1	6.5	0.8	15	8
R6	Mulgoa	0.5	<0.1	1.0	0.1	13	7
R7	Wallacia	0.4	<0.1	0.9	0.1	13	7
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.6	<0.1	1.6	0.3	14	7
R14	Lawson Road, Badgerys Creek	1.4	0.1	4.0	0.6	14	8
R15	Mersey Rd, Greendale	1.0	0.1	1.4	0.3	14	7
R17	Luddenham Road	0.7	<0.1	1.5	0.3	14	7
R18	Cnr Adams & Elizabeth Drive	0.7	0.1	1.8	0.4	14	7
R19	Cnr Adams & Anton Road	1.9	0.2	2.4	0.4	14	7
R21	Cnr Willowdene Ave and Vicar Park Lane	0.8	<0.1	1.5	0.2	14	7
R22	Rossmore, Victor Ave	0.9	<0.1	2.0	0.3	14	7
R23	Wallacia, Greendale Rd	0.6	<0.1	1.3	0.1	13	7
R24	Badgerys Creek 1 NE	3.9	0.3	4.3	0.7	14	8
R25	Badgerys Creek 2 SW	0.6	<0.1	1.3	0.3	13	7
R27	Greendale, Dwyer Rd	0.1	<0.1	0.7	0.1	13	7
R30	Rossmore residential	0.3	<0.1	3.5	0.7	14	8
R31	Mt Vernon residential	0.9	<0.1	2.2	0.3	14	7
R34	Emmaus Residential Aged Care	0.4	<0.1	2.3	0.5	14	7
R35	Mamre After School and Vacation Care	0.3	<0.1	2.0	0.4	14	7
R36	Head Start After School Care	0.3	<0.1	4.4	0.7	16	8
R37	Schoolies at Mulgoa	0.7	<0.1	1.0	0.2	14	7
R38	Do-re-mi Day Care Centre	0.8	<0.1	2.4	0.5	14	7
R39	Little Amigos Austral Early Learning Centre	1.1	<0.1	2.2	0.4	14	7
R40	Little Smarties Childcare Centre	0.3	<0.1	2.4	0.4	14	7
R41	The Grove Academy	0.4	<0.1	1.9	0.3	14	7
R42	Horsley Kids	0.2	<0.1	1.0	0.2	14	7
R44	Bringelly Child Care Centre	0.6	<0.1	1.0	0.1	14	7
R46	Clementson Drive Early Educational Centre	1.3	<0.1	2.9	0.3	14	7
R48	Kids Korner West Hoxton Early Learning Centre	0.2	<0.1	2.7	0.3	14	7
R49	Luddenham Child Care Centre	0.5	<0.1	1.1	0.2	14	7
R52	The Frogs Lodge	0.6	<0.1	2.0	0.4	14	7
R53	Rossmore Community Preschool	0.3	<0.1	2.7	0.6	14	8
R54	Mulgoa Preschool	0.3	<0.1	0.7	0.1	13	7
R55	Jillys Educational Childcare Centre	0.6	<0.1	2.2	0.3	14	7
R57	Wallacia Progress Hall	0.4	<0.1	1.0	0.1	13	7

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
NEPM-AAQ goal		*n/a*	*n/a*	*n/a*	*n/a*	*25*	*8*
R59	Bringelly Community Centre	0.6	<0.1	2.5	0.4	14	7
R63	Luddenham Progress Hall	0.4	<0.1	0.7	0.1	13	7
R64	Mulgoa Hall	0.4	<0.1	0.7	0.1	13	7
R65	Emmaus Catholic College	0.3	<0.1	2.1	0.4	14	7
R66	University of Sydney Farms	0.3	<0.1	1.0	0.1	13	7
R68	Christadelphian Heritage College Sydney	0.8	<0.1	2.8	0.4	14	7
R69	Mamre Anglican School	0.3	<0.1	2.0	0.4	14	7
R72	Irfan College	0.3	<0.1	6.3	1.1	14	8
R73	Luddenham Public School	0.6	<0.1	1.1	0.2	14	7
R74	Kemps Creek Public School	0.9	<0.1	2.2	0.3	14	7
R75	Trinity Catholic Primary School	0.3	<0.1	1.9	0.4	14	7
R76	Bringelly Public School	0.5	<0.1	5.4	0.7	15	8
R78	Mulgoa Public School	0.3	<0.1	0.7	0.1	13	7
R79	Rossmore Public School	0.3	<0.1	2.4	0.7	14	8
R80	Wallacia Public School	0.3	<0.1	0.8	0.1	13	7
R82	Bellfield College - Junior Campus	0.4	<0.1	1.5	0.4	14	7
R84	Bringelly Park	0.7	<0.1	2.3	0.4	14	7
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	0.4	<0.1	1.0	0.1	13	7
R86	Blaxland Crossing Reserve	0.3	<0.1	0.8	0.1	13	7
R87	Bill Anderson Reserve	0.7	<0.1	2.9	0.6	14	8
R88	Kemps Creek Nature Reserve	0.3	<0.1	1.5	0.3	14	7
R91	Western Sydney Parklands	0.5	<0.1	2.2	0.4	14	7
R93	Rossmore Grange	0.6	<0.1	1.9	0.3	14	7
R94	Freeburn Park	0.7	<0.1	1.4	0.2	14	7
R95	Overett Reserve	0.8	<0.1	2.3	0.4	14	7
R97	Mulgoa Park	0.4	<0.1	0.7	0.1	13	7
R98	Wallacia Bowling and Recreation Club	0.4	<0.1	1.0	0.1	13	7
R99	Hubertus Country Club	1.7	0.2	2.4	0.4	14	7
R100	Sugarloaf Cobbitty Equestrian Club	0.4	<0.1	1.1	0.1	13	7
R102	Panthers Wallacia	0.3	<0.1	1.0	0.1	13	7
R103	Twin Creeks Golf and Country Club	0.3	<0.1	1.8	0.3	14	7
R104	Sydney International Shooting Centre	0.7	<0.1	3.7	0.4	14	7
R108	Luddenham Showground	0.4	<0.1	1.0	0.2	14	7
R109	Kemps Creek Sporting and Bowling Club	0.4	<0.1	4.7	0.7	15	8
R110	St James Luddenham	0.5	<0.1	0.9	0.2	14	7
R111	Lin Ying temple	1.6	<0.1	3.0	0.5	14	7

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
NEPM-AAQ goal		*n/a*	*n/a*	*n/a*	*n/a*	*25*	*8*
R112	Vat Ketanak Khmer Kampuchea Krom	0.4	<0.1	2.2	0.3	14	7
R114	Anglican Church Sydney Diocese	0.3	<0.1	1.5	0.4	14	7
R115	Anglican Parish of Mulgoa	0.2	<0.1	0.8	0.1	13	7
R117	Bringelly Vineyard Church	0.6	<0.1	2.6	0.5	15	8
R118	Free Church of Tonga	0.7	<0.1	1.6	0.1	13	7
R120	Our Lady Queen of Peace	0.4	<0.1	2.9	0.5	14	8
R122	St Anthony	0.7	<0.1	2.1	0.4	15	7
R123	St Marys Church	0.4	<0.1	1.1	0.1	13	7
R124	Wallacia Christian Church	0.4	<0.1	0.9	0.1	13	7
R126	St Francis Xavier Church	0.6	<0.1	1.8	0.1	13	7
R127	Luddenham Uniting Church	0.3	<0.1	0.6	0.1	13	7
R130	Hopewood Health Retreat	0.4	<0.1	1.1	0.1	13	7
R131	Science of the Soul Study Centre	0.4	<0.1	4.6	0.7	15	8
R132	Bringelly shops	0.5	<0.1	3.3	0.4	14	7
R134	Kemps Creek shops	0.6	<0.1	2.4	0.6	14	8
R135	Luddenham shops	0.6	<0.1	0.9	0.2	14	7
R136	Mulgoa shops	0.5	<0.1	1.0	0.1	13	7
R137	Rossmore shops	0.3	<0.1	2.7	0.7	14	8
R138	Wallacia Shops	0.4	<0.1	0.9	0.1	13	7
R140	Holy Family Catholic Primary and Church	0.7	<0.1	1.5	0.3	14	7
R141	Edmund Rice Retreat and Conference Centre	0.3	<0.1	0.7	0.1	13	7

Figure F9: $PM_{2.5}$ 24-hour maximum Contour Plot during Stage 1 development - Airport

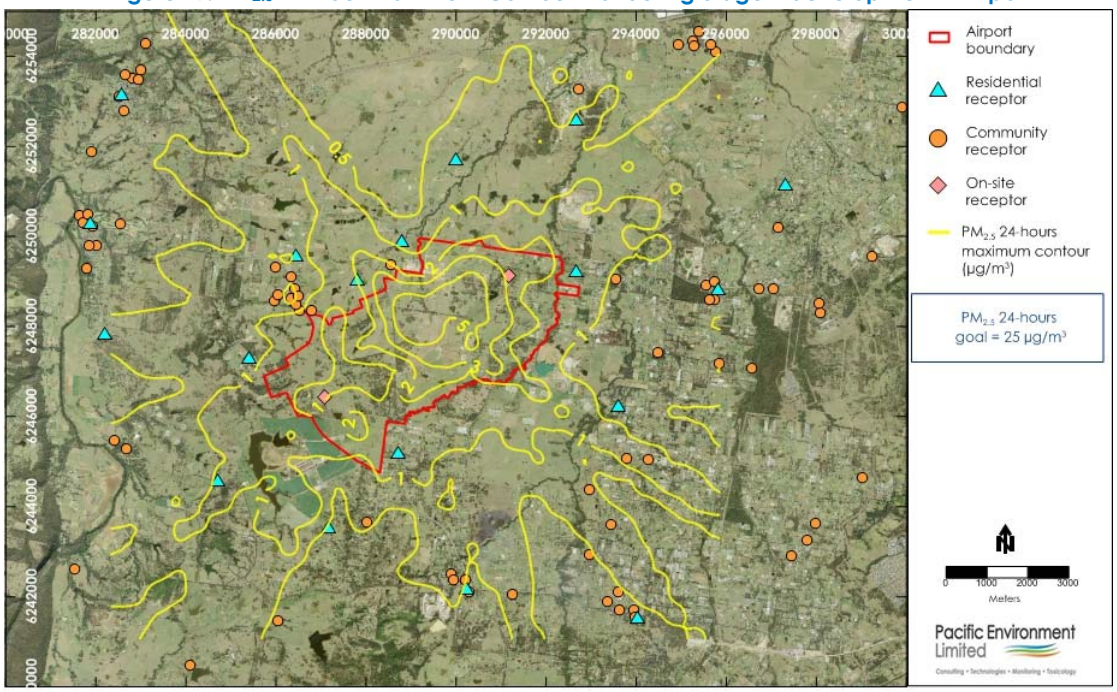


Figure F10: $PM_{2.5}$ Annual Average Contour Plot during Stage 1 development - Airport

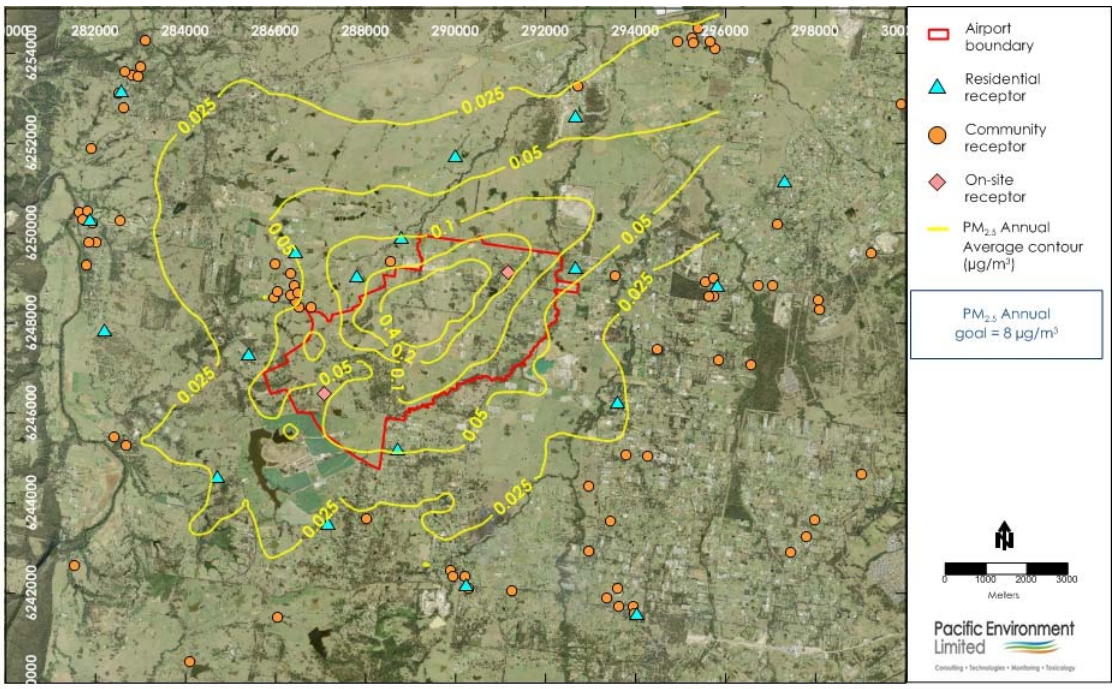


Figure F11: $PM_{2.5}$ 24-hour maximum Contour Plot during Stage 1 development - Airport + External Roadways

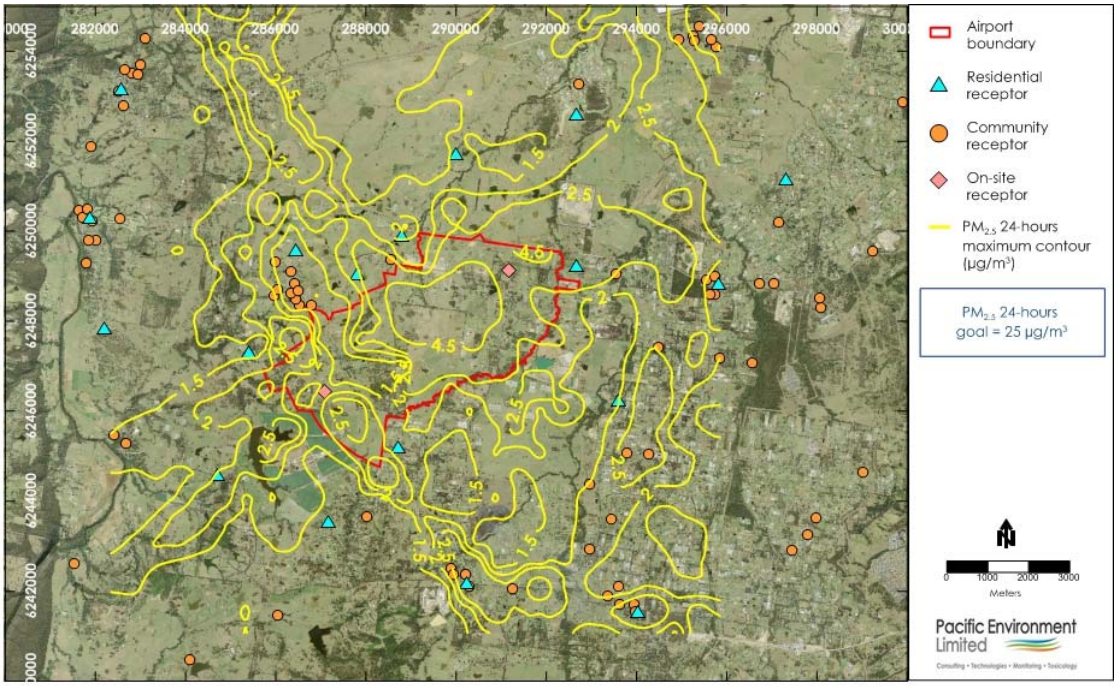


Figure F12: $PM_{2.5}$ Annual Contour Plot during Stage 1 development - Airport + External Roadways

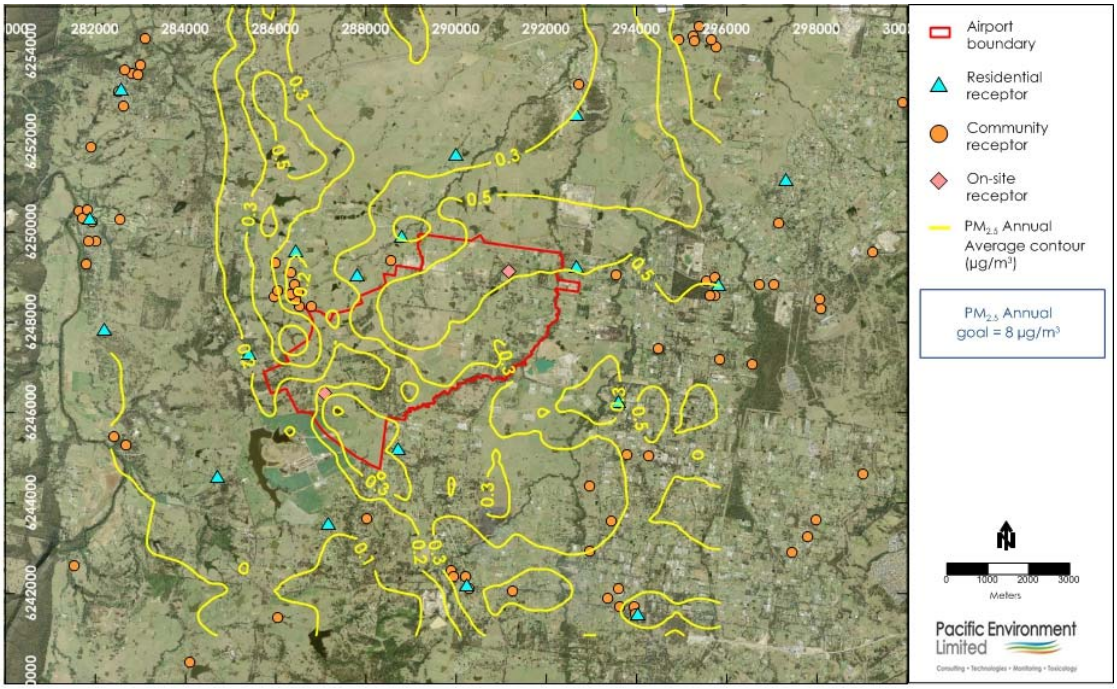


Figure F13: $PM_{2.5}$ 24-hour maximum Contour Plot during Stage 1 development – Cumulative

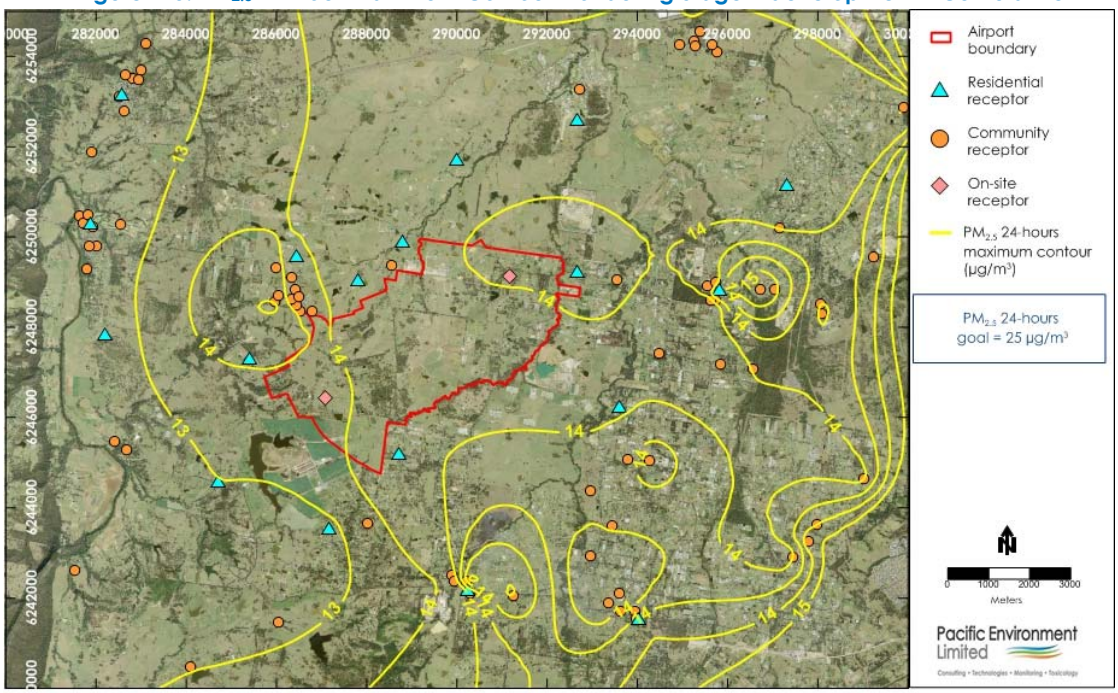
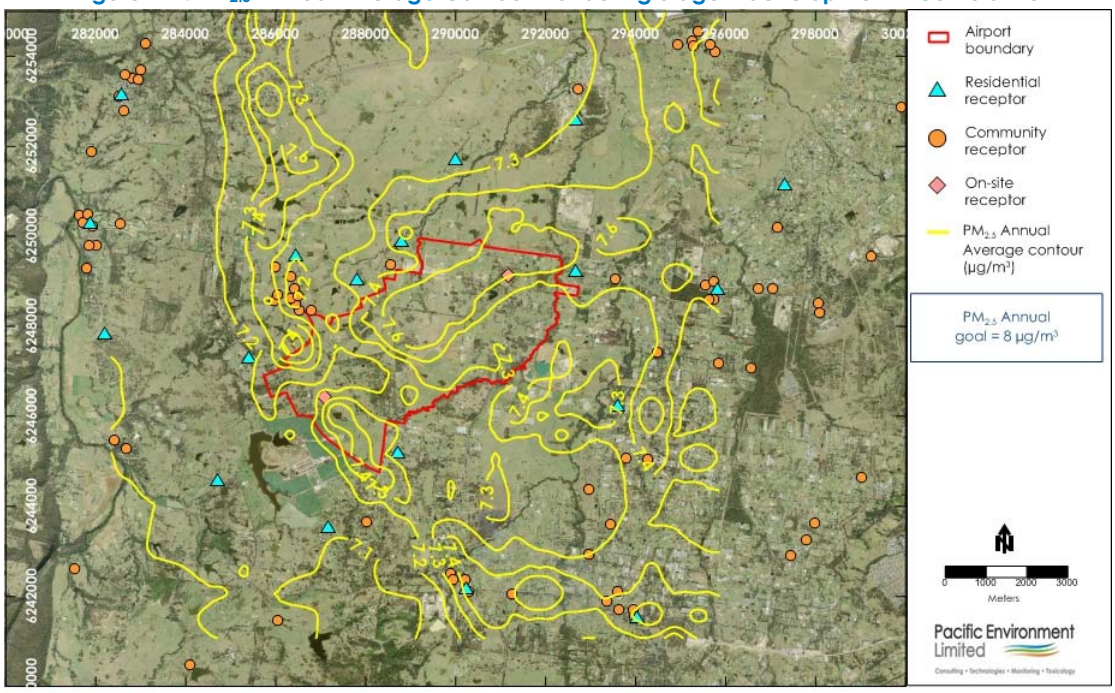


Figure F14: $PM_{2.5}$ Annual Average Contour Plot during Stage 1 development - Cumulative



F.1.4 Carbon monoxide

Table F4: Predicted incremental and cumulative CO concentrations during Stage 1 development.

Receptor	Receptor location	Airport (mg/m³)			Airport + external roadways (mg/m³)			Cumulative (mg/m³)		
		15-minute	1-hour	8-hour	15-minute	1-hour	8-hour	15-minute	1-hour	8-hour
Ambient objective / Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*100*	*30*	*10*
R1	Bringelly	0.6	0.4	0.1	3.2	2.4	0.3	5.3	3.9	1.5
R2	Luddenham	0.5	0.4	0.1	0.5	0.4	0.1	2.6	1.9	1.3
R3	Greendale, Greendale Road	0.9	0.7	0.1	1.6	1.2	0.2	3.7	2.7	1.4
R4	Kemps Creek	0.7	0.5	0.1	2	1.5	0.5	4.1	3	1.7
R6	Mulgoa	0.7	0.5	0.1	0.9	0.7	0.1	3	2.2	1.3
R7	Wallacia	0.3	0.2	0.0	0.9	0.7	0.1	3	2.2	1.3
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.9	0.7	0.1	1.5	1.1	0.2	3.6	2.6	1.4
R14	Lawson Road, Badgerys Creek	1.8	1.4	0.2	3.1	2.3	0.3	5.2	3.8	1.5
R15	Mersey Rd, Greendale	1.1	0.8	0.2	1.4	1	0.2	3.5	2.5	1.4
R17	Luddenham Road	0.5	0.4	0.1	1.1	0.8	0.2	3.2	2.3	1.4
R18	Cnr Adams & Elizabeth Drive	0.7	0.5	0.1	1.8	1.4	0.2	3.9	2.9	1.4
R19	Cnr Adams & Anton Road	2.3	1.7	0.3	2.4	1.8	0.3	4.5	3.3	1.5
R21	Cnr Willowdene Ave and Vicar Park Lane	1.1	0.8	0.2	1.7	1.3	0.2	3.8	2.8	1.4
R22	Rossmore, Victor Ave	1.0	0.8	0.1	1.1	0.9	0.2	3.2	2.4	1.4
R23	Wallacia, Greendale Rd	0.4	0.3	0.1	0.7	0.5	0.1	2.8	2	1.3
R24	Badgerys Creek 1 NE	3.1	2.3	0.5	3.1	2.3	0.5	5.2	3.8	1.7
R25	Badgerys Creek 2 SW	0.5	0.4	0.1	1	0.8	0.1	3.1	2.3	1.3
R27	Greendale, Dwyer Rd	0.2	0.1	0.0	0.3	0.2	0.1	2.4	1.7	1.3
R30	Rossmore residential	0.4	0.3	0.1	2.6	1.9	0.4	4.7	3.4	1.6
R31	Mt Vernon residential	0.8	0.6	0.1	0.9	0.6	0.2	3	2.1	1.4
R34	Emmaus Residential Aged Care	0.5	0.4	0.1	1.1	0.8	0.1	3.2	2.3	1.3
R35	Mamre After School and Vacation Care	0.4	0.3	0.1	0.7	0.5	0.1	2.8	2	1.3
R36	Head Start After School Care	0.7	0.5	0.1	2.3	1.7	0.3	4.4	3.2	1.5
R37	Schoolies at Mulgoa	0.4	0.3	0.1	0.7	0.5	0.1	2.8	2	1.3
R38	Do-re-mi Day Care Centre	1.2	0.9	0.1	2.3	1.7	0.2	4.4	3.2	1.4
R39	Little Amigos Austral Early Learning Centre	0.7	0.5	0.2	0.9	0.7	0.2	3	2.2	1.4
R40	Little Smarties Childcare Centre	0.5	0.4	0.1	0.7	0.5	0.1	2.8	2	1.3
R41	The Grove Academy	0.5	0.3	0.1	1.1	0.8	0.2	3.2	2.3	1.4
R42	Horsley Kids	0.4	0.3	0.0	0.5	0.3	0.1	2.6	1.8	1.3
R44	Bringelly Child Care Centre	0.6	0.4	0.1	0.8	0.6	0.1	2.9	2.1	1.3
R46	Clementson Drive Early Educational Centre	0.6	0.5	0.2	1.3	1	0.2	3.4	2.5	1.4

Receptor	Receptor location	Airport (mg/m³)			Airport + external roadways (mg/m³)			Cumulative (mg/m³)		
		15-minute	1-hour	8-hour	15-minute	1-hour	8-hour	15-minute	1-hour	8-hour
Ambient objective / Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*100*	*30*	*10*
R48	Kids Korner West Hoxton Early Learning Centre	0.3	0.2	0.0	1.2	0.9	0.2	3.3	2.4	1.4
R49	Luddenham Child Care Centre	0.3	0.3	0.0	0.4	0.3	0.1	2.5	1.8	1.3
R52	The Frogs Lodge	0.5	0.4	0.1	1	0.8	0.2	3.1	2.3	1.4
R53	Rossmore Community Preschool	0.4	0.3	0.1	1.8	1.4	0.2	3.9	2.9	1.4
R54	Mulgoa Preschool	0.4	0.3	0.1	0.6	0.5	0.1	2.7	2	1.3
R55	Jillys Educational Childcare Centre	0.6	0.5	0.1	1	0.8	0.2	3.1	2.3	1.4
R57	Wallacia Progress Hall	0.3	0.2	0.1	0.5	0.4	0.1	2.6	1.9	1.3
R59	Bringelly Community Centre	0.5	0.4	0.1	1	0.7	0.2	3.1	2.2	1.4
R63	Luddenham Progress Hall	0.3	0.2	0.1	0.4	0.3	0.1	2.5	1.8	1.3
R64	Mulgoa Hall	0.4	0.3	0.1	0.7	0.5	0.1	2.8	2	1.3
R65	Emmaus Catholic College	0.5	0.3	0.1	0.7	0.5	0.1	2.8	2	1.3
R66	University of Sydney Farms	0.4	0.3	0.1	0.8	0.6	0.1	2.9	2.1	1.3
R68	Christadelphian Heritage College Sydney	1.4	1.0	0.1	1.6	1.2	0.2	3.7	2.7	1.4
R69	Mamre Anglican School	0.4	0.3	0.1	0.7	0.5	0.1	2.8	2	1.3
R72	Irfan College	0.4	0.3	0.0	4.7	3.5	0.6	6.8	5	1.8
R73	Luddenham Public School	0.3	0.3	0.1	0.4	0.3	0.1	2.5	1.8	1.3
R74	Kemps Creek Public School	1.5	1.1	0.2	1.6	1.2	0.2	3.7	2.7	1.4
R75	Trinity Catholic Primary School	0.4	0.3	0.1	0.7	0.5	0.1	2.8	2	1.3
R76	Bringelly Public School	0.6	0.4	0.1	3.5	2.6	0.4	5.6	4.1	1.6
R78	Mulgoa Public School	0.4	0.3	0.1	0.6	0.5	0.1	2.7	2	1.3
R79	Rossmore Public School	0.4	0.3	0.1	1.1	0.8	0.2	3.2	2.3	1.4
R80	Wallacia Public School	0.3	0.3	0.0	1.1	0.8	0.1	3.2	2.3	1.3
R82	Bellfield College - Junior Campus	0.4	0.3	0.1	0.8	0.6	0.1	2.9	2.1	1.3
R84	Bringelly Park	0.5	0.4	0.1	0.9	0.7	0.2	3	2.2	1.4
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	0.3	0.2	0.1	0.9	0.7	0.1	3	2.2	1.3
R86	Blaxland Crossing Reserve	0.3	0.2	0.0	1	0.7	0.1	3.1	2.2	1.3
R87	Bill Anderson Reserve	0.6	0.4	0.1	1.9	1.4	0.3	4	2.9	1.5
R88	Kemps Creek Nature Reserve	0.4	0.3	0.0	1	0.7	0.2	3.1	2.2	1.4
R91	Western Sydney Parklands	0.9	0.6	0.1	1	0.8	0.2	3.1	2.3	1.4
R93	Rossmore Grange	0.6	0.5	0.1	0.9	0.7	0.2	3	2.2	1.4
R94	Freeburn Park	0.5	0.4	0.1	0.5	0.4	0.1	2.6	1.9	1.3

Receptor	Receptor location	Airport (mg/m³)			Airport + external roadways (mg/m³)			Cumulative (mg/m³)		
		15-minute	1-hour	8-hour	15-minute	1-hour	8-hour	15-minute	1-hour	8-hour
Ambient objective / Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*100*	*30*	*10*
R95	Overett Reserve	0.8	0.6	0.1	2.5	1.9	0.3	4.6	3.4	1.5
R97	Mulgoa Park	0.4	0.3	0.1	0.7	0.5	0.1	2.8	2	1.3
R98	Wallacia Bowling and Recreation Club	0.3	0.2	0.1	0.5	0.4	0.1	2.6	1.9	1.3
R99	Hubertus Country Club	1.7	1.3	0.2	1.8	1.3	0.2	3.9	2.8	1.4
R100	Sugarloaf Cobbitty Equestrian Club	0.4	0.3	0.1	0.7	0.5	0.1	2.8	2	1.3
R102	Panthers Wallacia	0.3	0.3	0.0	0.9	0.7	0.1	3	2.2	1.3
R103	Twin Creeks Golf and Country Club	0.4	0.3	0.1	0.8	0.6	0.1	2.9	2.1	1.3
R104	Sydney International Shooting Centre	1.2	0.9	0.1	2.2	1.7	0.3	4.3	3.2	1.5
R108	Luddenham Showground	0.3	0.2	0.1	0.6	0.4	0.1	2.7	1.9	1.3
R109	Kemps Creek Sporting and Bowling Club	0.8	0.6	0.1	3	2.2	0.5	5.1	3.7	1.7
R110	St James Luddenham	0.4	0.3	0.1	0.5	0.4	0.1	2.6	1.9	1.3
R111	Lin Ying temple	0.9	0.7	0.3	1.3	1	0.3	3.4	2.5	1.5
R112	Vat Ketanak Khmer Kampuchea Krom	0.4	0.3	0.1	0.9	0.7	0.2	3	2.2	1.4
R114	Anglican Church Sydney Diocese	0.3	0.3	0.0	0.8	0.6	0.2	2.9	2.1	1.4
R115	Anglican Parish of Mulgoa	0.4	0.3	0.1	0.6	0.5	0.1	2.7	2	1.3
R117	Bringelly Vineyard Church	1.0	0.7	0.1	1.7	1.3	0.2	3.8	2.8	1.4
R118	Free Church of Tonga	0.8	0.6	0.1	0.9	0.7	0.2	3	2.2	1.4
R120	Our Lady Queen of Peace	0.5	0.3	0.1	2.1	1.6	0.3	4.2	3.1	1.5
R122	St Anthony	0.6	0.5	0.2	1	0.7	0.2	3.1	2.2	1.4
R123	St Marys Church	0.7	0.5	0.1	0.9	0.7	0.2	3	2.2	1.4
R124	Wallacia Christian Church	0.3	0.2	0.0	0.8	0.6	0.1	2.9	2.1	1.3
R126	St Francis Xavier Church	0.8	0.6	0.1	0.9	0.7	0.2	3	2.2	1.4
R127	Luddenham Uniting Church	0.2	0.2	0.0	0.3	0.2	0.1	2.4	1.7	1.3
R130	Hopewood Health Retreat	0.4	0.3	0.1	0.5	0.4	0.1	2.6	1.9	1.3
R131	Science of the Soul Study Centre	0.8	0.6	0.1	2.4	1.8	0.5	4.5	3.3	1.7
R132	Bringelly shops	0.5	0.4	0.1	1.5	1.1	0.3	3.6	2.6	1.5
R134	Kemps Creek shops	0.6	0.4	0.1	1.3	1	0.2	3.4	2.5	1.4
R135	Luddenham shops	0.4	0.3	0.1	0.5	0.4	0.1	2.6	1.9	1.3
R136	Mulgoa shops	0.7	0.5	0.1	0.9	0.7	0.1	3	2.2	1.3
R137	Rossmore shops	0.4	0.3	0.1	1.5	1.1	0.2	3.6	2.6	1.4
R138	Wallacia Shops	0.3	0.2	0.0	0.9	0.6	0.1	3	2.1	1.3
R140	Holy Family Catholic Primary and Church	0.5	0.4	0.1	0.8	0.6	0.1	2.9	2.1	1.3
R141	Edmund Rice Retreat and Conference Centre	0.5	0.3	0.1	0.7	0.5	0.1	2.8	2	1.3

Figure F14: CO 1-hour Contour Plot during Stage 1 development - Airport

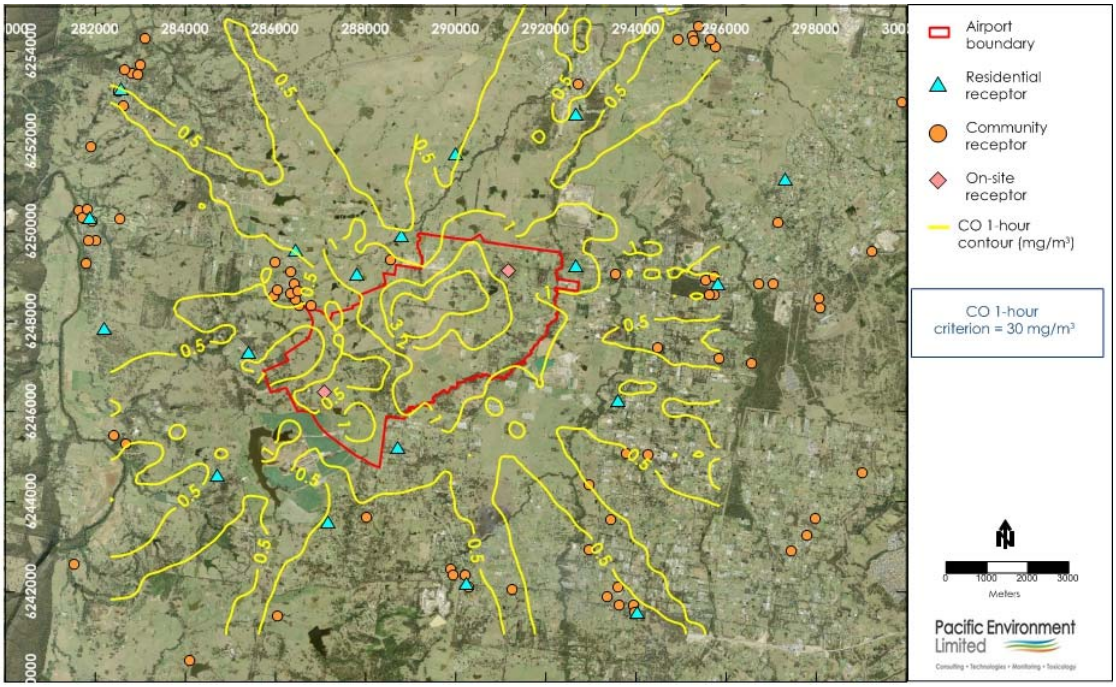


Figure F15: CO 8-hour Contour Plot during Stage 1 development - Airport

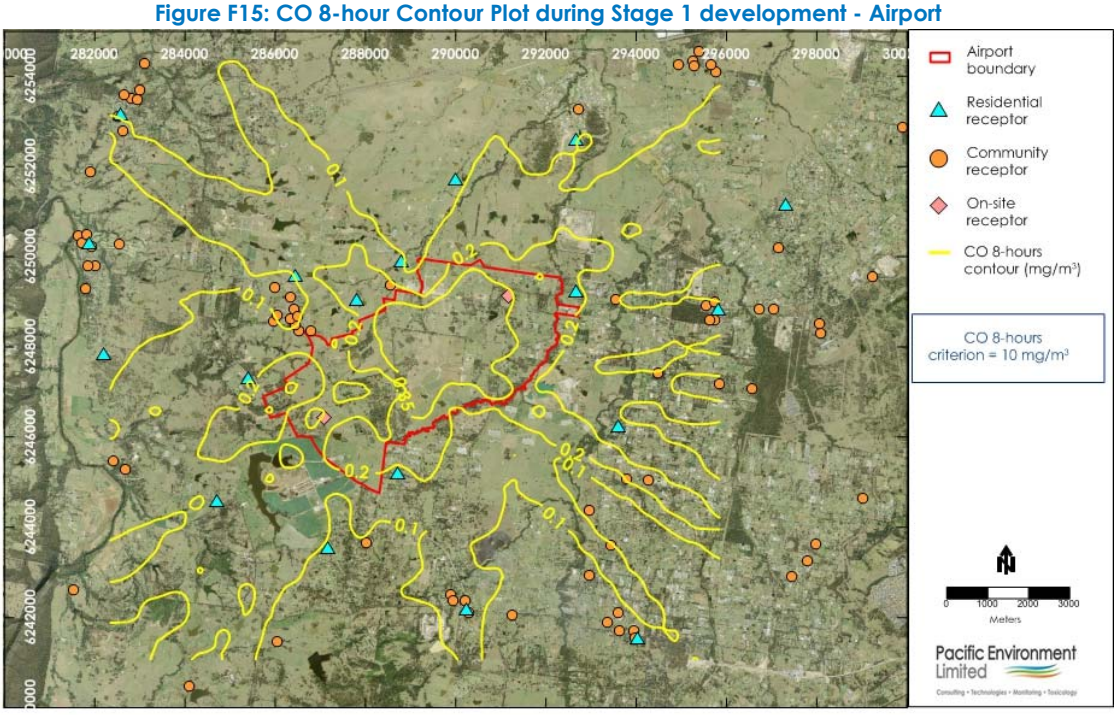


Figure F16: CO 1-hour Contour Plot during Stage 1 development - Airport + External Roadways

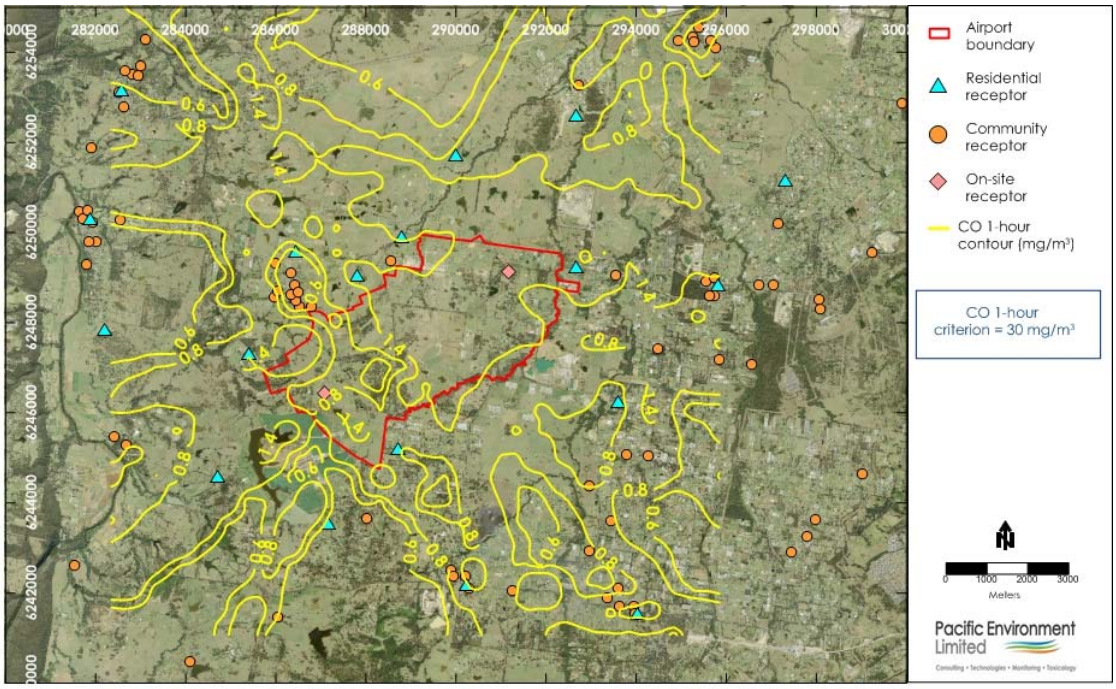


Figure F17: CO 8-hour Contour Plot during Stage 1 development - Airport + External Roadways

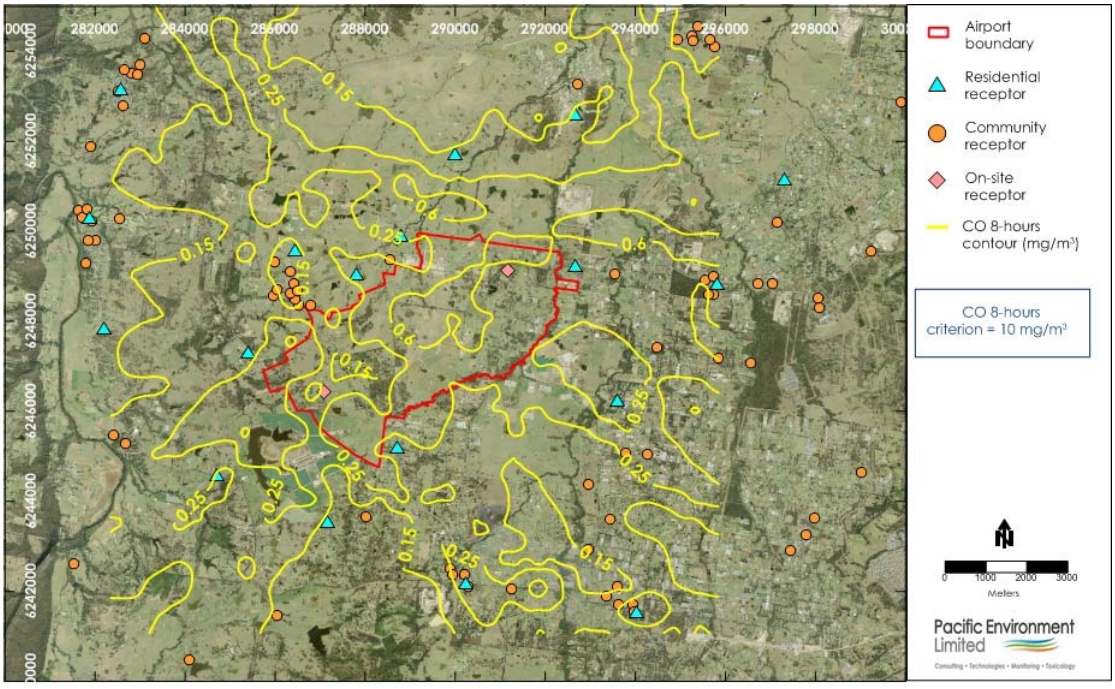


Figure F18: CO 1-hour Contour Plot during Stage 1 development - Cumulative

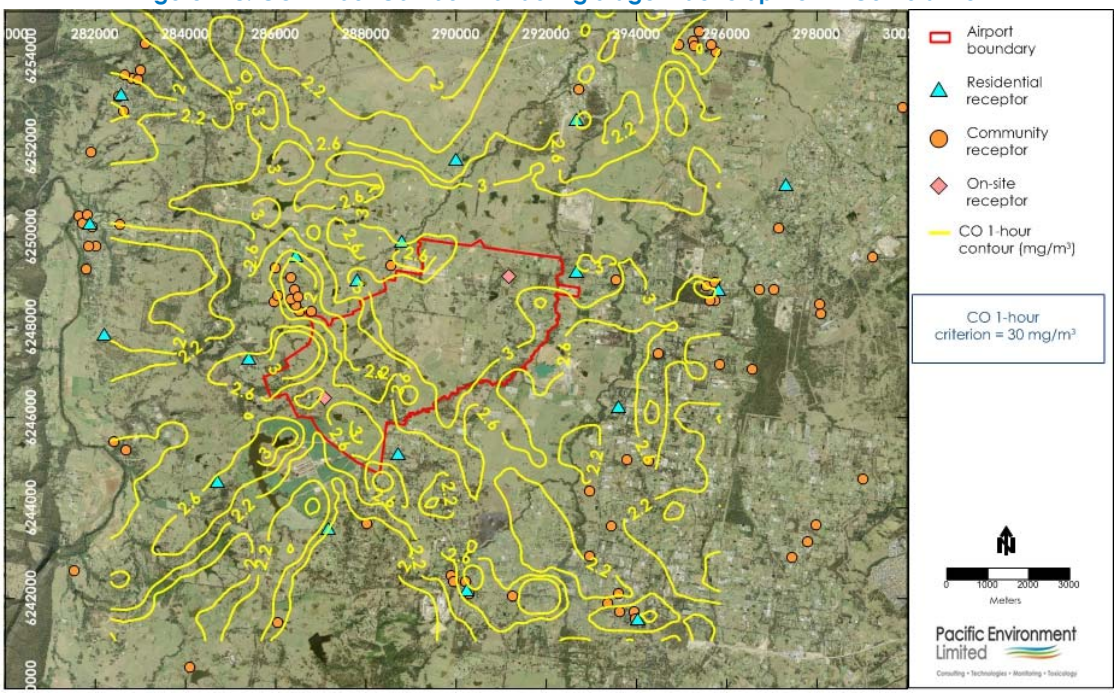
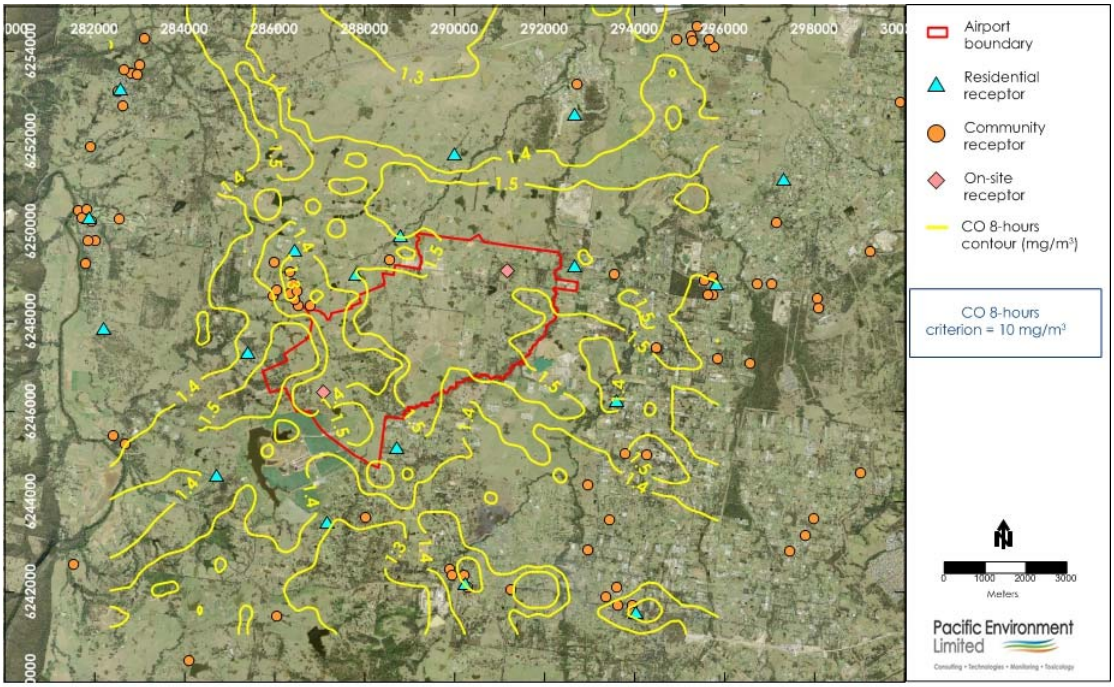


Figure F19: CO 8-hour Contour Plot during Stage 1 development - Cumulative



F.1.5 Sulphur dioxide

Table F5-a: Predicted incremental SO_2 concentrations during Stage 1 development

Receptor	Receptor location	Airport (µg/m³)				Airport + external roadways (µg/m³)			
		10-minute	1-hour	24-hour	Annual	10-minute	1-hour	24-hour	Annual

Ambient objective / Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
R1	Bringelly	28	19	1.8	0.1	29	19	2	0.1
R2	Luddenham	18	12	1.4	0.2	19	12	1.4	0.2
R3	Greendale, Greendale Road	63	42	4.6	0.2	65	43	4.7	0.2
R4	Kemps Creek	24	16	2.2	0.1	24	16	2.3	0.1
R6	Mulgoa	122	81	2.4	0.1	122	81	2.4	0.1
R7	Wallacia	66	44	1.5	0.1	66	44	1.5	0.1
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	64	42	2.2	0.2	64	43	2.2	0.3
R14	Lawson Road, Badgerys Creek	85	56	4.6	0.3	86	57	4.9	0.3
R15	Mersey Rd, Greendale	49	32	3.9	0.3	49	32	3.9	0.3
R17	Luddenham Road	133	88	2.7	0.2	133	88	2.8	0.2
R18	Cnr Adams & Elizabeth Drive	39	26	2.5	0.6	41	27	2.5	0.6
R19	Cnr Adams & Anton Road	102	67	4.4	0.8	102	68	4.5	0.8
R21	Cnr Willowdene Ave and Vicar Park Lane	51	34	3.8	0.2	52	34	3.8	0.2
R22	Rossmore, Victor Ave	25	16	2.4	0.1	25	16	2.5	0.1
R23	Wallacia, Greendale Rd	83	55	2.8	0.1	84	56	2.9	0.1
R24	Badgerys Creek 1 NE	87	57	7.4	0.7	87	57	7.4	0.7
R25	Badgerys Creek 2 SW	84	56	2.2	0.1	85	56	2.2	0.2
R27	Greendale, Dwyer Rd	16	11	0.6	0.1	16	11	0.7	0.1
R30	Rossmore residential	24	16	1.7	0.1	24	16	1.9	0.1
R31	Mt Vernon residential	90	59	4.2	0.1	90	59	4.3	0.2
R34	Emmaus Residential Aged Care	42	28	2.1	0.2	42	28	2.2	0.2
R35	Mamre After School and Vacation Care	47	31	2.1	0.2	47	31	2.1	0.2
R36	Head Start After School Care	28	19	1.6	0.0	29	19	1.8	0.1
R37	Schoolies at Mulgoa	45	30	2.3	0.2	47	31	2.3	0.3
R38	Do-re-mi Day Care Centre	65	43	3.2	0.1	65	43	3.3	0.1
R39	Little Amigos Austral Early Learning Centre	61	40	4.1	0.1	62	41	4.2	0.1
R40	Little Smarties Childcare Centre	42	28	1.8	0.2	42	28	1.8	0.2
R41	The Grove Academy	30	20	1.2	0.1	30	20	1.2	0.1
R42	Horsley Kids	28	19	1.5	0.1	29	19	1.6	0.1
R44	Bringelly Child Care Centre	23	16	2.3	0.1	24	16	2.3	0.1
R46	Clementson Drive Early Educational Centre	37	24	4.1	0.1	37	25	4.2	0.1
R48	Kids Korner West Hoxton Early Learning Centre	51	34	1.2	0.1	52	35	1.2	0.1
R49	Luddenham Child Care Centre	56	37	1.7	0.2	56	37	1.7	0.2
R52	The Frogs Lodge	34	22	2.9	0.1	34	22	3	0.1
R53	Rossmore Community Preschool	28	18	1.6	0.1	28	18	1.8	0.1
R54	Mulgoa Preschool	27	18	1.8	0.1	28	18	1.8	0.1

Receptor	Receptor location	Airport (µg/m³)				Airport + external roadways (µg/m³)			
		10-minute	1-hour	24-hour	Annual	10-minute	1-hour	24-hour	Annual
Ambient objective / Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
R55	Jillys Educational Childcare Centre	32	21	2.1	0.1	32	21	2.2	0.1
R57	Wallacia Progress Hall	28	19	1.6	0.1	28	19	1.6	0.1
R59	Bringelly Community Centre	33	22	1.9	0.1	33	22	2	0.1
R63	Luddenham Progress Hall	60	40	1.2	0.1	61	40	1.2	0.1
R64	Mulgoa Hall	37	25	2.2	0.1	38	25	2.2	0.1
R65	Emmaus Catholic College	45	30	2.2	0.2	46	30	2.2	0.2
R66	University of Sydney Farms	41	27	1.4	0.1	42	28	1.4	0.1
R68	Christadelphian Heritage College Sydney	32	21	2.7	0.1	32	21	2.8	0.1
R69	Mamre Anglican School	48	32	2.2	0.2	48	32	2.2	0.2
R72	Irfan College	10	7	1.3	0.0	11	7	1.4	0.1
R73	Luddenham Public School	38	25	1.7	0.2	39	26	1.7	0.2
R74	Kemps Creek Public School	52	34	2.9	0.1	54	36	3	0.1
R75	Trinity Catholic Primary School	45	30	2.0	0.2	45	30	2	0.2
R76	Bringelly Public School	45	30	1.8	0.1	46	30	2	0.2
R78	Mulgoa Public School	36	24	1.9	0.1	36	24	2	0.1
R79	Rossmore Public School	22	14	1.7	0.1	22	15	1.8	0.1
R80	Wallacia Public School	29	19	1.3	0.1	30	20	1.3	0.1
R82	Bellfield College - Junior Campus	33	22	1.8	0.1	33	22	1.9	0.1
R84	Bringelly Park	32	21	1.9	0.1	32	21	2	0.1
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	27	18	1.9	0.1	27	18	2	0.1
R86	Blaxland Crossing Reserve	36	24	1.3	0.1	37	24	1.3	0.1
R87	Bill Anderson Reserve	22	14	2.4	0.1	22	14	2.5	0.1
R88	Kemps Creek Nature Reserve	29	19	1.0	0.1	29	19	1.1	0.1
R91	Western Sydney Parklands	59	39	2.2	0.1	59	39	2.3	0.1
R93	Rossmore Grange	56	37	1.9	0.1	58	38	1.9	0.1
R94	Freeburn Park	54	36	2.0	0.2	56	37	2	0.2
R95	Overett Reserve	49	33	2.4	0.1	49	33	2.6	0.2
R97	Mulgoa Park	38	25	2.2	0.1	39	26	2.2	0.1
R98	Wallacia Bowling and Recreation Club	28	19	1.5	0.1	29	19	1.6	0.1
R99	Hubertus Country Club	73	48	4.3	0.8	73	48	4.3	0.8
R100	Sugarloaf Cobbitty Equestrian Club	84	56	2.3	0.1	85	56	2.3	0.1
R102	Panthers Wallacia	49	32	1.5	0.1	49	33	1.5	0.1
R103	Twin Creeks Golf and Country Club	56	37	1.6	0.2	56	37	1.6	0.2

Receptor	Receptor location	Airport (µg/m³)				Airport + external roadways (µg/m³)			
		10-minute	1-hour	24-hour	Annual	10-minute	1-hour	24-hour	Annual
Ambient objective / Assessment criterion		*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*	*n/a*
R104	Sydney International Shooting Centre	36	24	2.6	0.1	37	24	2.9	0.1
R108	Luddenham Showground	33	22	1.6	0.2	33	22	1.7	0.2
R109	Kemps Creek Sporting and Bowling Club	29	19	1.9	0.1	30	20	2.1	0.1
R110	St James Luddenham	33	22	1.9	0.3	35	23	1.9	0.3
R111	Lin Ying temple	49	32	4.6	0.1	49	32	4.6	0.1
R112	Vat Ketanak Khmer Kampuchea Krom	24	16	1.8	0.1	24	16	1.9	0.1
R114	Anglican Church Sydney Diocese	19	13	1.7	0.1	19	13	1.8	0.1
R115	Anglican Parish of Mulgoa	29	19	1.6	0.1	29	19	1.7	0.1
R117	Bringelly Vineyard Church	161	106	2.0	0.1	161	107	2.1	0.1
R118	Free Church of Tonga	61	41	3.5	0.1	62	41	3.6	0.1
R120	Our Lady Queen of Peace	32	21	1.4	0.1	32	21	1.5	0.1
R122	St Anthony	40	26	3.9	0.1	40	27	4	0.1
R123	St Marys Church	52	35	2.3	0.1	53	35	2.3	0.1
R124	Wallacia Christian Church	30	20	1.5	0.1	30	20	1.6	0.1
R126	St Francis Xavier Church	70	46	4.3	0.1	70	46	4.4	0.1
R127	Luddenham Uniting Church	41	27	1.0	0.1	41	27	1	0.1
R130	Hopewood Health Retreat	25	16	1.7	0.1	25	16	1.8	0.1
R131	Science of the Soul Study Centre	25	16	1.9	0.1	25	16	2.1	0.1
R132	Bringelly shops	62	41	1.9	0.1	62	41	2	0.1
R134	Kemps Creek shops	31	20	2.3	0.1	31	21	2.4	0.1
R135	Luddenham shops	31	20	2.0	0.3	31	20	2	0.3
R136	Mulgoa shops	59	39	2.5	0.1	60	40	2.5	0.1
R137	Rossmore shops	22	15	1.8	0.1	22	15	1.9	0.1
R138	Wallacia Shops	32	21	1.5	0.1	32	21	1.5	0.1
R140	Holy Family Catholic Primary and Church	32	21	2.4	0.3	32	21	2.4	0.3
R141	Edmund Rice Retreat and Conference Centre	44	29	1.8	0.1	44	29	1.8	0.1

Figure F20: SO_2 1-hour Contour Plot during Stage 1 development –Airport

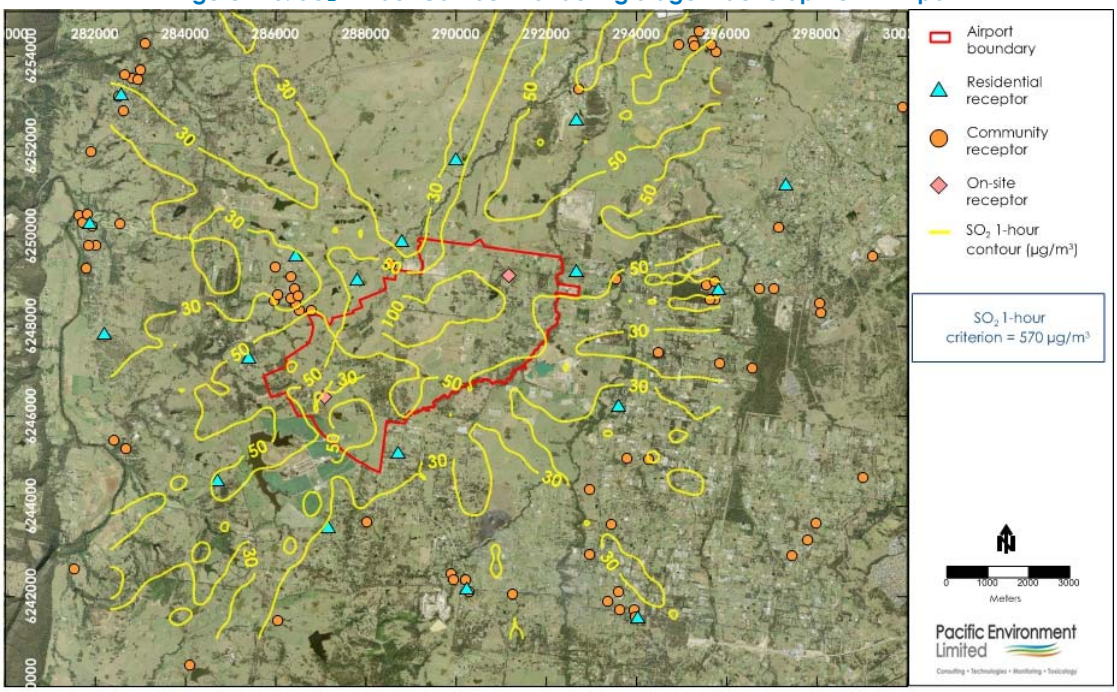


Figure F21: SO_2 24-hour Maximum Contour Plot during Stage 1 development – Airport

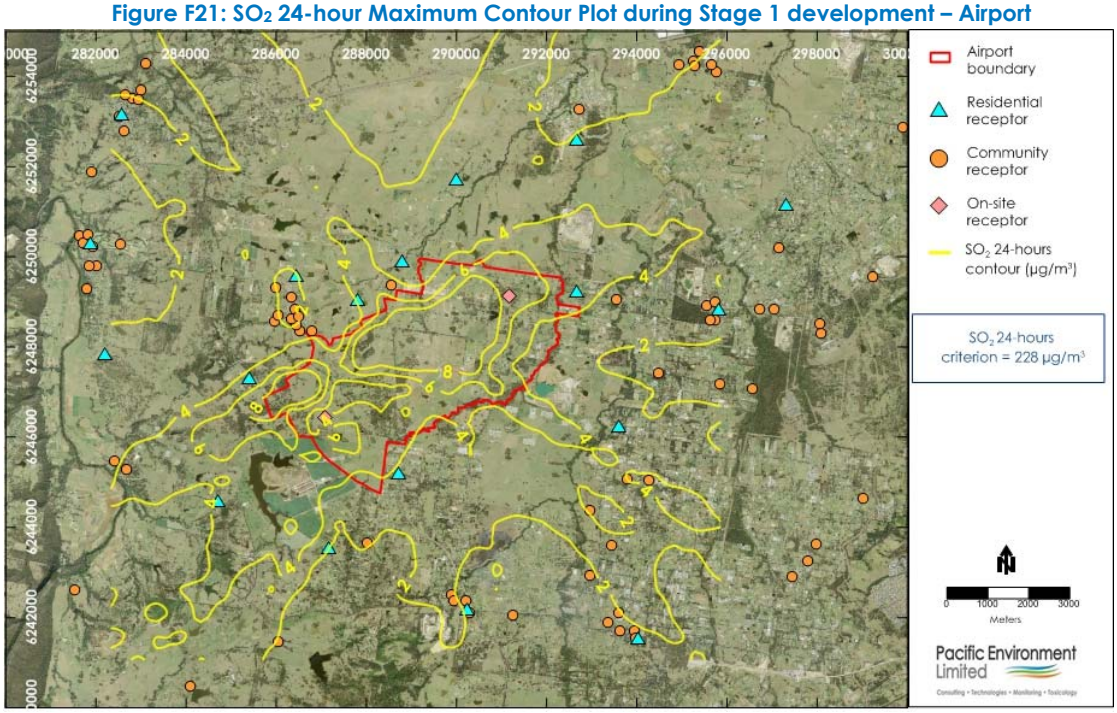


Figure F22: SO_2 Annual Average Contour Plot during Stage 1 development - Airport

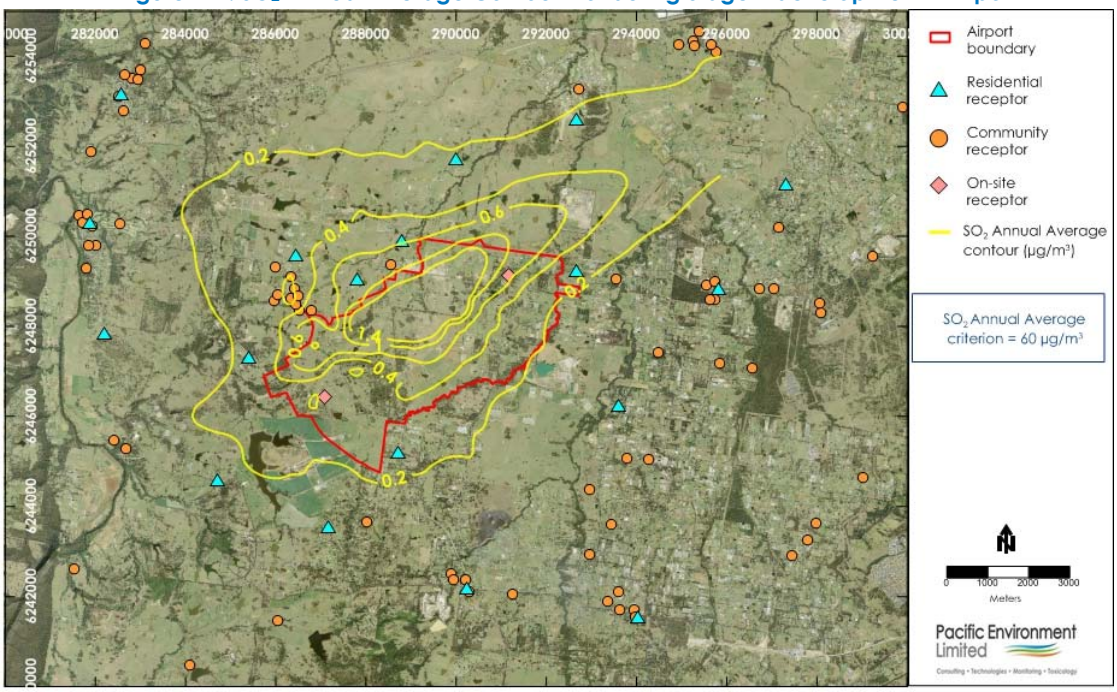


Figure F23: SO_2 1-hour Contour Plot during Stage 1 development – Airport + External Roadways

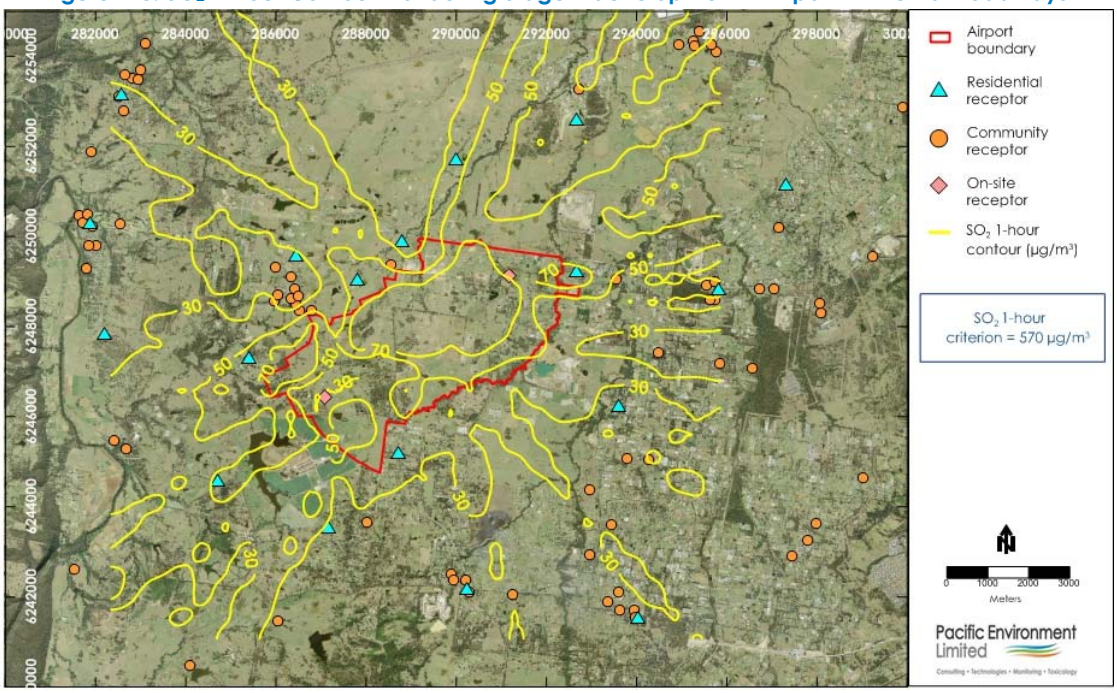


Figure F24: SO_2 24-hours Contour Plot during Stage 1 development – Airport + External Roadways

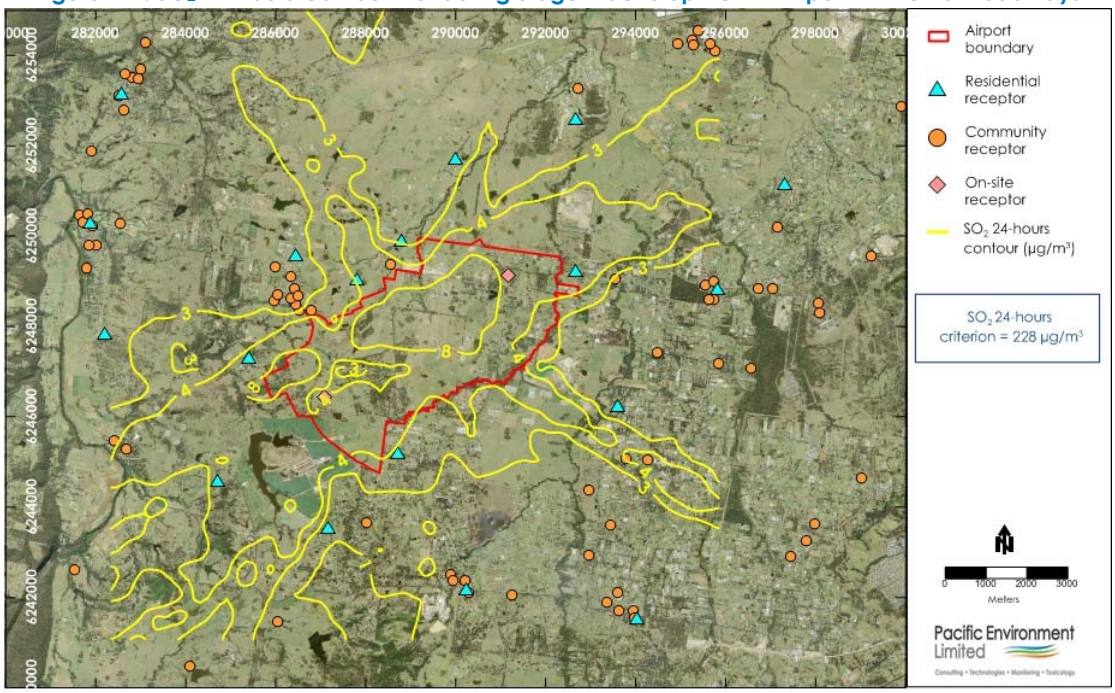


Figure F25: SO_2 Annual Average Contour Plot during Stage 1 development – Airport + External Roadways

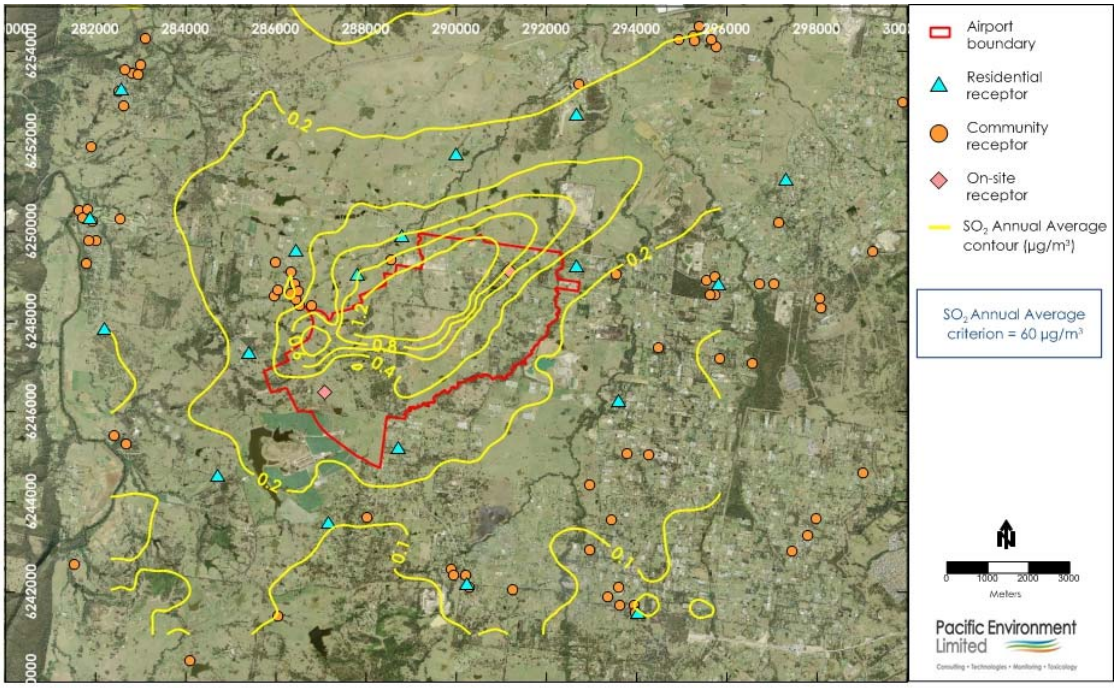


Table F5-b: Predicted cumulative SO_2 concentrations during Stage 1 development.

Receptor	Receptor location	Cumulative (µg/m³)			
		10-minute	1-hour	24-hour	Annual
Ambient objective / Assessment criterion		*712*	*570*	*228*	*60*
R1	Bringelly	109	53	11.9	1.3
R2	Luddenham	99	46	11.3	1.4
R3	Greendale, Greendale Road	145	77	14.6	1.4
R4	Kemps Creek	104	50	12.2	1.3
R6	Mulgoa	202	115	12.3	1.3
R7	Wallacia	146	78	11.4	1.3
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	144	77	12.1	1.5
R14	Lawson Road, Badgerys Creek	166	91	14.8	1.5
R15	Mersey Rd, Greendale	129	66	13.8	1.5
R17	Luddenham Road	213	122	12.7	1.4
R18	Cnr Adams & Elizabeth Drive	121	61	12.4	1.8
R19	Cnr Adams & Anton Road	182	102	14.4	2.0
R21	Cnr Willowdene Ave and Vicar Park Lane	132	68	13.7	1.4
R22	Rossmore, Victor Ave	105	50	12.4	1.3
R23	Wallacia, Greendale Rd	164	90	12.8	1.3
R24	Badgerys Creek 1 NE	167	91	17.3	1.9
R25	Badgerys Creek 2 SW	165	90	12.1	1.4
R27	Greendale, Dwyer Rd	96	45	10.6	1.3
R30	Rossmore residential	104	50	11.8	1.3
R31	Mt Vernon residential	170	93	14.2	1.4
R34	Emmaus Residential Aged Care	122	62	12.1	1.4

Receptor	Receptor location	Cumulative (µg/m³)			
		10-minute	1-hour	24-hour	Annual
Ambient objective / Assessment criterion		*712*	*570*	*228*	*60*
R35	Mamre After School and Vacation Care	127	65	12.0	1.4
R36	Head Start After School Care	109	53	11.7	1.3
R37	Schoolies at Mulgoa	127	65	12.2	1.5
R38	Do-re-mi Day Care Centre	145	77	13.2	1.3
R39	Little Amigos Austral Early Learning Centre	142	75	14.1	1.3
R40	Little Smarties Childcare Centre	122	62	11.7	1.4
R41	The Grove Academy	110	54	11.1	1.3
R42	Horsley Kids	109	53	11.5	1.3
R44	Bringelly Child Care Centre	104	50	12.2	1.3
R46	Clementson Drive Early Educational Centre	117	59	14.1	1.3
R48	Kids Korner West Hoxton Early Learning Centre	132	69	11.1	1.3
R49	Luddenham Child Care Centre	136	71	11.6	1.4
R52	The Frogs Lodge	114	56	12.9	1.3
R53	Rossmore Community Preschool	108	52	11.7	1.3
R54	Mulgoa Preschool	108	52	11.7	1.3
R55	Jillys Educational Childcare Centre	112	55	12.1	1.3
R57	Wallacia Progress Hall	108	53	11.5	1.3
R59	Bringelly Community Centre	113	56	11.9	1.3
R63	Luddenham Progress Hall	141	74	11.1	1.3
R64	Mulgoa Hall	118	59	12.1	1.3
R65	Emmaus Catholic College	126	64	12.1	1.4
R66	University of Sydney Farms	122	62	11.3	1.3
R68	Christadelphian Heritage College Sydney	112	55	12.7	1.3
R69	Mamre Anglican School	128	66	12.1	1.4
R72	Irfan College	91	41	11.3	1.3
R73	Luddenham Public School	119	60	11.6	1.4
R74	Kemps Creek Public School	134	70	12.9	1.3
R75	Trinity Catholic Primary School	125	64	11.9	1.4
R76	Bringelly Public School	126	64	11.9	1.4
R78	Mulgoa Public School	116	58	11.9	1.3
R79	Rossmore Public School	102	49	11.7	1.3
R80	Wallacia Public School	110	54	11.2	1.3
R82	Bellfield College - Junior Campus	113	56	11.8	1.3
R84	Bringelly Park	112	55	11.9	1.3
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	107	52	11.9	1.3
R86	Blaxland Crossing Reserve	117	58	11.2	1.3
R87	Bill Anderson Reserve	102	48	12.4	1.3
R88	Kemps Creek Nature Reserve	109	53	11.0	1.3
R91	Western Sydney Parklands	139	73	12.2	1.3
R93	Rossmore Grange	138	72	11.8	1.3
R94	Freeburn Park	136	71	11.9	1.4
R95	Overett Reserve	129	67	12.5	1.4

Receptor	Receptor location	Cumulative (µg/m³)			
		10-minute	1-hour	24-hour	Annual
Ambient objective / Assessment criterion		*712*	*570*	*228*	*60*
R97	Mulgoa Park	119	60	12.1	1.3
R98	Wallacia Bowling and Recreation Club	109	53	11.5	1.3
R99	Hubertus Country Club	153	82	14.2	2.0
R100	Sugarloaf Cobbitty Equestrian Club	165	90	12.2	1.3
R102	Panthers Wallacia	129	67	11.4	1.3
R103	Twin Creeks Golf and Country Club	136	71	11.5	1.4
R104	Sydney International Shooting Centre	117	58	12.8	1.3
R108	Luddenham Showground	113	56	11.6	1.4
R109	Kemps Creek Sporting and Bowling Club	110	54	12.0	1.3
R110	St James Luddenham	115	57	11.8	1.5
R111	Lin Ying temple	129	66	14.5	1.3
R112	Vat Ketanak Khmer Kampuchea Krom	104	50	11.8	1.3
R114	Anglican Church Sydney Diocese	99	47	11.7	1.3
R115	Anglican Parish of Mulgoa	109	53	11.6	1.3
R117	Bringelly Vineyard Church	241	141	12.0	1.3
R118	Free Church of Tonga	142	75	13.5	1.3
R120	Our Lady Queen of Peace	112	55	11.4	1.3
R122	St Anthony	120	61	13.9	1.3
R123	St Marys Church	133	69	12.2	1.3
R124	Wallacia Christian Church	110	54	11.5	1.3
R126	St Francis Xavier Church	150	80	14.3	1.3
R127	Luddenham Uniting Church	121	61	10.9	1.3
R130	Hopewood Health Retreat	105	50	11.7	1.3
R131	Science of the Soul Study Centre	105	50	12.0	1.3
R132	Bringelly shops	142	75	11.9	1.3
R134	Kemps Creek shops	111	55	12.3	1.3
R135	Luddenham shops	111	54	11.9	1.5
R136	Mulgoa shops	140	74	12.4	1.3
R137	Rossmore shops	102	49	11.8	1.3
R138	Wallacia Shops	112	55	11.4	1.3
R140	Holy Family Catholic Primary and Church	112	55	12.3	1.5
R141	Edmund Rice Retreat and Conference Centre	124	63	11.7	1.3

Figure F26: SO_2 1-hour Contour Plot during Stage 1 development - Cumulative

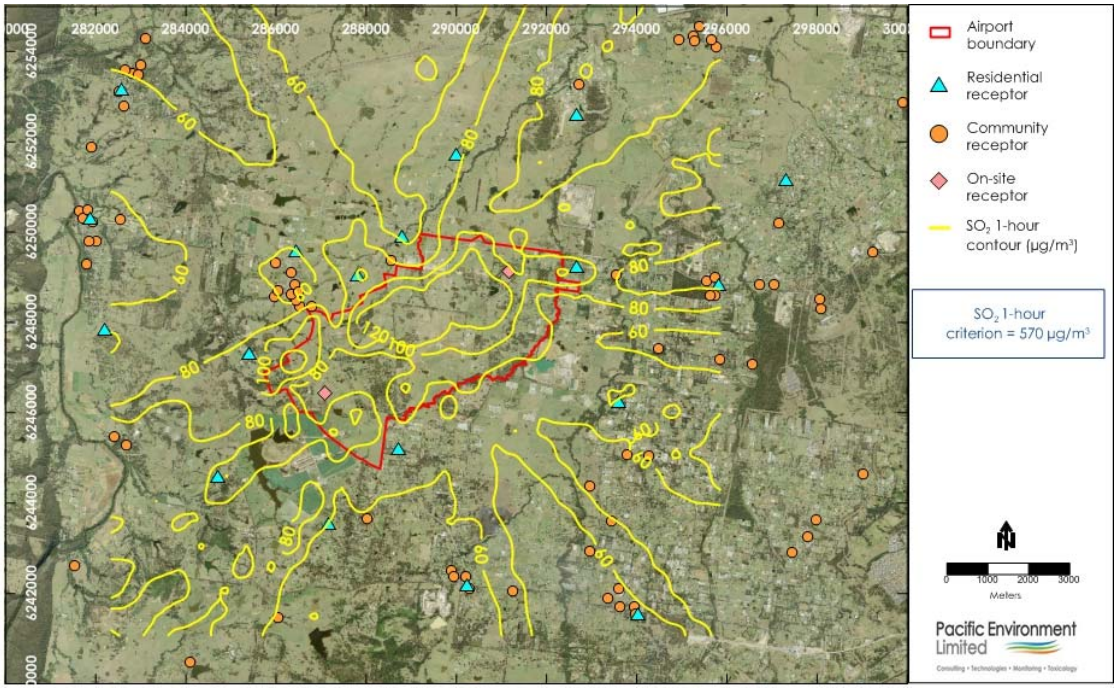


Figure F27: SO_2 24-hours Contour Plot during Stage 1 development - Cumulative

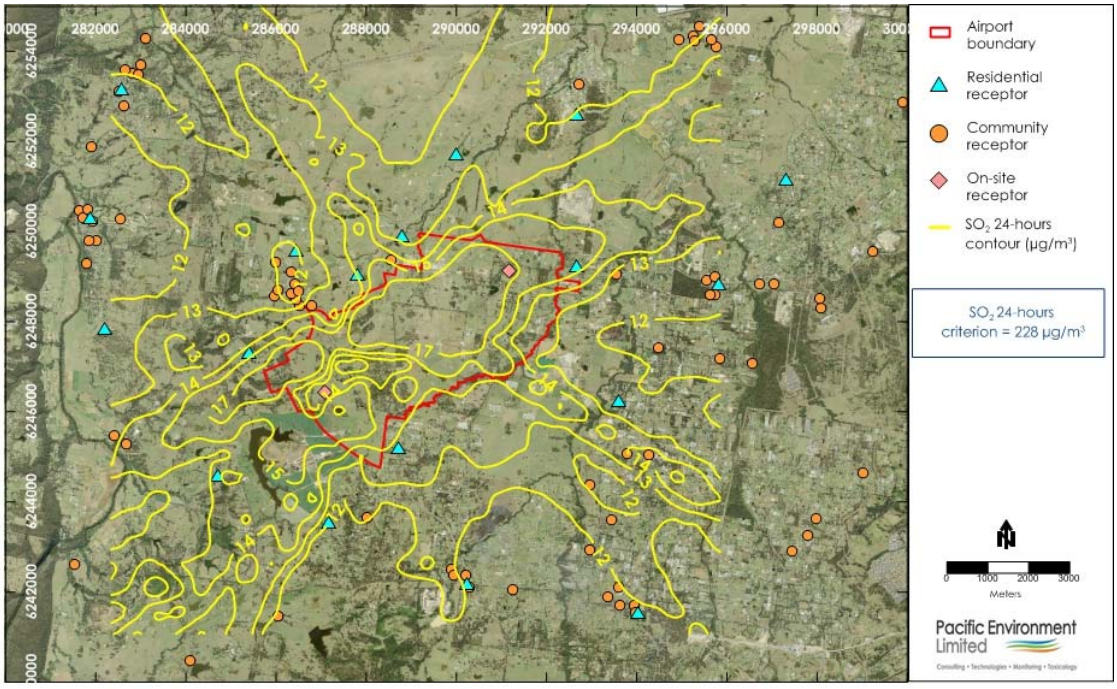
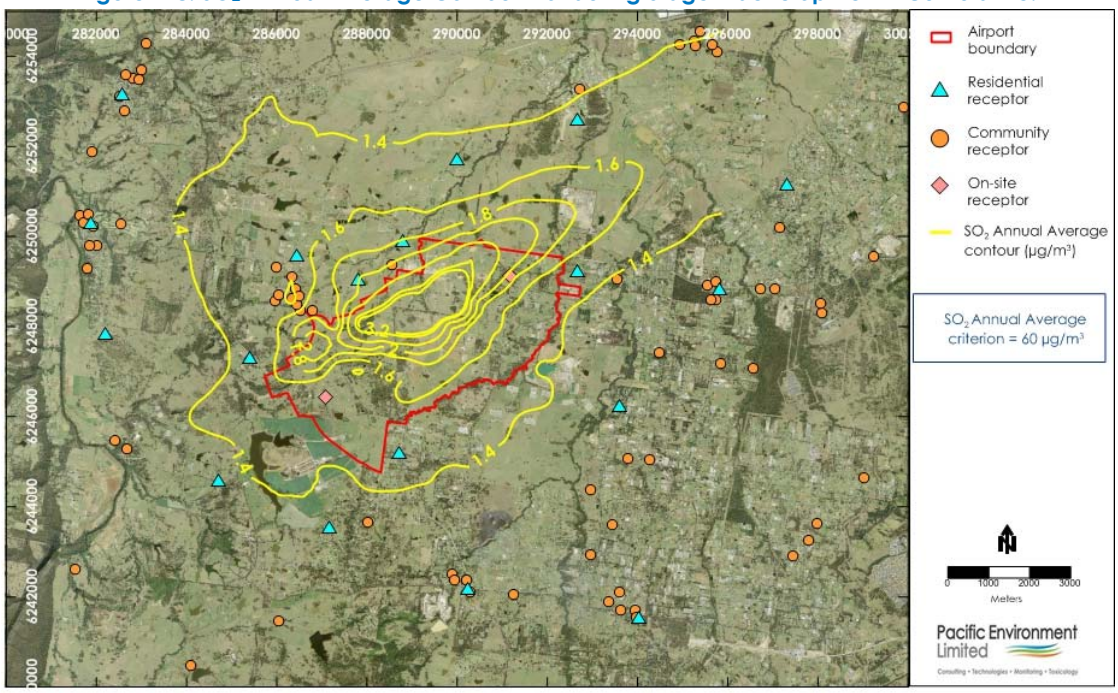


Figure F28: SO_2 Annual Average Contour Plot during Stage 1 development - Cumulative.



F.1.6 Air toxics

Table F6-a: Predicted incremental 99.9th percentile 1-hour average air toxic concentrations during Stage 1 development

Receptor ID	Receptor description	Airport (µg/m³)				Airport + external roadways (µg/m³)			
		Benzene	Toluene	Xylene	Formaldehyde	Benzene	Toluene	Xylene	Formaldehyde
NSW EPA criterion		*29*	*360*	*180*	*20*	*29*	*360*	*180*	*20*
R1	Bringelly	0.1	0.0	0.0	0.7	2.0	0.8	0.5	14.9
R2	Luddenham	0.2	0.1	0.1	1.5	1.3	0.5	0.3	9.3
R3	Greendale, Greendale Road	0.2	0.1	0.0	1.2	1.2	0.5	0.3	8.8
R4	Kemps Creek	0.1	0.0	0.0	0.9	2.3	0.9	0.6	17.1
R6	Mulgoa	0.1	0.0	0.0	0.7	0.8	0.3	0.2	5.6
R7	Wallacia	0.1	0.0	0.0	0.7	0.6	0.2	0.2	4.3
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.1	0.0	0.0	0.8	1.0	0.4	0.3	7.4
R14	Lawson Road, Badgerys Creek	0.3	0.1	0.1	2.2	1.3	0.5	0.3	9.3
R15	Mersey Rd, Greendale	0.3	0.1	0.1	1.8	1.5	0.6	0.4	11.0
R17	Luddenham Road	0.1	0.1	0.0	1.0	0.9	0.3	0.2	6.2
R18	Cnr Adams & Elizabeth Drive	0.2	0.1	0.0	1.4	1.3	0.5	0.4	9.8
R19	Cnr Adams & Anton Road	0.4	0.1	0.1	2.6	2.2	0.8	0.6	16.1
R21	Cnr Willowdene Ave and Vicar Park Lane	0.2	0.1	0.1	1.5	1.1	0.4	0.3	8.1
R22	Rossmore, Victor Ave	0.2	0.1	0.0	1.1	0.8	0.3	0.2	5.8

Receptor ID	Receptor description	Airport (µg/m³)				Airport + external roadways (µg/m³)			
		Benzene	Toluene	Xylene	Formaldehyde	Benzene	Toluene	Xylene	Formaldehyde
NSW EPA criterion		*29*	*360*	*180*	*20*	*29*	*360*	*180*	*20*
R23	Wallacia, Greendale Rd	0.1	0.0	0.0	0.9	0.6	0.2	0.2	4.6
R24	Badgerys Creek 1 NE	0.6	0.2	0.2	4.2	3.1	1.2	0.8	22.6
R25	Badgerys Creek 2 SW	0.3	0.1	0.1	2.0	1.8	0.7	0.5	13.5
R27	Greendale, Dwyer Rd	0.1	0.1	0.0	1.0	0.9	0.4	0.2	6.8
R30	Rossmore residential	0.1	0.0	0.0	0.5	1.6	0.6	0.4	11.8
R31	Mt Vernon residential	0.2	0.1	0.1	1.4	1.0	0.4	0.3	7.0
R34	Emmaus Residential Aged Care	0.1	0.0	0.0	0.9	0.9	0.3	0.2	6.7
R35	Mamre After School and Vacation Care	0.1	0.0	0.0	0.7	0.8	0.3	0.2	5.8
R36	Head Start After School Care	0.1	0.0	0.0	0.6	1.4	0.5	0.4	10.4
R37	Schoolies at Mulgoa	0.3	0.1	0.1	2.0	1.2	0.4	0.3	8.6
R38	Do-re-mi Day Care Centre	0.1	0.0	0.0	0.9	0.9	0.3	0.2	6.4
R39	Little Amigos Austral Early Learning Centre	0.2	0.1	0.0	1.3	0.7	0.3	0.2	5.3
R40	Little Smarties Childcare Centre	0.1	0.0	0.0	0.7	0.9	0.3	0.2	6.6
R41	The Grove Academy	0.1	0.0	0.0	0.4	0.6	0.2	0.2	4.3
R42	Horsley Kids	0.1	0.0	0.0	0.8	0.7	0.3	0.2	5.1
R44	Bringelly Child Care Centre	0.2	0.1	0.1	1.7	1.3	0.5	0.3	9.2
R46	Clementson Drive Early Educational Centre	0.2	0.1	0.1	1.5	0.9	0.3	0.2	6.4
R48	Kids Korner West Hoxton Early Learning Centre	0.0	0.0	0.0	0.4	0.9	0.3	0.2	6.2
R49	Luddenham Child Care Centre	0.2	0.1	0.1	1.7	1.2	0.5	0.3	9.1
R52	The Frogs Lodge	0.1	0.0	0.0	0.9	0.7	0.3	0.2	5.3
R53	Rossmore Community Preschool	0.1	0.0	0.0	0.5	1.3	0.5	0.4	9.8
R54	Mulgoa Preschool	0.1	0.0	0.0	0.6	0.6	0.2	0.2	4.6
R55	Jillys Educational Childcare Centre	0.1	0.0	0.0	0.8	0.6	0.2	0.2	4.5
R57	Wallacia Progress Hall	0.1	0.0	0.0	0.7	0.6	0.2	0.2	4.5
R59	Bringelly Community Centre	0.1	0.0	0.0	0.8	1.5	0.6	0.4	10.8
R63	Luddenham Progress Hall	0.3	0.1	0.1	2.3	1.1	0.4	0.3	7.9
R64	Mulgoa Hall	0.1	0.0	0.0	0.6	0.8	0.3	0.2	5.7
R65	Emmaus Catholic College	0.1	0.0	0.0	0.7	0.8	0.3	0.2	5.5
R66	University of Sydney Farms	0.1	0.0	0.0	0.6	0.7	0.3	0.2	5.5
R68	Christadelphian Heritage College Sydney	0.1	0.1	0.0	1.1	1.0	0.4	0.3	7.3
R69	Mamre Anglican	0.1	0.0	0.0	0.7	0.8	0.3	0.2	6.0

Receptor ID	Receptor description	Airport (µg/m³)				Airport + external roadways (µg/m³)			
		Benzene	Toluene	Xylene	Formaldehyde	Benzene	Toluene	Xylene	Formaldehyde
NSW EPA criterion		*29*	*360*	*180*	*20*	*29*	*360*	*180*	*20*
	School								
R72	Irfan College	0.1	0.0	0.0	0.7	3.2	1.2	0.9	23.6
R73	Luddenham Public School	0.3	0.1	0.1	2.5	1.4	0.5	0.4	10.1
R74	Kemps Creek Public School	0.2	0.1	0.0	1.2	0.9	0.4	0.2	6.8
R75	Trinity Catholic Primary School	0.1	0.0	0.0	0.7	0.8	0.3	0.2	5.9
R76	Bringelly Public School	0.1	0.0	0.0	0.8	1.7	0.7	0.5	12.7
R78	Mulgoa Public School	0.1	0.0	0.0	0.6	0.8	0.3	0.2	5.6
R79	Rossmore Public School	0.1	0.0	0.0	0.5	2.2	0.8	0.6	15.9
R80	Wallacia Public School	0.1	0.0	0.0	0.6	0.6	0.2	0.2	4.4
R82	Bellfield College - Junior Campus	0.1	0.0	0.0	0.5	0.7	0.3	0.2	5.4
R84	Bringelly Park	0.1	0.0	0.0	0.8	1.1	0.4	0.3	8.1
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	0.1	0.0	0.0	0.7	0.6	0.2	0.2	4.4
R86	Blaxland Crossing Reserve	0.1	0.0	0.0	0.6	0.6	0.2	0.1	4.1
R87	Bill Anderson Reserve	0.1	0.1	0.0	1.0	1.5	0.6	0.4	10.8
R88	Kemps Creek Nature Reserve	0.0	0.0	0.0	0.3	0.6	0.2	0.2	4.7
R91	Western Sydney Parklands	0.1	0.0	0.0	0.8	0.9	0.4	0.2	6.7
R93	Rossmore Grange	0.1	0.0	0.0	0.7	0.6	0.2	0.2	4.5
R94	Freeburn Park	0.4	0.1	0.1	2.6	1.4	0.5	0.4	10.4
R95	Overett Reserve	0.1	0.0	0.0	0.9	0.9	0.3	0.2	6.5
R97	Mulgoa Park	0.1	0.0	0.0	0.6	0.8	0.3	0.2	5.9
R98	Wallacia Bowling and Recreation Club	0.1	0.0	0.0	0.7	0.6	0.2	0.2	4.3
R99	Hubertus Country Club	0.3	0.1	0.1	2.0	1.7	0.6	0.5	12.4
R100	Sugarloaf Cobbitty Equestrian Club	0.1	0.0	0.0	0.7	0.9	0.3	0.2	6.3
R102	Panthers Wallacia	0.1	0.0	0.0	0.7	0.6	0.2	0.2	4.6
R103	Twin Creeks Golf and Country Club	0.1	0.0	0.0	0.6	0.7	0.3	0.2	5.4
R104	Sydney International Shooting Centre	0.1	0.1	0.0	1.0	1.5	0.6	0.4	10.7
R108	Luddenham Showground	0.1	0.0	0.0	0.9	1.1	0.4	0.3	8.0
R109	Kemps Creek Sporting and Bowling Club	0.1	0.0	0.0	0.7	2.3	0.9	0.6	16.6
R110	St James Luddenham	0.3	0.1	0.1	1.8	1.3	0.5	0.4	9.7
R111	Lin Ying temple	0.2	0.1	0.1	1.8	1.5	0.6	0.4	11.3
R112	Vat Ketanak Khmer Kampuchea Krom	0.1	0.0	0.0	0.5	0.6	0.2	0.2	4.7

Receptor ID	Receptor description	Airport (µg/m³)				Airport + external roadways (µg/m³)			
		Benzene	Toluene	Xylene	Formaldehyde	Benzene	Toluene	Xylene	Formaldehyde
NSW EPA criterion		*29*	*360*	*180*	*20*	*29*	*360*	*180*	*20*
R114	Anglican Church Sydney Diocese	0.1	0.0	0.0	0.5	1.1	0.4	0.3	8.1
R115	Anglican Parish of Mulgoa	0.1	0.0	0.0	0.6	0.6	0.2	0.2	4.5
R117	Bringelly Vineyard Church	0.1	0.0	0.0	0.9	1.2	0.5	0.3	9.1
R118	Free Church of Tonga	0.1	0.1	0.0	1.0	1.0	0.4	0.3	7.3
R120	Our Lady Queen of Peace	0.1	0.0	0.0	0.5	1.3	0.5	0.3	9.5
R122	St Anthony	0.1	0.1	0.0	1.1	0.9	0.3	0.2	6.5
R123	St Marys Church	0.1	0.0	0.0	0.7	0.7	0.3	0.2	5.1
R124	Wallacia Christian Church	0.1	0.0	0.0	0.7	0.6	0.2	0.2	4.3
R126	St Francis Xavier Church	0.2	0.1	0.0	1.2	0.9	0.4	0.2	6.8
R127	Luddenham Uniting Church	0.2	0.1	0.1	1.8	0.9	0.4	0.2	6.8
R130	Hopewood Health Retreat	0.1	0.0	0.0	0.6	0.6	0.2	0.2	4.5
R131	Science of the Soul Study Centre	0.1	0.0	0.0	0.7	2.0	0.8	0.5	14.5
R132	Bringelly shops	0.1	0.0	0.0	0.8	1.2	0.4	0.3	8.5
R134	Kemps Creek shops	0.1	0.0	0.0	1.0	1.0	0.4	0.3	7.6
R135	Luddenham shops	0.3	0.1	0.1	2.0	1.4	0.5	0.4	10.2
R136	Mulgoa shops	0.1	0.0	0.0	0.7	0.7	0.3	0.2	5.4
R137	Rossmore shops	0.1	0.0	0.0	0.5	1.6	0.6	0.4	11.9
R138	Wallacia Shops	0.1	0.0	0.0	0.7	0.6	0.2	0.2	4.2
R140	Holy Family Catholic Primary and Church	0.2	0.1	0.1	1.4	1.1	0.4	0.3	8.4
R141	Edmund Rice Retreat and Conference Centre	0.1	0.0	0.0	0.6	0.7	0.3	0.2	5.3

Figure F29: Benzene 99.9th percentile 1-hour average Contour Plot during Stage 1 development – Airport

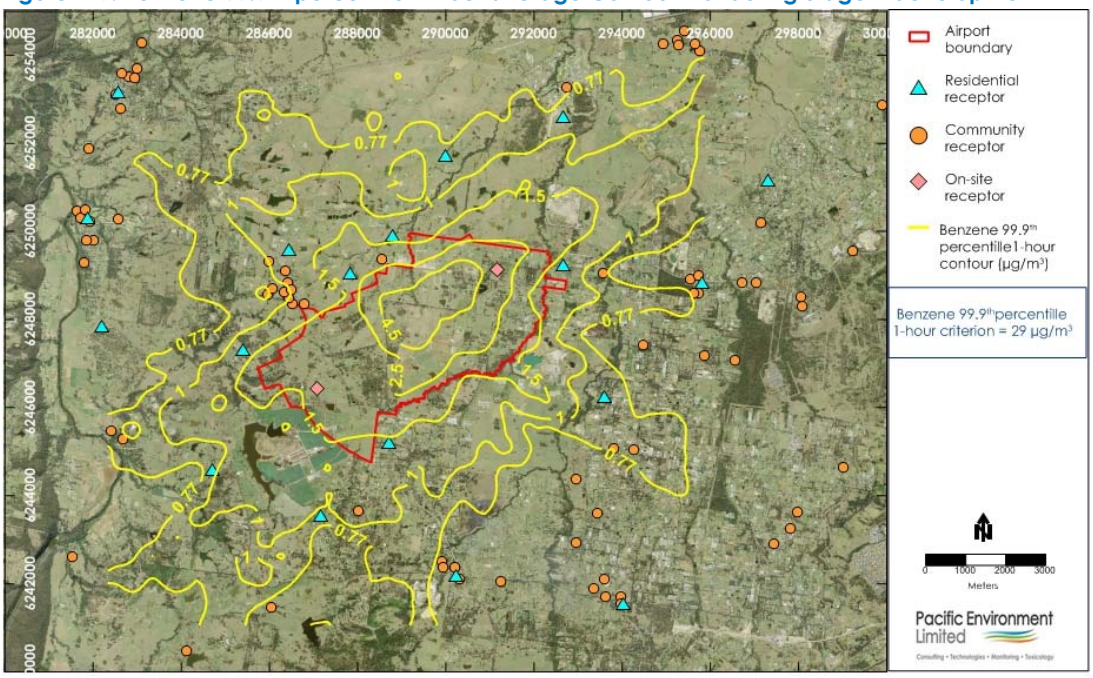


Figure F30: Toluene 99.9th percentile 1-hour average Contour Plot during Stage 1 development – Airport

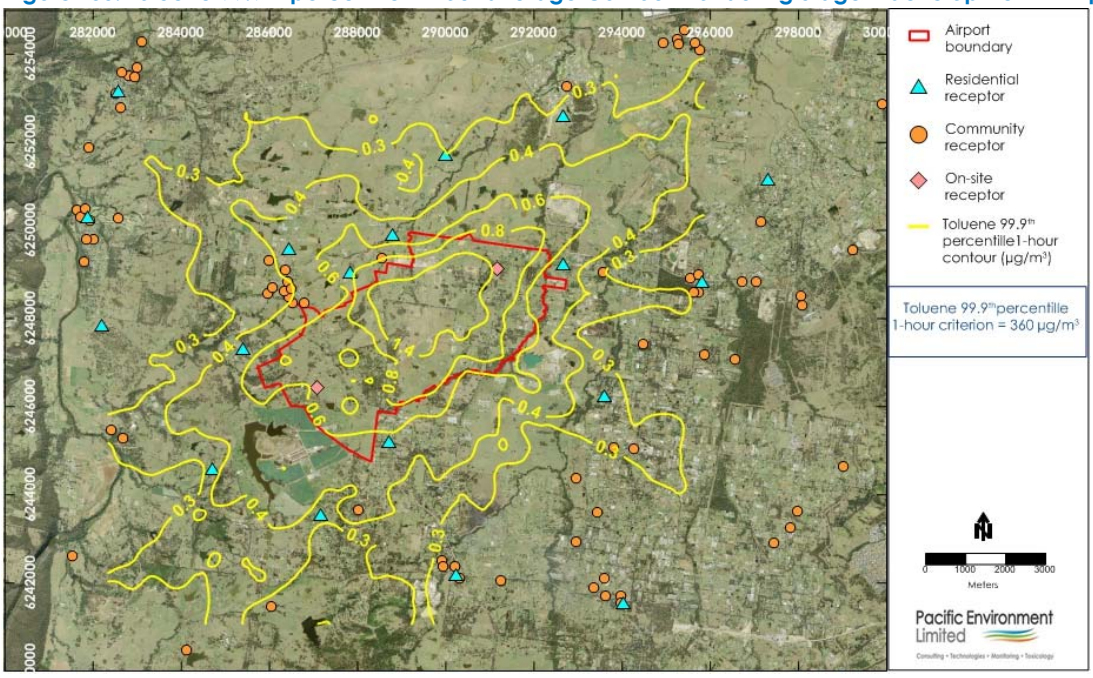


Figure F31: Xylene 99.9th percentile 1-hour average Contour Plot during Stage 1 development – Airport

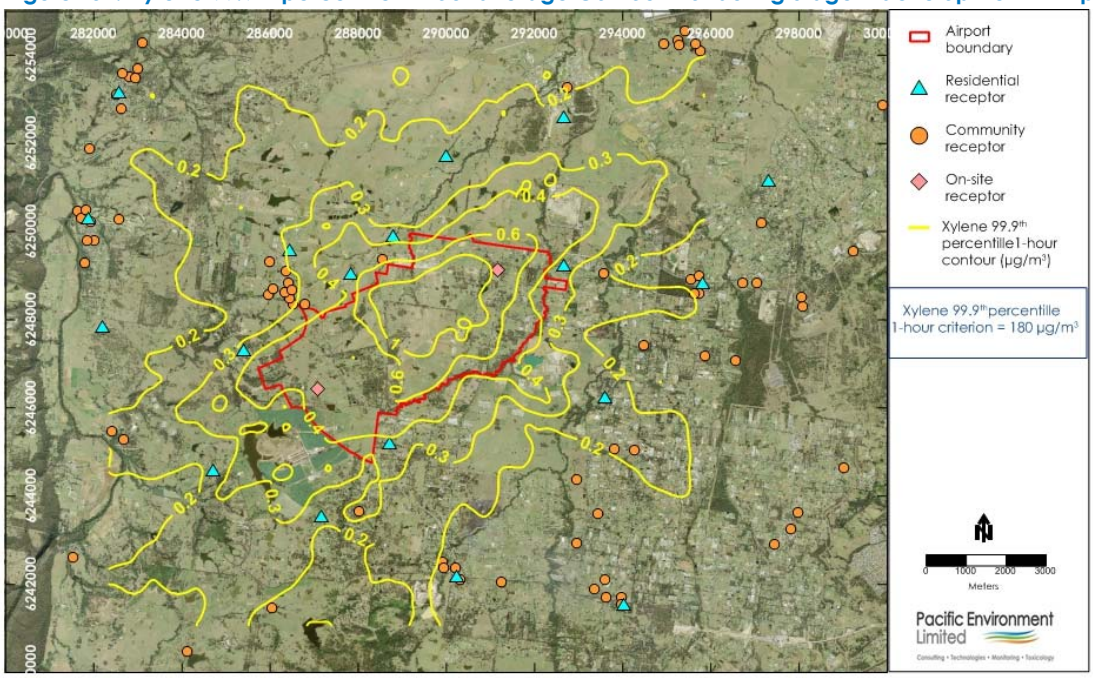


Figure F32: Formaldehyde 99.9th percentile 1-hour average Contour Plot during Stage 1 development – Airport

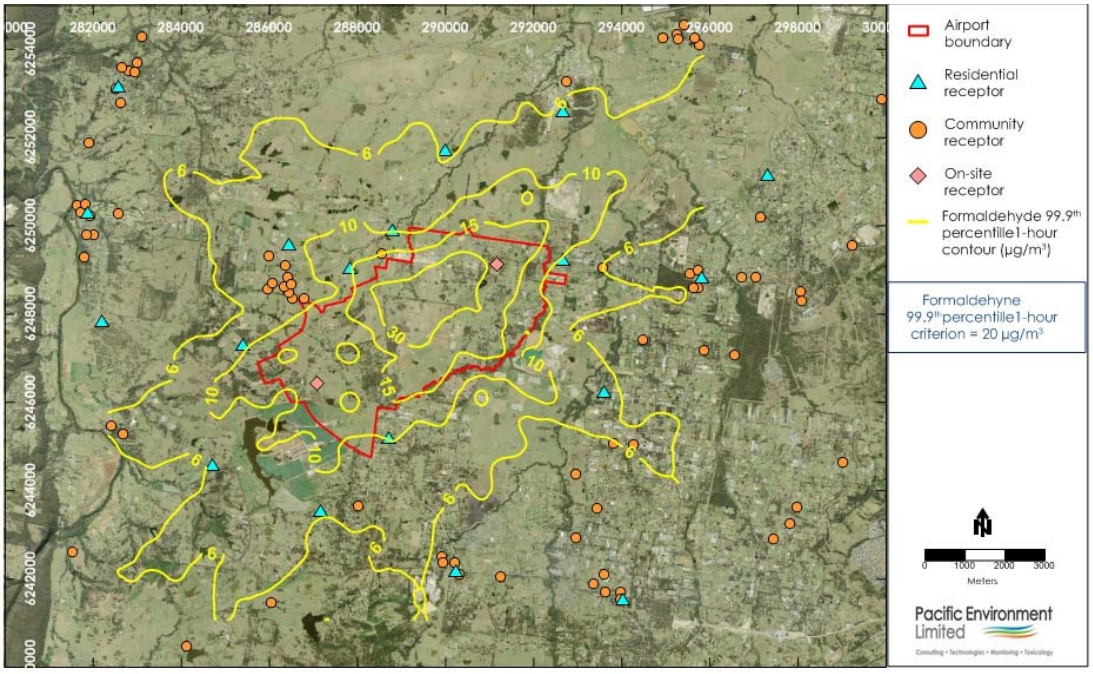


Figure F33: Benzene 99.9th percentile 1-hour average Contour Plot during Stage 1 development – Airport + External Roadways

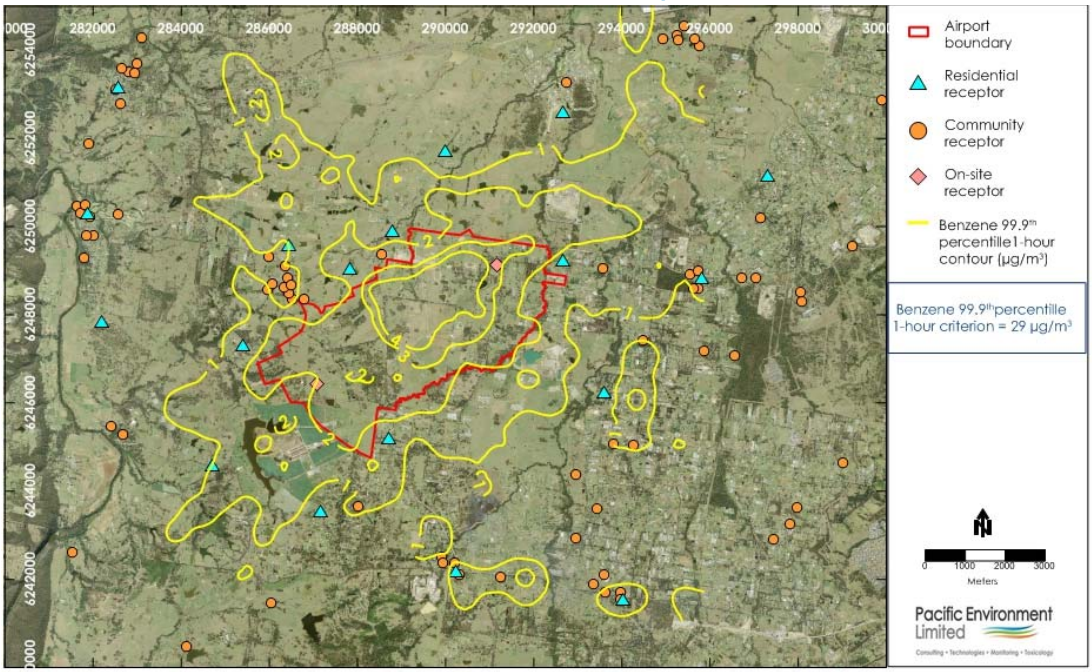


Figure F34: Toluene 99.9th percentile 1-hour average Contour Plot during Stage 1 development – Airport + External Roadways

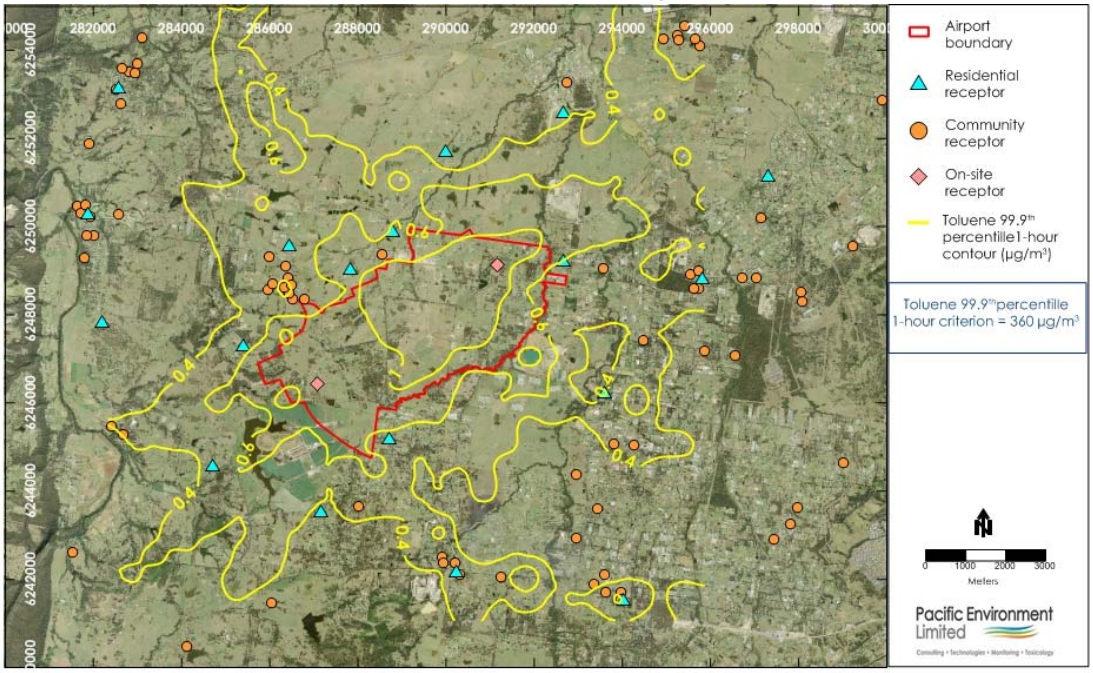


Figure F35: Xylene 99.9th percentile 1-hour average Contour Plot during Stage 1 development – Airport + External Roadways

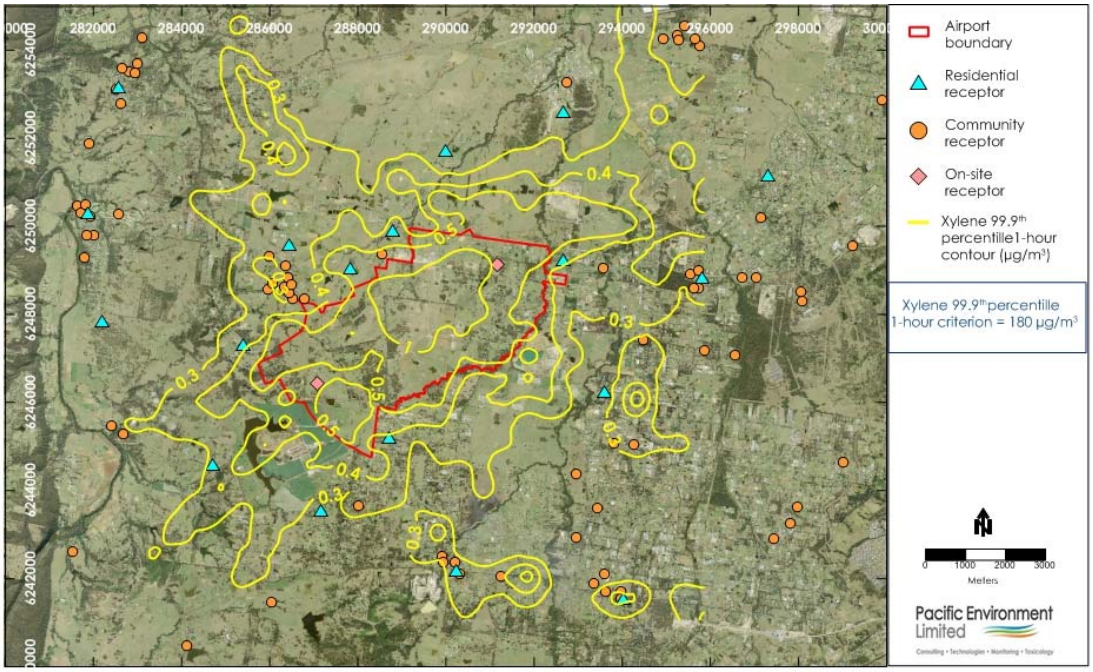


Figure F36: Formaldehyde 99.9th percentile 1-hour average Contour Plot during Stage 1 development – Airport + External Roadways

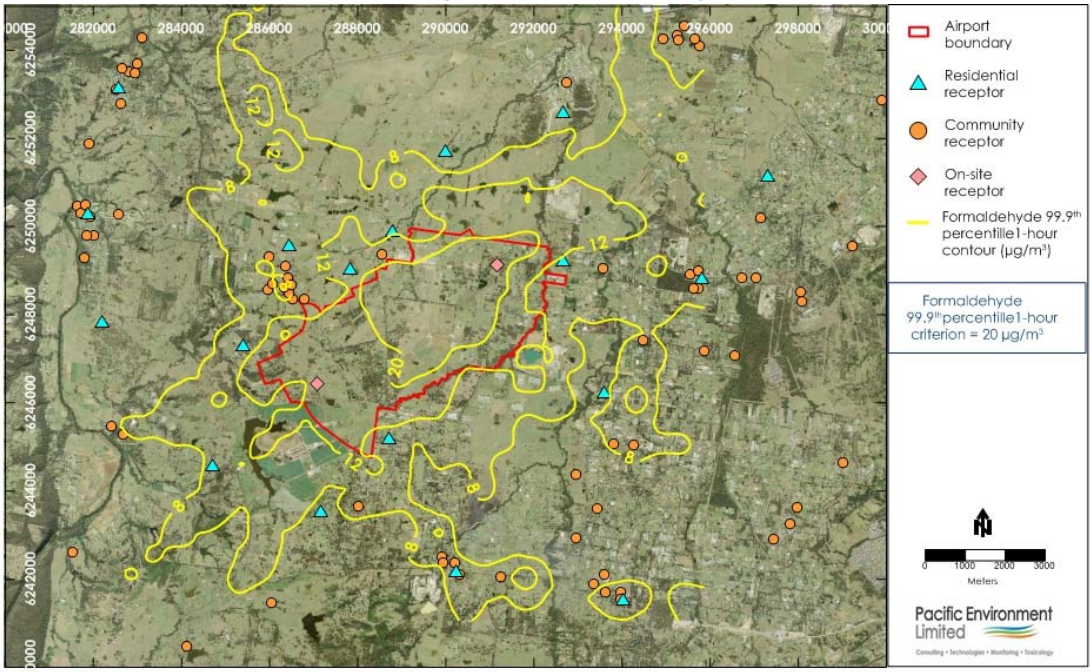


Table F6-a: Predicted incremental 24-hour average air toxic concentrations during Stage 1 development

Receptor	Receptor location	Airport (µg/m³)			Airport + external roadways (µg/m³)		
		Toluene	Xylene	Formaldehyde	Toluene	Xylene	Formaldehyde
NEPM-AAQ investigation level		*4,160*	*1,170*	*853*	*4,160*	*1,170*	*853*
R1	Bringelly	0.0	0.0	0.9	0.1	0.1	2.1
R2	Luddenham	0.1	0.1	1.6	0.1	0.1	1.5
R3	Greendale, Greendale Road	0.1	0.1	1.5	0.1	0.1	1.6
R4	Kemps Creek	0.1	0.0	1.1	0.2	0.1	3.4
R6	Mulgoa	0.0	0.0	0.8	0.1	0.0	1.0
R7	Wallacia	0.0	0.0	0.8	0.0	0.0	0.9
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.0	0.0	0.8	0.1	0.0	1.2
R14	Lawson Road, Badgerys Creek	0.1	0.1	2.4	0.1	0.1	2.7
R15	Mersey Rd, Greendale	0.1	0.1	2.0	0.1	0.1	1.8
R17	Luddenham Road	0.1	0.0	1.1	0.1	0.0	1.1
R18	Cnr Adams & Elizabeth Drive	0.1	0.1	1.5	0.1	0.1	1.4
R19	Cnr Adams & Anton Road	0.1	0.1	2.7	0.2	0.1	3.0
R21	Cnr Willowdene Ave and Vicar Park Lane	0.1	0.1	1.7	0.1	0.1	1.5
R22	Rossmore, Victor Ave	0.1	0.0	1.2	0.1	0.1	1.4
R23	Wallacia, Greendale Rd	0.1	0.0	1.1	0.1	0.0	1.1
R24	Badgerys Creek 1 NE	0.2	0.2	4.6	0.3	0.2	5.1
R25	Badgerys Creek 2 SW	0.1	0.1	2.1	0.1	0.1	2.4
R27	Greendale, Dwyer Rd	0.1	0.0	1.0	0.1	0.0	1.3
R30	Rossmore residential	0.0	0.0	0.5	0.1	0.1	2.4
R31	Mt Vernon residential	0.1	0.1	1.4	0.1	0.1	1.5
R34	Emmaus Residential Aged Care	0.1	0.0	1.1	0.1	0.0	1.3
R35	Mamre After School and Vacation Care	0.0	0.0	0.7	0.1	0.0	1.0
R36	Head Start After School Care	0.0	0.0	0.6	0.1	0.1	2.1
R37	Schoolies at Mulgoa	0.1	0.1	2.5	0.1	0.1	2.2
R38	Do-re-mi Day Care Centre	0.1	0.0	1.0	0.1	0.0	1.3
R39	Little Amigos Austral Early Learning Centre	0.1	0.1	1.6	0.1	0.1	1.6
R40	Little Smarties Childcare Centre	0.0	0.0	0.8	0.1	0.0	1.1
R41	The Grove Academy	0.0	0.0	0.5	0.1	0.0	1.1
R42	Horsley Kids	0.0	0.0	0.8	0.0	0.0	0.8
R44	Bringelly Child Care Centre	0.1	0.1	1.9	0.1	0.1	1.7
R46	Clementson Drive Early Educational Centre	0.1	0.1	1.7	0.1	0.1	1.6
R48	Kids Korner West Hoxton Early Learning Centre	0.0	0.0	0.4	0.1	0.0	1.1

Receptor	Receptor location	Airport (µg/m³)			Airport + external roadways (µg/m³)		
		Toluene	Xylene	Formaldehyde	Toluene	Xylene	Formaldehyde
NEPM-AAQ investigation level		*4,160*	*1,170*	*853*	*4,160*	*1,170*	*853*
R49	Luddenham Child Care Centre	0.1	0.1	2.1	0.1	0.1	1.9
R52	The Frogs Lodge	0.1	0.0	1.0	0.1	0.0	1.2
R53	Rossmore Community Preschool	0.0	0.0	0.5	0.1	0.1	1.8
R54	Mulgoa Preschool	0.0	0.0	0.6	0.0	0.0	0.8
R55	Jillys Educational Childcare Centre	0.0	0.0	0.9	0.1	0.1	1.6
R57	Wallacia Progress Hall	0.0	0.0	0.7	0.0	0.0	0.9
R59	Bringelly Community Centre	0.0	0.0	0.9	0.1	0.1	1.9
R63	Luddenham Progress Hall	0.1	0.1	2.5	0.1	0.1	2.1
R64	Mulgoa Hall	0.0	0.0	0.6	0.0	0.0	0.9
R65	Emmaus Catholic College	0.0	0.0	0.8	0.1	0.0	1.1
R66	University of Sydney Farms	0.0	0.0	0.7	0.0	0.0	0.9
R68	Christadelphian Heritage College Sydney	0.1	0.0	1.2	0.1	0.1	2.2
R69	Mamre Anglican School	0.0	0.0	0.7	0.1	0.0	1.0
R72	Irfan College	0.0	0.0	0.8	0.2	0.2	4.4
R73	Luddenham Public School	0.1	0.1	2.8	0.1	0.1	2.4
R74	Kemps Creek Public School	0.1	0.0	1.3	0.1	0.1	2.0
R75	Trinity Catholic Primary School	0.0	0.0	0.7	0.1	0.0	1.0
R76	Bringelly Public School	0.0	0.0	0.9	0.2	0.1	2.9
R78	Mulgoa Public School	0.0	0.0	0.6	0.0	0.0	0.8
R79	Rossmore Public School	0.0	0.0	0.5	0.1	0.1	1.6
R80	Wallacia Public School	0.0	0.0	0.7	0.0	0.0	0.8
R82	Bellfield College - Junior Campus	0.0	0.0	0.5	0.1	0.0	1.0
R84	Bringelly Park	0.0	0.0	0.9	0.1	0.1	1.7
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	0.1	0.0	1.0	0.0	0.0	0.9
R86	Blaxland Crossing Reserve	0.0	0.0	0.7	0.0	0.0	0.8
R87	Bill Anderson Reserve	0.1	0.0	1.3	0.1	0.1	1.6
R88	Kemps Creek Nature Reserve	0.0	0.0	0.3	0.1	0.0	1.1
R91	Western Sydney Parklands	0.0	0.0	0.8	0.1	0.1	1.9
R93	Rossmore Grange	0.0	0.0	0.8	0.1	0.1	1.4
R94	Freeburn Park	0.2	0.1	3.4	0.2	0.1	2.9
R95	Overett Reserve	0.1	0.0	1.0	0.1	0.1	1.5
R97	Mulgoa Park	0.0	0.0	0.6	0.0	0.0	0.9
R98	Wallacia Bowling and Recreation Club	0.0	0.0	0.7	0.0	0.0	0.8
R99	Hubertus Country Club	0.1	0.1	2.0	0.1	0.1	2.0
R100	Sugarloaf Cobbitty Equestrian Club	0.0	0.0	0.7	0.1	0.0	1.1

Receptor	Receptor location	Airport (µg/m³)			Airport + external roadways (µg/m³)		
		Toluene	Xylene	Formaldehyde	Toluene	Xylene	Formaldehyde
NEPM-AAQ investigation level		*4,160*	*1,170*	*853*	*4,160*	*1,170*	*853*
R102	Panthers Wallacia	0.0	0.0	0.8	0.0	0.0	0.9
R103	Twin Creeks Golf and Country Club	0.0	0.0	0.6	0.0	0.0	0.7
R104	Sydney International Shooting Centre	0.1	0.0	1.1	0.2	0.1	3.1
R108	Luddenham Showground	0.1	0.0	1.0	0.1	0.0	1.1
R109	Kemps Creek Sporting and Bowling Club	0.0	0.0	0.8	0.2	0.1	3.4
R110	St James Luddenham	0.1	0.1	2.2	0.1	0.1	1.9
R111	Lin Ying temple	0.1	0.1	2.2	0.1	0.1	2.1
R112	Vat Ketanak Khmer Kampuchea Krom	0.0	0.0	0.5	0.1	0.0	1.1
R114	Anglican Church Sydney Diocese	0.0	0.0	0.5	0.1	0.0	1.3
R115	Anglican Parish of Mulgoa	0.0	0.0	0.6	0.0	0.0	0.8
R117	Bringelly Vineyard Church	0.0	0.0	0.9	0.1	0.1	1.6
R118	Free Church of Tonga	0.1	0.0	1.2	0.1	0.0	1.3
R120	Our Lady Queen of Peace	0.0	0.0	0.6	0.1	0.1	1.5
R122	St Anthony	0.1	0.0	1.1	0.1	0.1	1.6
R123	St Marys Church	0.0	0.0	0.7	0.0	0.0	0.9
R124	Wallacia Christian Church	0.0	0.0	0.8	0.1	0.0	1.0
R126	St Francis Xavier Church	0.1	0.0	1.2	0.1	0.1	1.4
R127	Luddenham Uniting Church	0.1	0.1	2.3	0.1	0.1	1.9
R130	Hopewood Health Retreat	0.0	0.0	0.6	0.0	0.0	0.8
R131	Science of the Soul Study Centre	0.0	0.0	0.8	0.2	0.1	3.4
R132	Bringelly shops	0.0	0.0	0.9	0.1	0.1	1.9
R134	Kemps Creek shops	0.1	0.0	1.2	0.1	0.1	1.7
R135	Luddenham shops	0.1	0.1	2.2	0.1	0.1	1.9
R136	Mulgoa shops	0.0	0.0	0.8	0.1	0.0	1.0
R137	Rossmore shops	0.0	0.0	0.5	0.1	0.1	1.8
R138	Wallacia Shops	0.0	0.0	0.8	0.0	0.0	0.9
R140	Holy Family Catholic Primary and Church	0.1	0.1	1.7	0.1	0.1	1.5
R141	Edmund Rice Retreat and Conference Centre	0.0	0.0	0.7	0.0	0.0	0.7

Figure F37: Xylene 24-hour Contour Plot during Stage 1 development – Airport

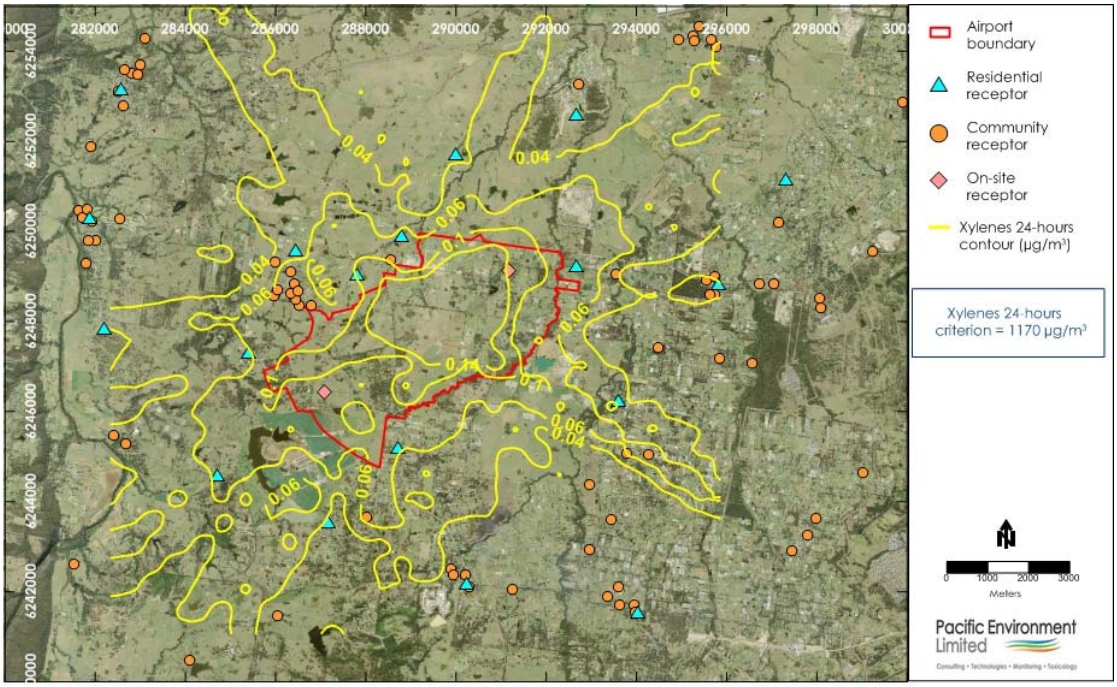


Figure F38: Toluene 24-hour Contour Plot during Stage 1 development – Airport

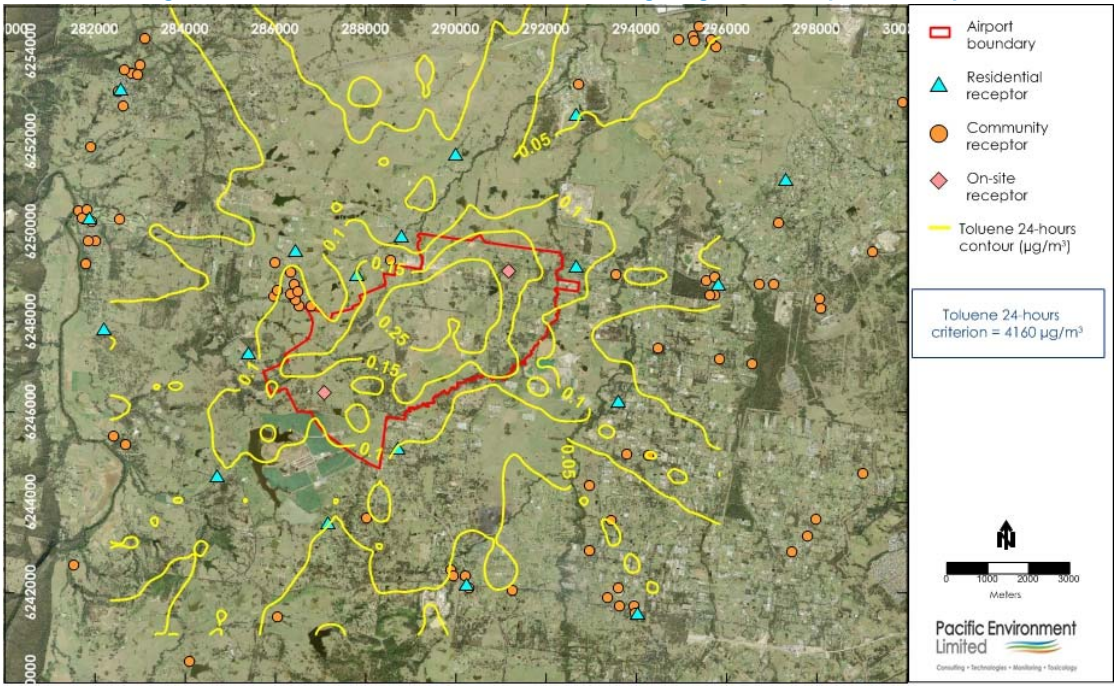


Figure F39: Formaldehyde 24-hour Contour Plot during Stage 1 development - Airport

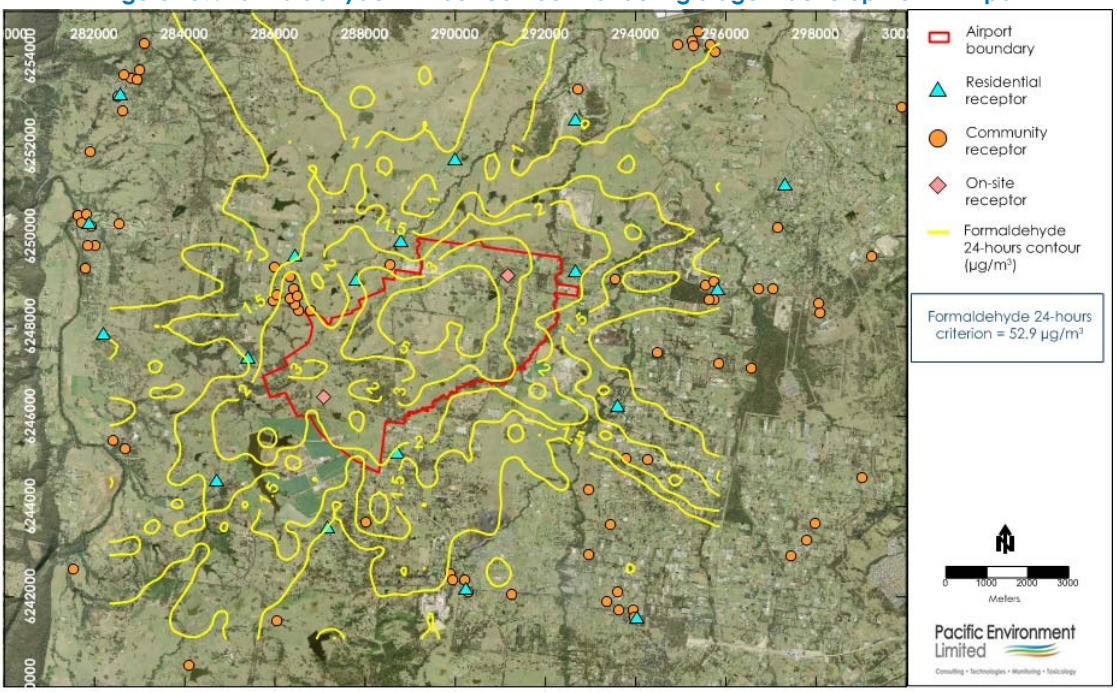


Figure F41: Xylene 24-hour Contour Plot during Stage 1 development – Airport + External Roadways

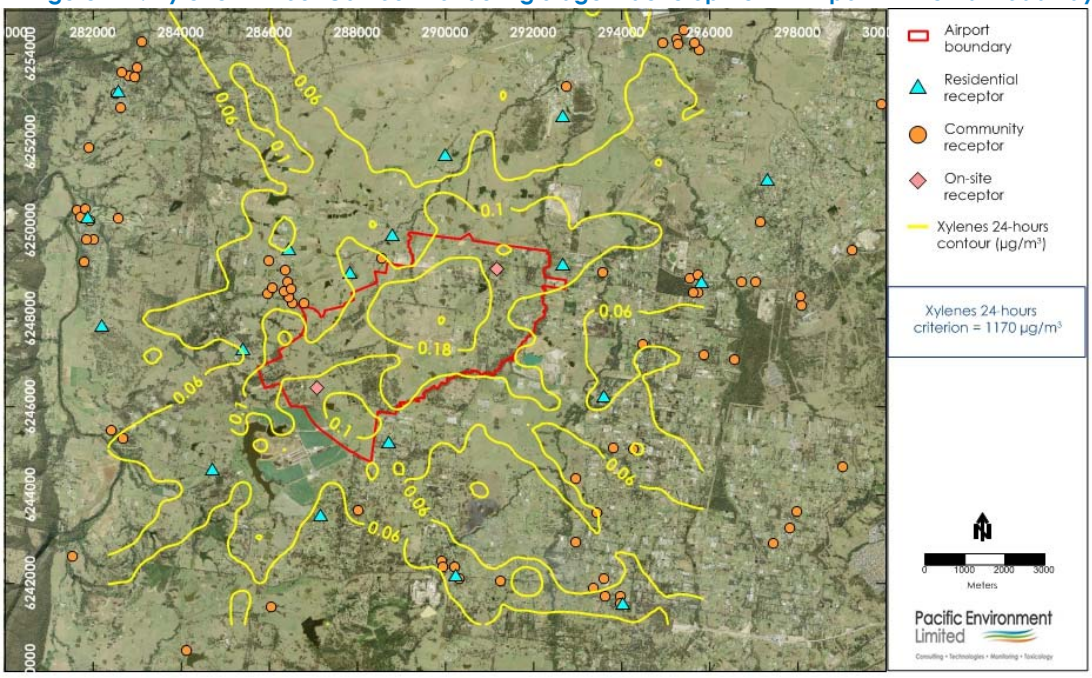


Figure F42: Toluene 24-hour Contour Plot during Stage 1 development – Airport + External Roadways

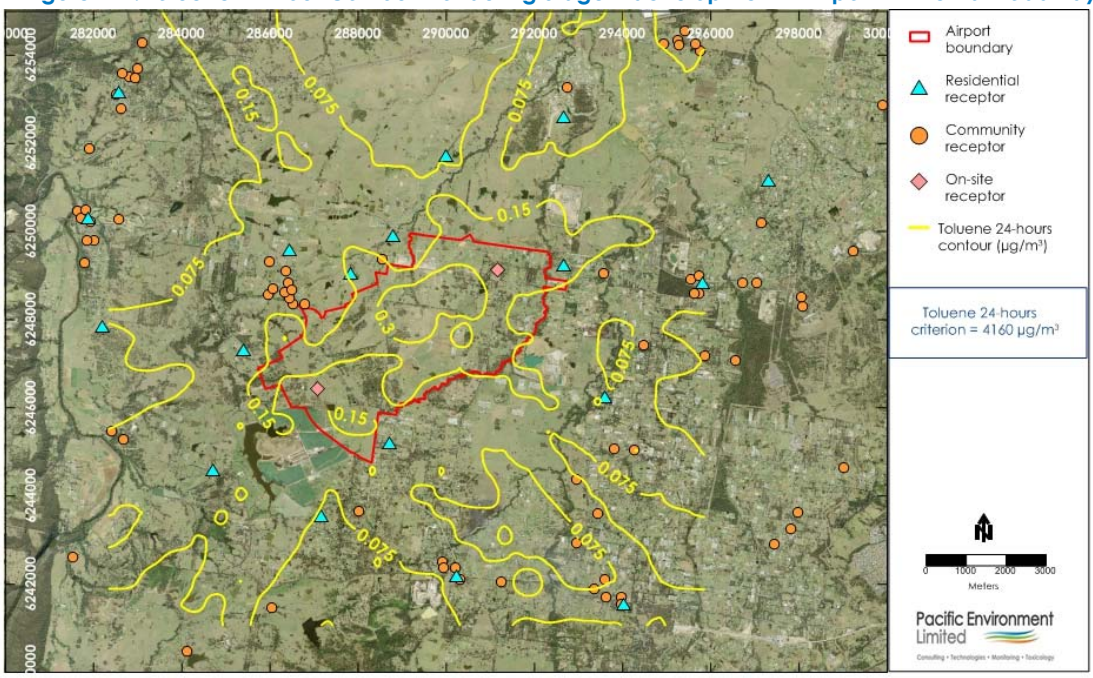


Figure F43: Formaldehyde 24-hour Contour Plot during Stage 1 development – Airport + External Roadways

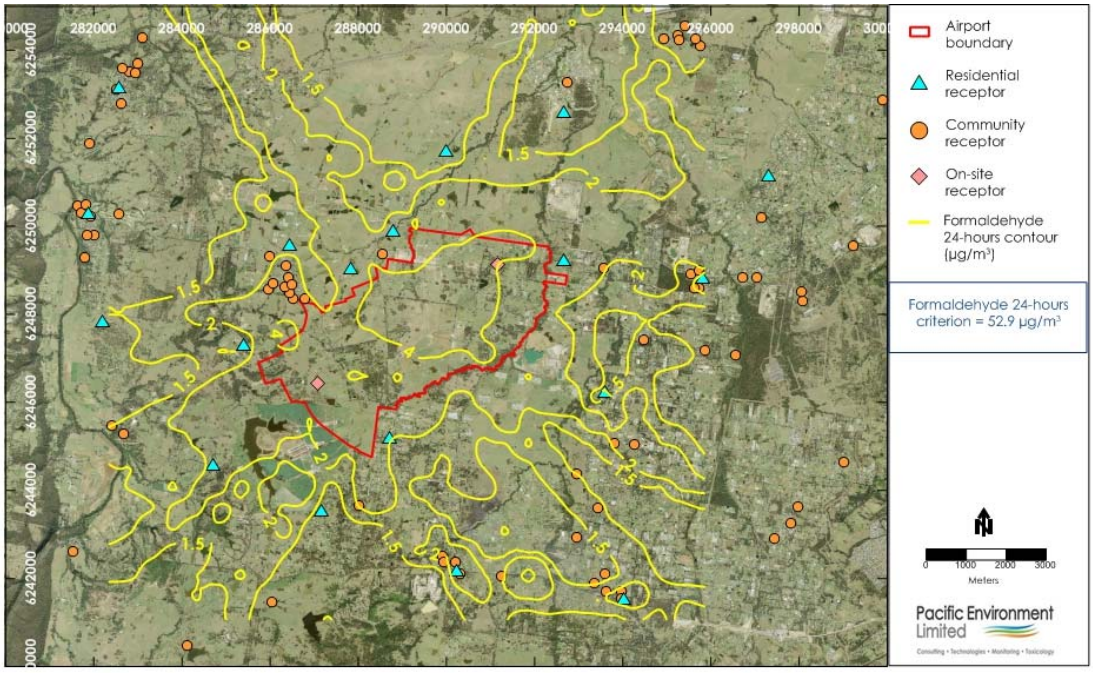


Table F6-b: Predicted cumulative 24-hour average air toxic concentrations during Stage 1 development.

Receptor	Receptor location	Cumulative (µg/m³)		
		Toluene	Xylene	Formaldehyde

NEPM-AAQ investigation level		4,160	1,170	53
R1	Bringelly	15.4	16.7	6.4
R2	Luddenham	15.4	16.7	5.8
R3	Greendale, Greendale Road	15.4	16.7	5.9
R4	Kemps Creek	15.5	16.7	7.7
R6	Mulgoa	15.4	16.6	5.3
R7	Wallacia	15.3	16.6	5.2
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	15.4	16.6	5.5
R14	Lawson Road, Badgerys Creek	15.4	16.7	7.0
R15	Mersey Rd, Greendale	15.4	16.7	6.1
R17	Luddenham Road	15.4	16.6	5.4
R18	Cnr Adams & Elizabeth Drive	15.4	16.7	5.7
R19	Cnr Adams & Anton Road	15.5	16.7	7.3
R21	Cnr Willowdene Ave and Vicar Park Lane	15.4	16.7	5.8
R22	Rossmore, Victor Ave	15.4	16.7	5.7
R23	Wallacia, Greendale Rd	15.4	16.6	5.4
R24	Badgerys Creek 1 NE	15.6	16.8	9.4
R25	Badgerys Creek 2 SW	15.4	16.7	6.7
R27	Greendale, Dwyer Rd	15.4	16.6	5.6
R30	Rossmore residential	15.4	16.7	6.7
R31	Mt Vernon residential	15.4	16.7	5.8
R34	Emmaus Residential Aged Care	15.4	16.6	5.6
R35	Mamre After School and Vacation Care	15.4	16.6	5.3
R36	Head Start After School Care	15.4	16.7	6.4
R37	Schoolies at Mulgoa	15.4	16.7	6.5
R38	Do-re-mi Day Care Centre	15.4	16.6	5.6
R39	Little Amigos Austral Early Learning Centre	15.4	16.7	5.9
R40	Little Smarties Childcare Centre	15.4	16.6	5.4
R41	The Grove Academy	15.4	16.6	5.4
R42	Horsley Kids	15.3	16.6	5.1
R44	Bringelly Child Care Centre	15.4	16.7	6.0
R46	Clementson Drive Early Educational Centre	15.4	16.7	5.9
R48	Kids Korner West Hoxton Early Learning Centre	15.4	16.6	5.4
R49	Luddenham Child Care Centre	15.4	16.7	6.2
R52	The Frogs Lodge	15.4	16.6	5.5
R53	Rossmore Community Preschool	15.4	16.7	6.1
R54	Mulgoa Preschool	15.3	16.6	5.1
R55	Jillys Educational Childcare Centre	15.4	16.7	5.9
R57	Wallacia Progress Hall	15.3	16.6	5.2
R59	Bringelly Community Centre	15.4	16.7	6.2
R63	Luddenham Progress Hall	15.4	16.7	6.4
R64	Mulgoa Hall	15.3	16.6	5.2

Receptor	Receptor location	Cumulative (µg/m³)		
		Toluene	Xylene	Formaldehyde
	NEPM-AAQ investigation level	*4,160*	*1,170*	*53*
R65	Emmaus Catholic College	15.4	16.6	5.4
R66	University of Sydney Farms	15.3	16.6	5.2
R68	Christadelphian Heritage College Sydney	15.4	16.7	6.5
R69	Mamre Anglican School	15.4	16.6	5.3
R72	Irfan College	15.5	16.8	8.7
R73	Luddenham Public School	15.4	16.7	6.7
R74	Kemps Creek Public School	15.4	16.7	6.3
R75	Trinity Catholic Primary School	15.4	16.6	5.3
R76	Bringelly Public School	15.5	16.7	7.2
R78	Mulgoa Public School	15.3	16.6	5.1
R79	Rossmore Public School	15.4	16.7	5.9
R80	Wallacia Public School	15.3	16.6	5.1
R82	Bellfield College - Junior Campus	15.4	16.6	5.3
R84	Bringelly Park	15.4	16.7	6.0
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	15.3	16.6	5.2
R86	Blaxland Crossing Reserve	15.3	16.6	5.1
R87	Bill Anderson Reserve	15.4	16.7	5.9
R88	Kemps Creek Nature Reserve	15.4	16.6	5.4
R91	Western Sydney Parklands	15.4	16.7	6.2
R93	Rossmore Grange	15.4	16.7	5.7
R94	Freeburn Park	15.5	16.7	7.2
R95	Overett Reserve	15.4	16.7	5.8
R97	Mulgoa Park	15.3	16.6	5.2
R98	Wallacia Bowling and Recreation Club	15.3	16.6	5.1
R99	Hubertus Country Club	15.4	16.7	6.3
R100	Sugarloaf Cobbitty Equestrian Club	15.4	16.6	5.4
R102	Panthers Wallacia	15.3	16.6	5.2
R103	Twin Creeks Golf and Country Club	15.3	16.6	5.0
R104	Sydney International Shooting Centre	15.5	16.7	7.4
R108	Luddenham Showground	15.4	16.6	5.4
R109	Kemps Creek Sporting and Bowling Club	15.5	16.7	7.7
R110	St James Luddenham	15.4	16.7	6.2
R111	Lin Ying temple	15.4	16.7	6.4
R112	Vat Ketanak Khmer Kampuchea Krom	15.4	16.6	5.4
R114	Anglican Church Sydney Diocese	15.4	16.6	5.6
R115	Anglican Parish of Mulgoa	15.3	16.6	5.1
R117	Bringelly Vineyard Church	15.4	16.7	5.9
R118	Free Church of Tonga	15.4	16.6	5.6
R120	Our Lady Queen of Peace	15.4	16.7	5.8

Receptor	Receptor location	Cumulative (µg/m³)		
		Toluene	Xylene	Formaldehyde
NEPM-AAQ investigation level		*4,160*	*1,170*	*53*
R122	St Anthony	15.4	16.7	5.9
R123	St Marys Church	15.3	16.6	5.2
R124	Wallacia Christian Church	15.4	16.6	5.3
R126	St Francis Xavier Church	15.4	16.7	5.7
R127	Luddenham Uniting Church	15.4	16.7	6.2
R130	Hopewood Health Retreat	15.3	16.6	5.1
R131	Science of the Soul Study Centre	15.5	16.7	7.7
R132	Bringelly shops	15.4	16.7	6.2
R134	Kemps Creek shops	15.4	16.7	6.0
R135	Luddenham shops	15.4	16.7	6.2
R136	Mulgoa shops	15.4	16.6	5.3
R137	Rossmore shops	15.4	16.7	6.1
R138	Wallacia Shops	15.3	16.6	5.2
R140	Holy Family Catholic Primary and Church	15.4	16.7	5.8
R141	Edmund Rice Retreat and Conference Centre	15.3	16.6	5.0

Figure F43: Toluene 24-hour Contour Plot during Stage 1 development – Cumulative

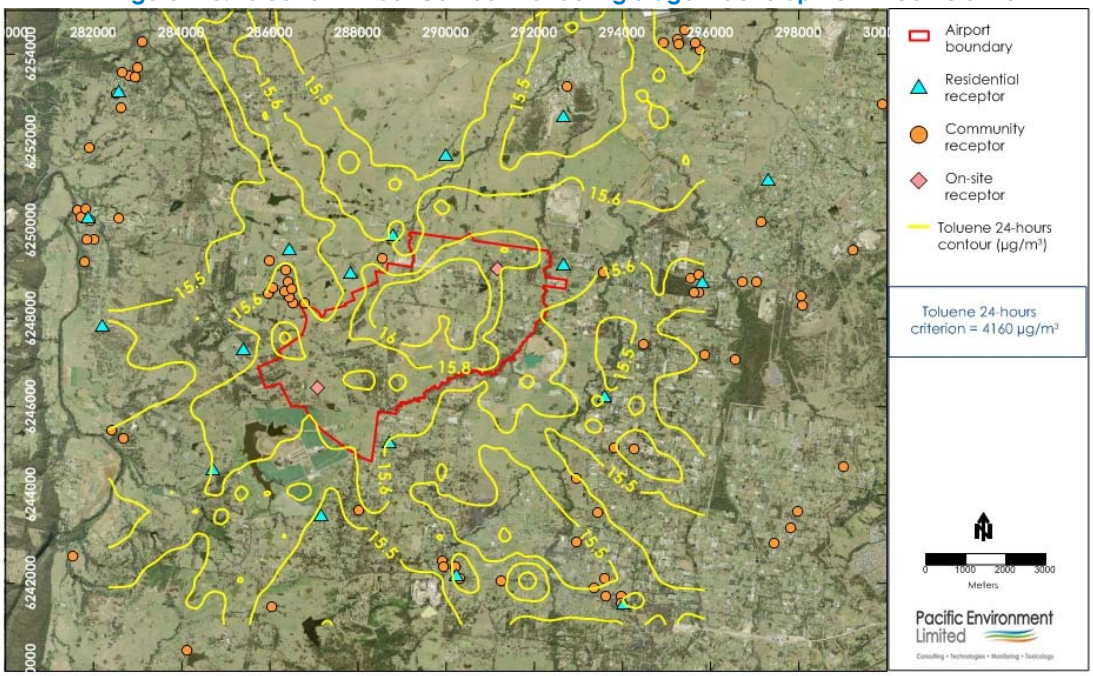


Figure F44: Xylene 24-hour Contour Plot during Stage 1 development – Cumulative

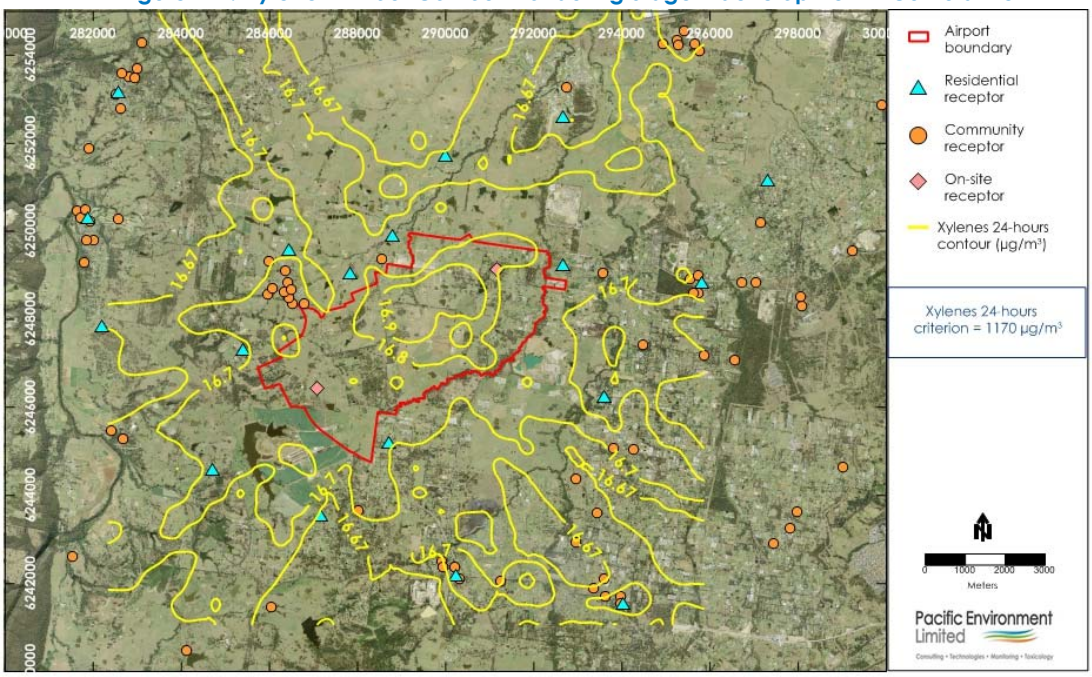


Figure F45: Formaldehyde 24-hour Contour Plot during Stage 1 development – Cumulative

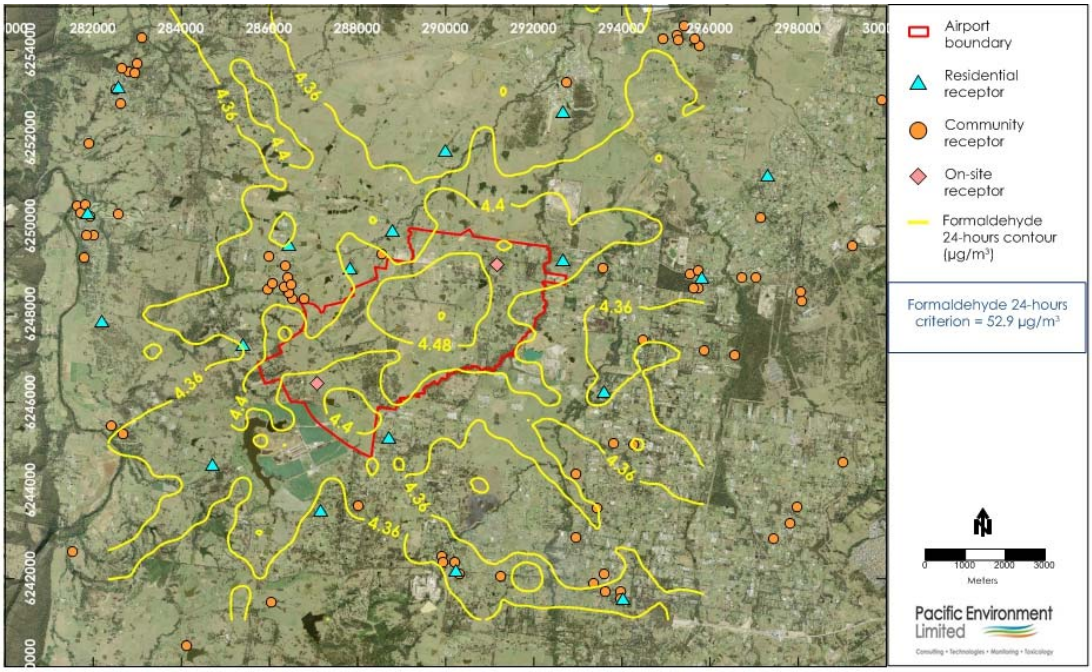


Table F7-a: Predicted incremental annual average air toxic concentrations during Stage 1 development.

Receptor	Receptor location	Airport (µg/m³)			Airport + external roadways (µg/m³)		
		Benzene	Benzene	Benzene	Benzene	Toluene	Xylene
NEPM-AAQ investigation level					*1*	*2*	*1*

Receptor	Receptor location	Airport (µg/m³)			Airport + external roadways (µg/m³)		
		Benzene	Benzene	Benzene	Benzene	Toluene	Xylene
NEPM-AAQ investigation level					*1*	*2*	*1*
R1	Bringelly	0.01	<0.01	<0.01	0.05	0.02	0.01
R2	Luddenham	0.02	0.01	0.01	0.03	0.01	0.01
R3	Greendale, Greendale Road	0.01	<0.01	<0.01	0.02	0.01	<0.01
R4	Kemps Creek	0.01	<0.01	<0.01	0.07	0.03	0.02
R6	Mulgoa	0.01	<0.01	<0.01	0.02	0.01	<0.01
R7	Wallacia	0.01	<0.01	<0.01	0.01	0.01	<0.01
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.01	0.01	<0.01	0.04	0.01	0.01
R14	Lawson Road, Badgerys Creek	0.02	0.01	<0.01	0.06	0.02	0.02
R15	Mersey Rd, Greendale	0.01	0.01	<0.01	0.04	0.01	0.01
R17	Luddenham Road	0.01	0.01	<0.01	0.04	0.01	0.01
R18	Cnr Adams & Elizabeth Drive	0.03	0.01	0.01	0.05	0.02	0.01
R19	Cnr Adams & Anton Road	0.04	0.02	0.01	0.06	0.02	0.02
R21	Cnr Willowdene Ave and Vicar Park Lane	0.01	<0.01	<0.01	0.02	0.01	0.01
R22	Rossmore, Victor Ave	0.01	<0.01	<0.01	0.03	0.01	0.01
R23	Wallacia, Greendale Rd	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
R24	Badgerys Creek 1 NE	0.06	0.02	0.02	0.10	0.04	0.03
R25	Badgerys Creek 2 SW	0.02	0.01	<0.01	0.04	0.02	0.01
R27	Greendale, Dwyer Rd	0.01	<0.01	<0.01	0.01	0.01	<0.01
R30	Rossmore residential	<0.01	<0.01	<0.01	0.06	0.02	0.02
R31	Mt Vernon residential	0.01	<0.01	<0.01	0.03	0.01	0.01
R34	Emmaus Residential Aged Care	0.01	0.01	<0.01	0.05	0.02	0.01
R35	Mamre After School and Vacation Care	0.01	<0.01	<0.01	0.04	0.02	0.01
R36	Head Start After School Care	<0.01	<0.01	<0.01	0.05	0.02	0.01
R37	Schoolies at Mulgoa	0.02	0.01	<0.01	0.03	0.01	0.01
R38	Do-re-mi Day Care Centre	0.01	<0.01	<0.01	0.04	0.02	0.01
R39	Little Amigos Austral Early Learning Centre	<0.01	<0.01	<0.01	0.03	0.01	0.01
R40	Little Smarties Childcare Centre	0.01	<0.01	<0.01	0.04	0.02	0.01
R41	The Grove Academy	<0.01	<0.01	<0.01	0.03	0.01	0.01
R42	Horsley Kids	0.01	<0.01	<0.01	0.02	0.01	0.01
R44	Bringelly Child Care Centre	0.01	<0.01	<0.01	0.02	0.01	0.01
R46	Clementson Drive Early Educational Centre	0.01	<0.01	<0.01	0.03	0.01	0.01
R48	Kids Korner West Hoxton Early Learning Centre	<0.01	<0.01	<0.01	0.03	0.01	0.01
R49	Luddenham Child Care Centre	0.02	0.01	<0.01	0.03	0.01	0.01
R52	The Frogs Lodge	<0.01	<0.01	<0.01	0.04	0.01	0.01
R53	Rossmore Community Preschool	<0.01	<0.01	<0.01	0.05	0.02	0.01
R54	Mulgoa Preschool	0.01	<0.01	<0.01	0.02	0.01	<0.01
R55	Jillys Educational Childcare Centre	<0.01	<0.01	<0.01	0.03	0.01	0.01
R57	Wallacia Progress Hall	0.01	<0.01	<0.01	0.01	0.01	<0.01
R59	Bringelly Community Centre	0.01	<0.01	<0.01	0.04	0.01	0.01
R63	Luddenham Progress Hall	0.01	0.01	<0.01	0.02	0.01	0.01
R64	Mulgoa Hall	0.01	<0.01	<0.01	0.02	0.01	<0.01
R65	Emmaus Catholic College	0.01	0.01	<0.01	0.04	0.02	0.01
R66	University of Sydney Farms	0.01	<0.01	<0.01	0.01	<0.01	<0.01
R68	Christadelphian Heritage College Sydney	0.01	<0.01	<0.01	0.04	0.01	0.01
R69	Mamre Anglican School	0.01	<0.01	<0.01	0.04	0.02	0.01
R72	Irfan College	<0.01	<0.01	<0.01	0.10	0.04	0.03
R73	Luddenham Public School	0.02	0.01	<0.01	0.03	0.01	0.01

Receptor	Receptor location	Airport (µg/m³)			Airport + external roadways (µg/m³)		
		Benzene	Benzene	Benzene	Benzene	Toluene	Xylene
NEPM-AAQ investigation level					*1*	*2*	*1*
R74	Kemps Creek Public School	0.01	<0.01	<0.01	0.03	0.01	0.01
R75	Trinity Catholic Primary School	0.01	<0.01	<0.01	0.04	0.02	0.01
R76	Bringelly Public School	0.01	<0.01	<0.01	0.06	0.02	0.02
R78	Mulgoa Public School	0.01	<0.01	<0.01	0.02	0.01	<0.01
R79	Rossmore Public School	<0.01	<0.01	<0.01	0.07	0.03	0.02
R80	Wallacia Public School	0.01	<0.01	<0.01	0.01	0.01	<0.01
R82	Bellfield College - Junior Campus	<0.01	<0.01	<0.01	0.04	0.01	0.01
R84	Bringelly Park	0.01	<0.01	<0.01	0.04	0.01	0.01
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
R86	Blaxland Crossing Reserve	0.01	<0.01	<0.01	0.01	<0.01	<0.01
R87	Bill Anderson Reserve	0.01	<0.01	<0.01	0.05	0.02	0.01
R88	Kemps Creek Nature Reserve	<0.01	<0.01	<0.01	0.03	0.01	0.01
R91	Western Sydney Parklands	<0.01	<0.01	<0.01	0.03	0.01	0.01
R93	Rossmore Grange	<0.01	<0.01	<0.01	0.03	0.01	0.01
R94	Freeburn Park	0.02	0.01	<0.01	0.03	0.01	0.01
R95	Overett Reserve	0.01	<0.01	<0.01	0.05	0.02	0.01
R97	Mulgoa Park	0.01	<0.01	<0.01	0.02	0.01	<0.01
R98	Wallacia Bowling and Recreation Club	0.01	<0.01	<0.01	0.01	0.01	<0.01
R99	Hubertus Country Club	0.04	0.01	0.01	0.06	0.02	0.02
R100	Sugarloaf Cobbitty Equestrian Club	0.01	<0.01	<0.01	0.01	<0.01	<0.01
R102	Panthers Wallacia	0.01	<0.01	<0.01	0.02	0.01	<0.01
R103	Twin Creeks Golf and Country Club	0.01	<0.01	<0.01	0.03	0.01	0.01
R104	Sydney International Shooting Centre	<0.01	<0.01	<0.01	0.04	0.01	0.01
R108	Luddenham Showground	0.02	0.01	<0.01	0.03	0.01	0.01
R109	Kemps Creek Sporting and Bowling Club	<0.01	<0.01	<0.01	0.07	0.02	0.02
R110	St James Luddenham	0.02	0.01	<0.01	0.03	0.01	0.01
R111	Lin Ying temple	0.01	<0.01	<0.01	0.05	0.02	0.01
R112	Vat Ketanak Khmer Kampuchea Krom	<0.01	<0.01	<0.01	0.03	0.01	0.01
R114	Anglican Church Sydney Diocese	<0.01	<0.01	<0.01	0.03	0.01	0.01
R115	Anglican Parish of Mulgoa	0.01	<0.01	<0.01	0.02	0.01	<0.01
R117	Bringelly Vineyard Church	0.01	<0.01	<0.01	0.05	0.02	0.01
R118	Free Church of Tonga	0.01	<0.01	<0.01	0.01	0.01	<0.01
R120	Our Lady Queen of Peace	0.01	<0.01	<0.01	0.05	0.02	0.01
R122	St Anthony	<0.01	<0.01	<0.01	0.04	0.01	0.01
R123	St Marys Church	0.01	<0.01	<0.01	0.02	0.01	<0.01
R124	Wallacia Christian Church	0.01	<0.01	<0.01	0.01	0.01	<0.01
R126	St Francis Xavier Church	0.01	<0.01	<0.01	0.01	0.01	<0.01
R127	Luddenham Uniting Church	0.01	<0.01	<0.01	0.02	0.01	0.01
R130	Hopewood Health Retreat	0.01	<0.01	<0.01	0.01	<0.01	<0.01
R131	Science of the Soul Study Centre	<0.01	<0.01	<0.01	0.07	0.03	0.02
R132	Bringelly shops	0.01	<0.01	<0.01	0.04	0.02	0.01
R134	Kemps Creek shops	0.01	<0.01	<0.01	0.06	0.02	0.02
R135	Luddenham shops	0.02	0.01	0.01	0.03	0.01	0.01
R136	Mulgoa shops	0.01	<0.01	<0.01	0.02	0.01	<0.01
R137	Rossmore shops	<0.01	<0.01	<0.01	0.07	0.03	0.02
R138	Wallacia Shops	0.01	<0.01	<0.01	0.01	0.01	<0.01

Receptor	Receptor location	Airport (µg/m³)			Airport + external roadways (µg/m³)		
		Benzene	Benzene	Benzene	Benzene	Toluene	Xylene
NEPM-AAQ investigation level					*1*	*2*	*1*
R140	Holy Family Catholic Primary and Church	0.02	0.01	<0.01	0.04	0.01	0.01
R141	Edmund Rice Retreat and Conference Centre	0.01	<0.01	<0.01	0.01	0.01	<0.01

Figure F46: Benzene Annual average Contour Plot during Stage 1 development – Airport

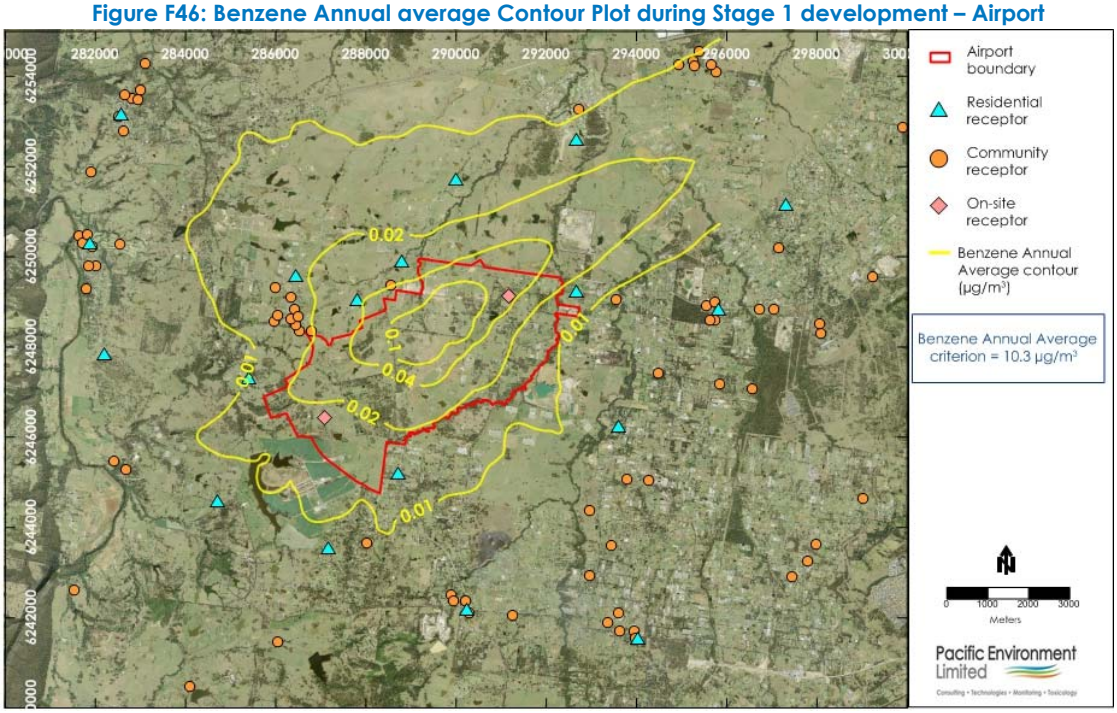


Figure F47: Toluene Annual average Contour Plot during Stage 1 development – Airport

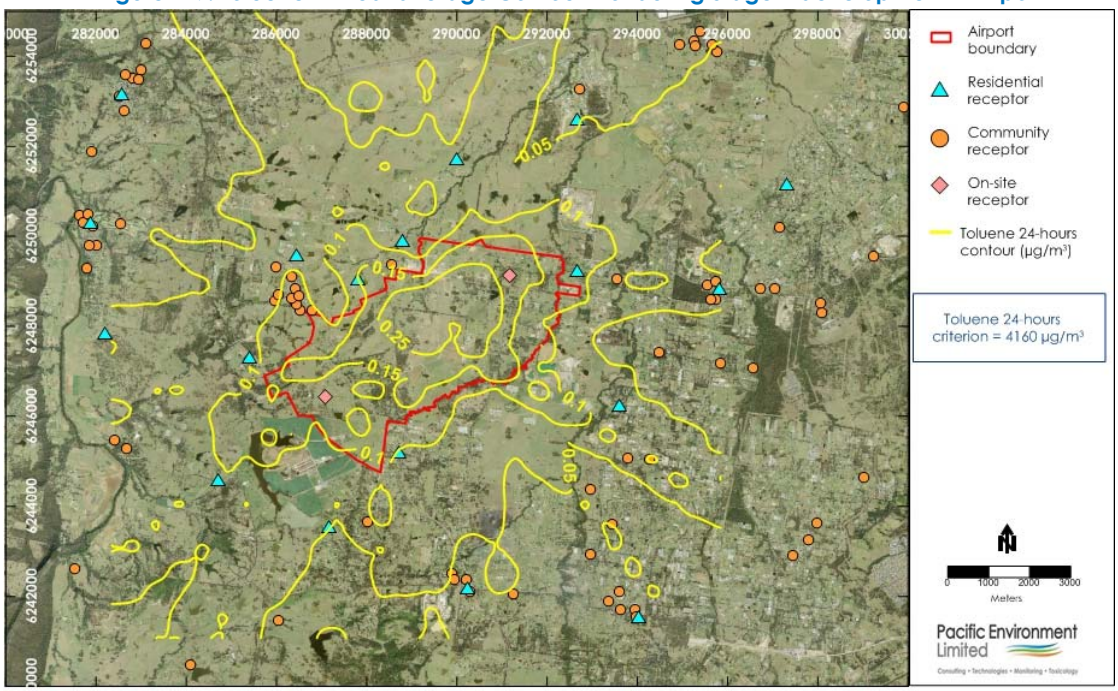


Figure F48: Xylene Annual average Contour Plot during Stage 1 development – Airport

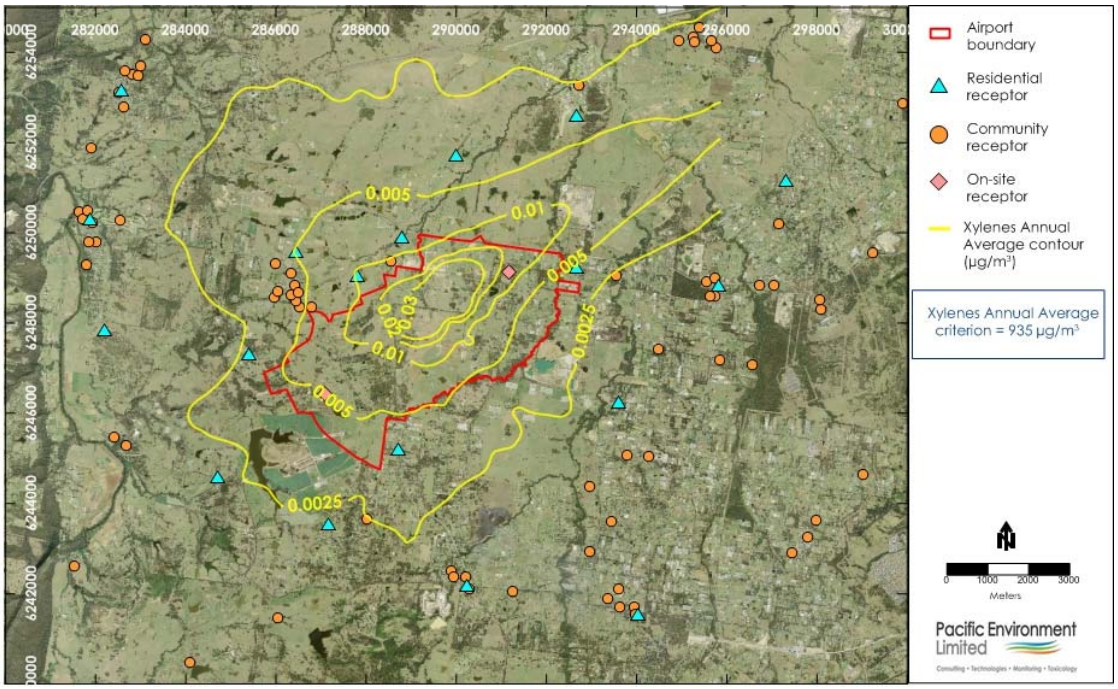


Figure F49: Benzene Annual average Contour Plot during Stage 1 development – Airport + External Roadways.

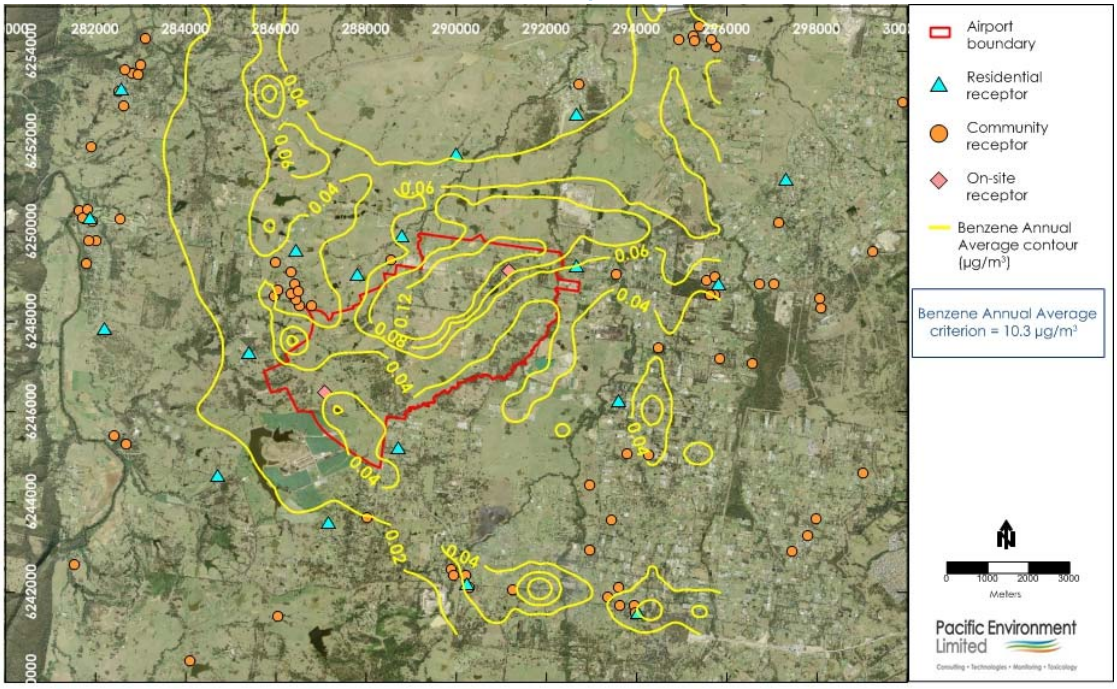


Figure F50: Xylene Annual average Contour Plot during Stage 1 development - Airport + External Roadways

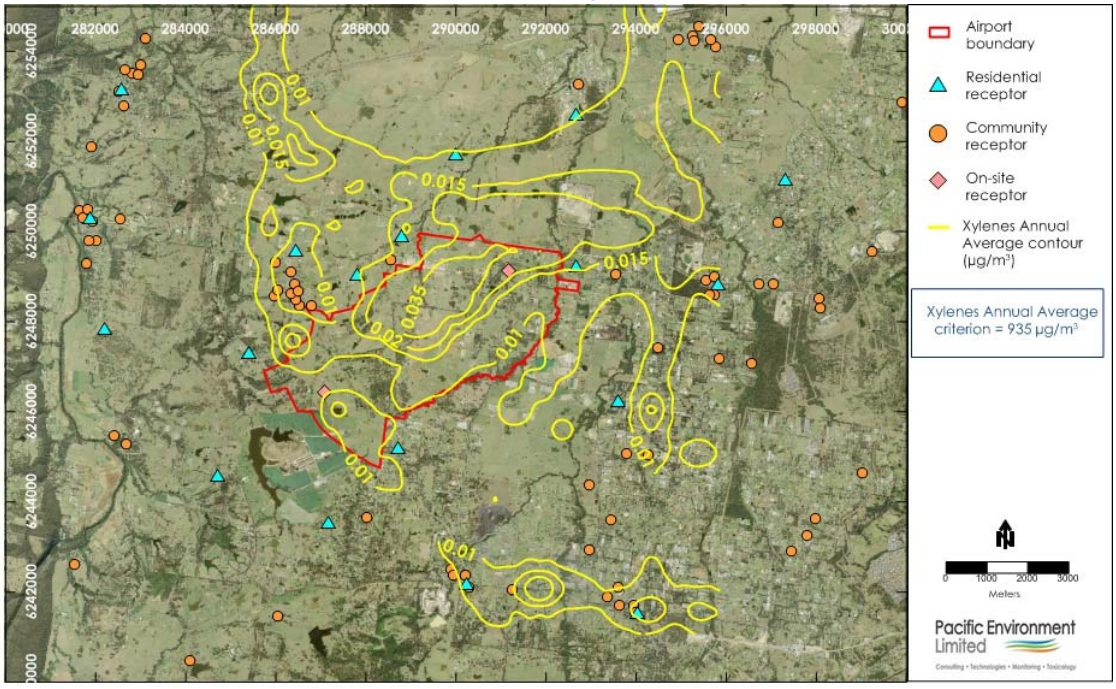


Figure F51: Toluene Annual average Contour Plot during Stage 1 development - Airport + External Roadways

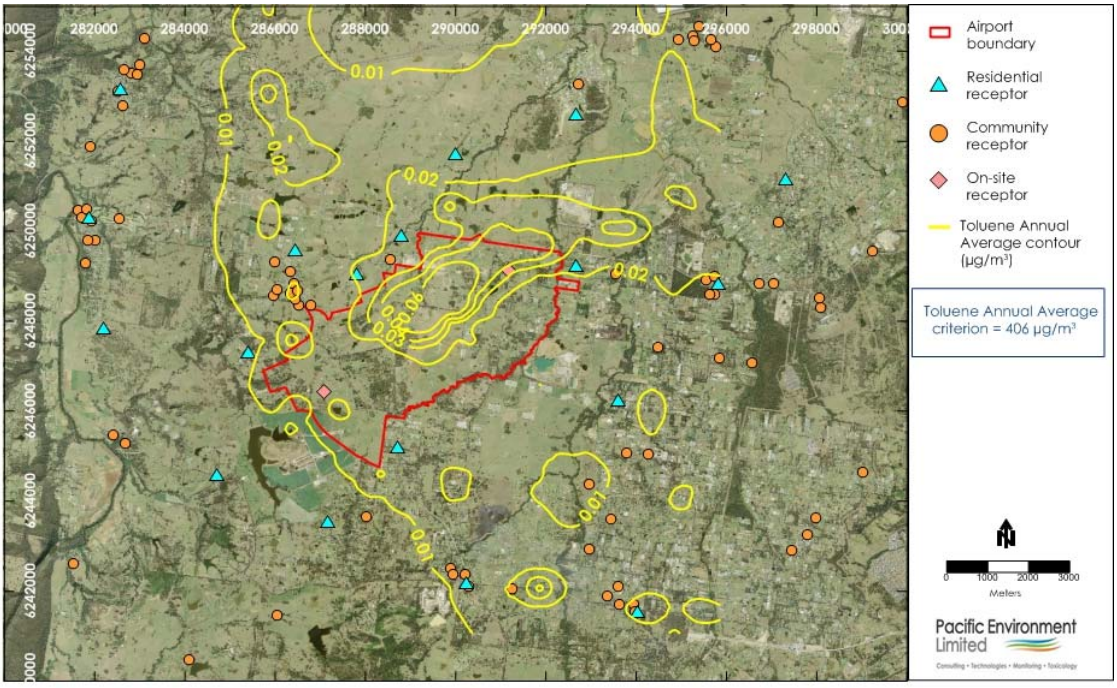


Table F7-b: Predicted cumulative annual average air toxic concentrations during Stage 1 development.

Receptor	Receptor location	Cumulative (µg/m³)		
		Benzene	Toluene	Xylene
NEPM-AAQ investigation level		*1*	*2*	*1*
R1	Bringelly	1.05	3.72	2.41
R2	Luddenham	1.03	3.71	2.41
R3	Greendale, Greendale Road	1.02	3.71	2.40
R4	Kemps Creek	1.07	3.73	2.42
R6	Mulgoa	1.02	3.71	2.40
R7	Wallacia	1.01	3.71	2.40
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	1.04	3.71	2.41
R14	Lawson Road, Badgerys Creek	1.06	3.72	2.42
R15	Mersey Rd, Greendale	1.04	3.71	2.41
R17	Luddenham Road	1.04	3.71	2.41
R18	Cnr Adams & Elizabeth Drive	1.05	3.72	2.41
R19	Cnr Adams & Anton Road	1.06	3.72	2.42
R21	Cnr Willowdene Ave and Vicar Park Lane	1.02	3.71	2.41
R22	Rossmore, Victor Ave	1.03	3.71	2.41
R23	Wallacia, Greendale Rd	1.01	3.70	2.40
R24	Badgerys Creek 1 NE	1.10	3.74	2.43
R25	Badgerys Creek 2 SW	1.04	3.72	2.41
R27	Greendale, Dwyer Rd	1.01	3.71	2.40
R30	Rossmore residential	1.06	3.72	2.42
R31	Mt Vernon residential	1.03	3.71	2.41
R34	Emmaus Residential Aged Care	1.05	3.72	2.41

Receptor	Receptor location	Cumulative (µg/m³)		
		Benzene	Toluene	Xylene
NEPM-AAQ investigation level		*1*	*2*	*1*
R35	Mamre After School and Vacation Care	1.04	3.72	2.41
R36	Head Start After School Care	1.05	3.72	2.41
R37	Schoolies at Mulgoa	1.03	3.71	2.41
R38	Do-re-mi Day Care Centre	1.04	3.72	2.41
R39	Little Amigos Austral Early Learning Centre	1.03	3.71	2.41
R40	Little Smarties Childcare Centre	1.04	3.72	2.41
R41	The Grove Academy	1.03	3.71	2.41
R42	Horsley Kids	1.02	3.71	2.41
R44	Bringelly Child Care Centre	1.02	3.71	2.41
R46	Clementson Drive Early Educational Centre	1.03	3.71	2.41
R48	Kids Korner West Hoxton Early Learning Centre	1.03	3.71	2.41
R49	Luddenham Child Care Centre	1.03	3.71	2.41
R52	The Frogs Lodge	1.04	3.71	2.41
R53	Rossmore Community Preschool	1.05	3.72	2.41
R54	Mulgoa Preschool	1.02	3.71	2.40
R55	Jillys Educational Childcare Centre	1.03	3.71	2.41
R57	Wallacia Progress Hall	1.01	3.71	2.40
R59	Bringelly Community Centre	1.04	3.71	2.41
R63	Luddenham Progress Hall	1.02	3.71	2.41
R64	Mulgoa Hall	1.02	3.71	2.40
R65	Emmaus Catholic College	1.04	3.72	2.41
R66	University of Sydney Farms	1.01	3.70	2.40
R68	Christadelphian Heritage College Sydney	1.04	3.71	2.41
R69	Mamre Anglican School	1.04	3.72	2.41
R72	Irfan College	1.10	3.74	2.43
R73	Luddenham Public School	1.03	3.71	2.41
R74	Kemps Creek Public School	1.03	3.71	2.41
R75	Trinity Catholic Primary School	1.04	3.72	2.41
R76	Bringelly Public School	1.06	3.72	2.42
R78	Mulgoa Public School	1.02	3.71	2.40
R79	Rossmore Public School	1.07	3.73	2.42
R80	Wallacia Public School	1.01	3.71	2.40
R82	Bellfield College - Junior Campus	1.04	3.71	2.41
R84	Bringelly Park	1.04	3.71	2.41
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	1.01	3.70	2.40
R86	Blaxland Crossing Reserve	1.01	3.70	2.40
R87	Bill Anderson Reserve	1.05	3.72	2.41
R88	Kemps Creek Nature Reserve	1.03	3.71	2.41
R91	Western Sydney Parklands	1.03	3.71	2.41
R93	Rossmore Grange	1.03	3.71	2.41
R94	Freeburn Park	1.03	3.71	2.41
R95	Overett Reserve	1.05	3.72	2.41

Receptor	Receptor location	Cumulative (µg/m³)		
		Benzene	Toluene	Xylene
NEPM-AAQ investigation level		*1*	*2*	*1*
R97	Mulgoa Park	1.02	3.71	2.40
R98	Wallacia Bowling and Recreation Club	1.01	3.71	2.40
R99	Hubertus Country Club	1.06	3.72	2.42
R100	Sugarloaf Cobbitty Equestrian Club	1.01	3.70	2.40
R102	Panthers Wallacia	1.02	3.71	2.40
R103	Twin Creeks Golf and Country Club	1.03	3.71	2.41
R104	Sydney International Shooting Centre	1.04	3.71	2.41
R108	Luddenham Showground	1.03	3.71	2.41
R109	Kemps Creek Sporting and Bowling Club	1.07	3.72	2.42
R110	St James Luddenham	1.03	3.71	2.41
R111	Lin Ying temple	1.05	3.72	2.41
R112	Vat Ketanak Khmer Kampuchea Krom	1.03	3.71	2.41
R114	Anglican Church Sydney Diocese	1.03	3.71	2.41
R115	Anglican Parish of Mulgoa	1.02	3.71	2.40
R117	Bringelly Vineyard Church	1.05	3.72	2.41
R118	Free Church of Tonga	1.01	3.71	2.40
R120	Our Lady Queen of Peace	1.05	3.72	2.41
R122	St Anthony	1.04	3.71	2.41
R123	St Marys Church	1.02	3.71	2.40
R124	Wallacia Christian Church	1.01	3.71	2.40
R126	St Francis Xavier Church	1.01	3.71	2.40
R127	Luddenham Uniting Church	1.02	3.71	2.41
R130	Hopewood Health Retreat	1.01	3.70	2.40
R131	Science of the Soul Study Centre	1.07	3.73	2.42
R132	Bringelly shops	1.04	3.72	2.41
R134	Kemps Creek shops	1.06	3.72	2.42
R135	Luddenham shops	1.03	3.71	2.41
R136	Mulgoa shops	1.02	3.71	2.40
R137	Rossmore shops	1.07	3.73	2.42
R138	Wallacia Shops	1.01	3.71	2.40
R140	Holy Family Catholic Primary and Church	1.04	3.71	2.41
R141	Edmund Rice Retreat and Conference Centre	1.01	3.71	2.40

Figure F52: Benzene Annual average Contour Plot during Stage 1 development - Cumulative.

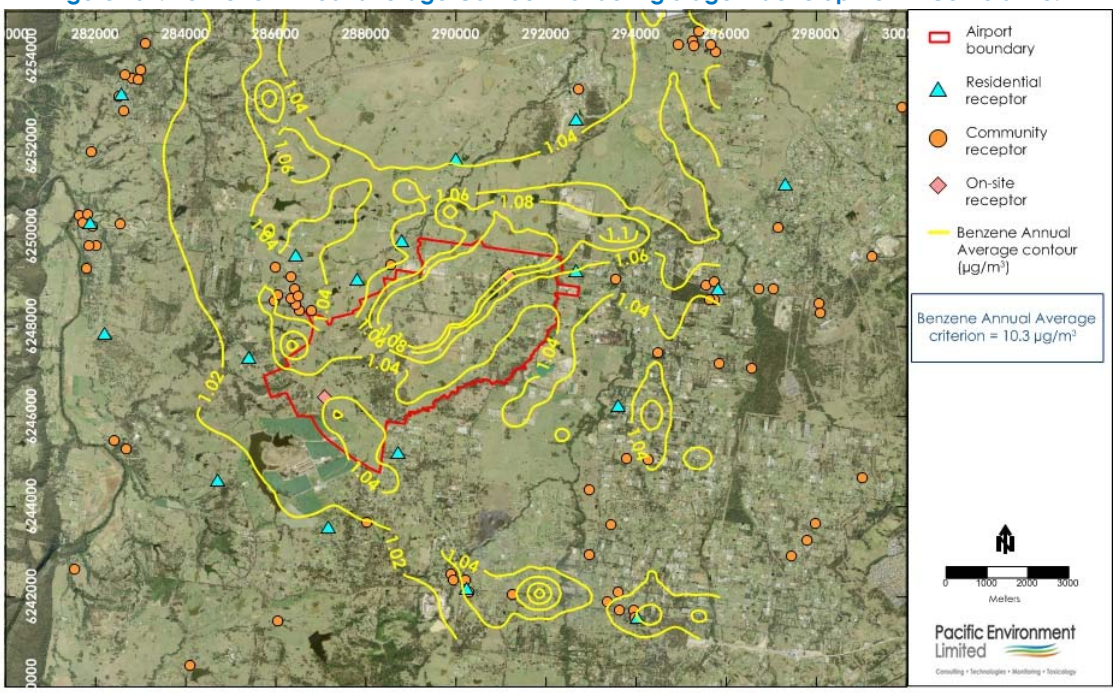


Figure F53: Xylene Annual average Contour Plot during Stage 1 development - Cumulative

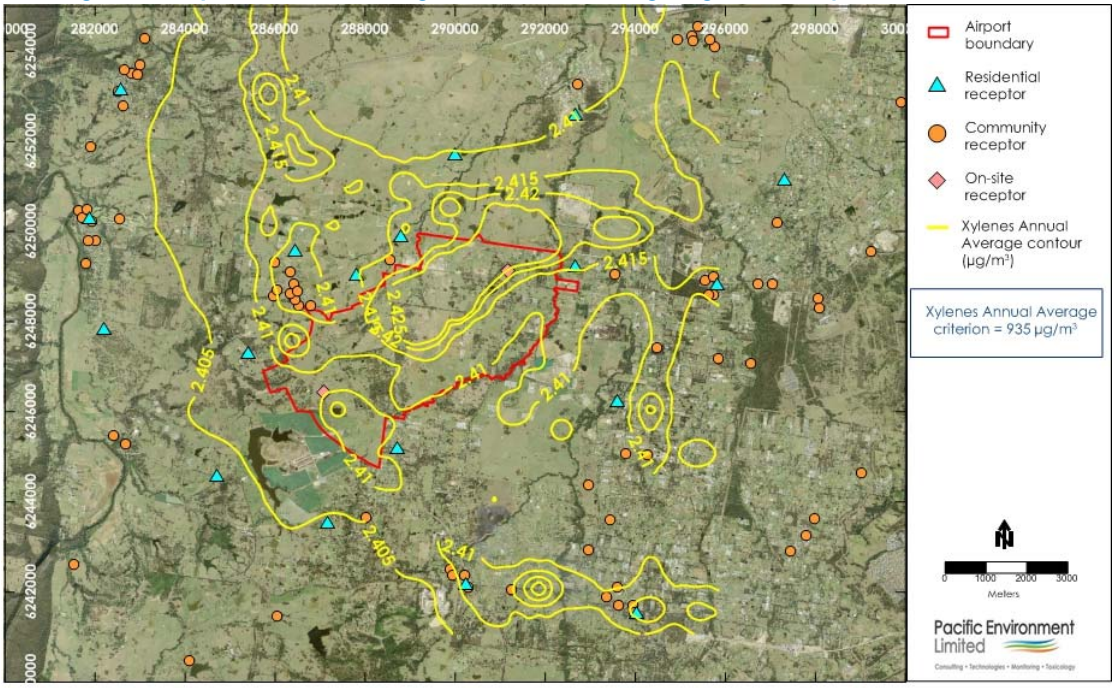
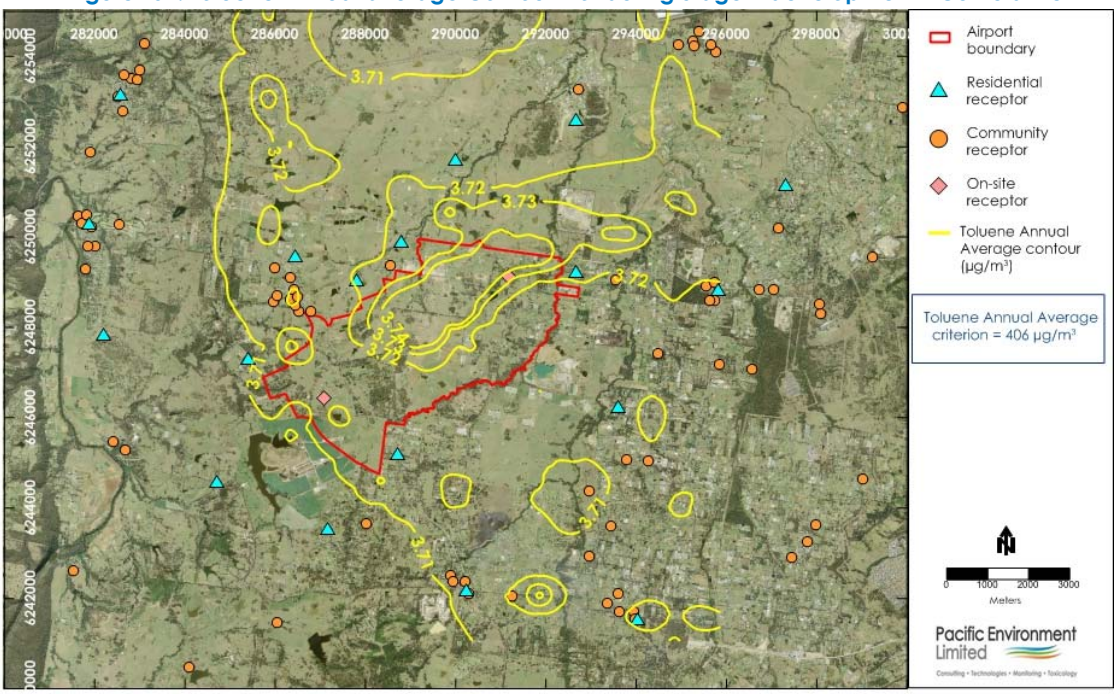


Figure F54: Toluene Annual average Contour Plot during Stage 1 development - Cumulative



F.1.7 Odour

Table F8: Predicted 99th percentile odour concentrations from aircraft exhaust

Receptor	Receptor location	Odour concentration 99th percentile (OU)
	Criterion	*2*
R1	Bringelly	<1
R2	Luddenham	<1
R3	Greendale, Greendale Road	<1
R4	Kemps Creek	<1
R6	Mulgoa	<1
R7	Wallacia	<1
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	<1
R14	Lawson Road, Badgerys Creek	<1
R15	Mersey Rd, Greendale	<1
R17	Luddenham Road	<1
R18	Cnr Adams & Elizabeth Drive	1
R19	Cnr Adams & Anton Road	1
R21	Cnr Willowdene Ave and Vicar Park Lane	<1
R22	Rossmore, Victor Ave	<1
R23	Wallacia, Greendale Rd	<1
R24	Badgerys Creek 1 NE	1
R25	Badgerys Creek 2 SW	<1
R27	Greendale, Dwyer Rd	<1
R30	Rossmore residential	<1
R31	Mt Vernon residential	<1
R34	Emmaus Residential Aged Care	<1
R35	Mamre After School and Vacation Care	<1
R36	Head Start After School Care	<1
R37	Schoolies at Mulgoa	<1

Receptor	Receptor location	Odour concentration 99th percentile (OU)
	Criterion	*2*
R38	Do-re-mi Day Care Centre	<1
R39	Little Amigos Austral Early Learning Centre	<1
R40	Little Smarties Childcare Centre	<1
R41	The Grove Academy	<1
R42	Horsley Kids	<1
R44	Bringelly Child Care Centre	<1
R46	Clementson Drive Early Educational Centre	<1
R48	Kids Korner West Hoxton Early Learning Centre	<1
R49	Luddenham Child Care Centre	<1
R52	The Frogs Lodge	<1
R53	Rossmore Community Preschool	<1
R54	Mulgoa Preschool	<1
R55	Jillys Educational Childcare Centre	<1
R57	Wallacia Progress Hall	<1
R59	Bringelly Community Centre	<1
R63	Luddenham Progress Hall	<1
R64	Mulgoa Hall	<1
R65	Emmaus Catholic College	<1
R66	University of Sydney Farms	<1
R68	Christadelphian Heritage College Sydney	<1
R69	Mamre Anglican School	<1
R72	Irfan College	<1
R73	Luddenham Public School	<1
R74	Kemps Creek Public School	<1
R75	Trinity Catholic Primary School	<1
R76	Bringelly Public School	<1
R78	Mulgoa Public School	<1
R79	Rossmore Public School	<1
R80	Wallacia Public School	<1
R82	Bellfield College - Junior Campus	<1
R84	Bringelly Park	<1
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	<1
R86	Blaxland Crossing Reserve	<1
R87	Bill Anderson Reserve	<1
R88	Kemps Creek Nature Reserve	<1
R91	Western Sydney Parklands	<1
R93	Rossmore Grange	<1
R94	Freeburn Park	<1
R95	Overett Reserve	<1
R97	Mulgoa Park	<1
R98	Wallacia Bowling and Recreation Club	<1
R99	Hubertus Country Club	1
R100	Sugarloaf Cobbitty Equestrian Club	<1
R102	Panthers Wallacia	<1
R103	Twin Creeks Golf and Country Club	<1
R104	Sydney International Shooting Centre	<1
R108	Luddenham Showground	<1
R109	Kemps Creek Sporting and Bowling Club	<1
R110	St James Luddenham	<1
R111	Lin Ying temple	<1
R112	Vat Ketanak Khmer Kampuchea Krom	<1
R114	Anglican Church Sydney Diocese	<1

Receptor	Receptor location	Odour concentration 99th percentile (OU)
Criterion		*2*
R115	Anglican Parish of Mulgoa	<1
R117	Bringelly Vineyard Church	<1
R118	Free Church of Tonga	<1
R120	Our Lady Queen of Peace	<1
R122	St Anthony	<1
R123	St Marys Church	<1
R124	Wallacia Christian Church	<1
R126	St Francis Xavier Church	<1
R127	Luddenham Uniting Church	<1
R130	Hopewood Health Retreat	<1
R131	Science of the Soul Study Centre	<1
R132	Bringelly shops	<1
R134	Kemps Creek shops	<1
R135	Luddenham shops	<1
R136	Mulgoa shops	<1
R137	Rossmore shops	<1
R138	Wallacia Shops	<1
R140	Holy Family Catholic Primary and Church	<1
R141	Edmund Rice Retreat and Conference Centre	<1

Table F8: Predicted 99th percentile odour concentrations from STP

Receptor	Receptor location	1-hour 99th percentile
Criterion		*2*
R1	Bringelly	<0.1
R2	Luddenham	<0.1
R3	Greendale, Greendale Road	<0.1
R4	Kemps Creek	<0.1
R6	Mulgoa	<0.1
R7	Wallacia	<0.1
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	<0.1
R14	Lawson Road, Badgerys Creek	<0.1
R15	Mersey Rd, Greendale	<0.1
R17	Luddenham Road	<0.1
R18	Cnr Adams & Elizabeth Drive	<0.1
R19	Cnr Adams & Anton Road	<0.1
R21	Cnr Willowdene Ave and Vicar Park Lane	<0.1
R22	Rossmore, Victor Ave	<0.1
R23	Wallacia, Greendale Rd	<0.1
R24	Badgerys Creek 1 NE	0.1
R25	Badgerys Creek 2 SW	<0.1
R27	Greendale, Dwyer Rd	<0.1
R30	Rossmore residential	<0.1
R31	Mt Vernon residential	<0.1
R34	Emmaus Residential Aged Care	<0.1
R35	Mamre After School and Vacation Care	<0.1
R36	Head Start After School Care	<0.1
R37	Schoolies at Mulgoa	<0.1
R38	Do-re-mi Day Care Centre	<0.1
R39	Little Amigos Austral Early Learning Centre	<0.1
R40	Little Smarties Childcare Centre	<0.1
R41	The Grove Academy	<0.1

Receptor	Receptor location	1-hour 99th percentile
Criterion		*2*
R42	Horsley Kids	<0.1
R44	Bringelly Child Care Centre	<0.1
R46	Clementson Drive Early Educational Centre	<0.1
R48	Kids Korner West Hoxton Early Learning Centre	<0.1
R49	Luddenham Child Care Centre	<0.1
R52	The Frogs Lodge	<0.1
R53	Rossmore Community Preschool	<0.1
R54	Mulgoa Preschool	<0.1
R55	Jillys Educational Childcare Centre	<0.1
R57	Wallacia Progress Hall	<0.1
R59	Bringelly Community Centre	<0.1
R63	Luddenham Progress Hall	<0.1
R64	Mulgoa Hall	<0.1
R65	Emmaus Catholic College	<0.1
R66	University of Sydney Farms	<0.1
R68	Christadelphian Heritage College Sydney	<0.1
R69	Mamre Anglican School	<0.1
R72	Irfan College	<0.1
R73	Luddenham Public School	<0.1
R74	Kemps Creek Public School	<0.1
R75	Trinity Catholic Primary School	<0.1
R76	Bringelly Public School	<0.1
R78	Mulgoa Public School	<0.1
R79	Rossmore Public School	<0.1
R80	Wallacia Public School	<0.1
R82	Bellfield College - Junior Campus	<0.1
R84	Bringelly Park	<0.1
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	<0.1
R86	Blaxland Crossing Reserve	<0.1
R87	Bill Anderson Reserve	<0.1
R88	Kemps Creek Nature Reserve	<0.1
R91	Western Sydney Parklands	<0.1
R93	Rossmore Grange	<0.1
R94	Freeburn Park	<0.1
R95	Overett Reserve	<0.1
R97	Mulgoa Park	<0.1
R98	Wallacia Bowling and Recreation Club	<0.1
R99	Hubertus Country Club	<0.1
R100	Sugarloaf Cobbitty Equestrian Club	<0.1
R102	Panthers Wallacia	<0.1
R103	Twin Creeks Golf and Country Club	<0.1
R104	Sydney International Shooting Centre	<0.1
R108	Luddenham Showground	<0.1
R109	Kemps Creek Sporting and Bowling Club	<0.1
R110	St James Luddenham	<0.1
R111	Lin Ying temple	<0.1
R112	Vat Ketanak Khmer Kampuchea Krom	<0.1
R114	Anglican Church Sydney Diocese	<0.1
R115	Anglican Parish of Mulgoa	<0.1
R117	Bringelly Vineyard Church	<0.1
R118	Free Church of Tonga	<0.1
R120	Our Lady Queen of Peace	<0.1
R122	St Anthony	<0.1

Receptor	Receptor location	1-hour 99th percentile
Criterion		*2*
R123	St Marys Church	<0.1
R124	Wallacia Christian Church	<0.1
R126	St Francis Xavier Church	<0.1
R127	Luddenham Uniting Church	<0.1
R130	Hopewood Health Retreat	<0.1
R131	Science of the Soul Study Centre	<0.1
R132	Bringelly shops	<0.1
R134	Kemps Creek shops	<0.1
R135	Luddenham shops	<0.1
R136	Mulgoa shops	<0.1
R137	Rossmore shops	<0.1
R138	Wallacia Shops	<0.1
R140	Holy Family Catholic Primary and Church	<0.1
R141	Edmund Rice Retreat and Conference Centre	<0.1

F.2 LONGER TERM DEVELOPMENT

F.2.1 Nitrogen dioxide

Table F9: Predicted cumulative NO_2 concentrations during longer term development

Receptor	Receptor location	Airport (µg/m³)			Cumulative (µg/m³)		
		24-hour	No. days > 246	Annual	24-hour	No. days > 246	Annual
Ambient objective / Assessment criterion		*320*	*n/a*	*62*	*320*	*n/a*	*62*
R1	Bringelly	237	0	17	246	0	25
R2	Luddenham	111	0	22	112	0	24
R3	Greendale, Greendale Road	**347**	2	22	**368**	3	24
R4	Kemps Creek	223	0	17	244	0	31
R6	Mulgoa	188	0	18	189	0	19
R7	Wallacia	241	0	17	243	0	18
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	155	0	21	164	0	26
R14	Lawson Road, Badgerys Creek	**517**	1	34	**519**	1	45
R15	Mersey Rd, Greendale	**343**	3	31	**349**	3	34
R17	Luddenham Road	310	4	22	313	4	26
R18	Cnr Adams & Elizabeth Drive	229	0	38	229	0	43
R19	Cnr Adams & Anton Road	211	0	47	211	0	50
R21	Cnr Willowdene Ave and Vicar Park Lane	**408**	1	24	**424**	2	27
R22	Rossmore, Victor Ave	242	1	18	246	1	23
R23	Wallacia, Greendale Rd	**342**	2	15	**347**	2	17
R24	Badgerys Creek 1 NE	**335**	4	55	**337**	11	57
R25	Badgerys Creek 2 SW	281	2	23	287	2	26
R27	Greendale, Dwyer Rd	116	0	14	117	0	16

Receptor	Receptor location	Airport (µg/m³)			Cumulative (µg/m³)		
		24-hour	No. days > 246	Annual	24-hour	No. days > 246	Annual
Ambient objective / Assessment criterion		*320*	*n/a*	*62*	*320*	*n/a*	*62*
R30	Rossmore residential	312	1	14	319	1	36
R31	Mt Vernon residential	**345**	1	22	**355**	1	26
R34	Emmaus Residential Aged Care	**337**	1	#N/A	**351**	1	26
R35	Mamre After School and Vacation Care	119	0	19	123	0	24
R36	Head Start After School Care	236	0	13	265	1	23
R37	Schoolies at Mulgoa	150	0	24	154	0	27
R38	Do-re-mi Day Care Centre	**398**	1	19	**421**	1	26
R39	Little Amigos Austral Early Learning Centre	260	1	14	263	1	19
R40	Little Smarties Childcare Centre	152	0	19	152	0	24
R41	The Grove Academy	203	0	15	207	0	20
R42	Horsley Kids	166	0	16	170	0	19
R44	Bringelly Child Care Centre	192	0	19	196	0	20
R46	Clementson Drive Early Educational Centre	239	1	16	244	0	21
R48	Kids Korner West Hoxton Early Learning Centre	302	2	14	307	2	18
R49	Luddenham Child Care Centre	163	0	21	164	0	22
R52	The Frogs Lodge	231	0	14	235	0	20
R53	Rossmore Community Preschool	265	1	14	268	1	26
R54	Mulgoa Preschool	271	1	17	278	1	19
R55	Jillys Educational Childcare Centre	173	0	16	175	0	21
R57	Wallacia Progress Hall	153	0	17	156	0	18
R59	Bringelly Community Centre	244	0	18	265	1	23
R63	Luddenham Progress Hall	122	0	18	201	0	19
R64	Mulgoa Hall	221	0	18	227	0	19
R65	Emmaus Catholic College	184	0	20	186	0	25
R66	University of Sydney Farms	257	1	17	261	1	18
R68	Christadelphian Heritage College Sydney	195	0	17	204	0	24
R69	Mamre Anglican School	314	1	19	**321**	1	25
R72	Irfan College	158	0	13	161	0	24
R73	Luddenham Public School	171	0	22	178	0	24
R74	Kemps Creek Public School	206	0	18	212	0	23
R75	Trinity Catholic Primary School	230	0	18	238	0	24
R76	Bringelly Public School	216	0	17	265	2	28
R78	Mulgoa Public School	183	0	17	186	0	19

Receptor	Receptor location	Airport (µg/m³)			Cumulative (µg/m³)		
		24-hour	No. days > 246	Annual	24-hour	No. days > 246	Annual
Ambient objective / Assessment criterion		*320*	*n/a*	*62*	*320*	*n/a*	*62*
R79	Rossmore Public School	149	0	14	153	0	25
R80	Wallacia Public School	207	0	16	209	0	18
R82	Bellfield College - Junior Campus	217	0	15	221	0	21
R84	Bringelly Park	248	1	18	266	1	23
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	278	1	15	290	1	16
R86	Blaxland Crossing Reserve	196	0	16	199	0	17
R87	Bill Anderson Reserve	231	0	18	248	1	30
R88	Kemps Creek Nature Reserve	174	0	14	176	0	19
R91	Western Sydney Parklands	307	2	15	315	2	20
R93	Rossmore Grange	211	0	17	212	0	21
R94	Freeburn Park	129	0	23	138	0	25
R95	Overett Reserve	**330**	1	28	**337**	1	36
R97	Mulgoa Park	246	1	18	261	1	19
R98	Wallacia Bowling and Recreation Club	163	0	16	166	0	18
R99	Hubertus Country Club	258	1	45	258	1	49
R100	Sugarloaf Cobbitty Equestrian Club	164	0	16	171	0	17
R102	Panthers Wallacia	254	1	18	261	1	19
R103	Twin Creeks Golf and Country Club	257	2	19	266	2	23
R104	Sydney International Shooting Centre	252	1	15	257	1	21
R108	Luddenham Showground	161	0	21	167	0	23
R109	Kemps Creek Sporting and Bowling Club	247	1	15	**351**	2	36
R110	St James Luddenham	186	0	25	191	0	26
R111	Lin Ying temple	296	1	16	304	1	24
R112	Vat Ketanak Khmer Kampuchea Krom	158	0	15	160	0	20
R114	Anglican Church Sydney Diocese	139	0	14	143	0	20
R115	Anglican Parish of Mulgoa	168	0	16	172	0	18
R117	Bringelly Vineyard Church	240	0	16	241	0	27
R118	Free Church of Tonga	257	1	16	261	1	17
R120	Our Lady Queen of Peace	172	0	17	174	0	26
R122	St Anthony	225	0	14	228	0	20
R123	St Marys Church	221	0	18	223	0	19
R124	Wallacia Christian Church	193	0	17	195	0	18
R126	St Francis Xavier Church	260	1	16	265	1	18

Receptor	Receptor location	Airport (µg/m³)			Cumulative (µg/m³)		
		24-hour	No. days > 246	Annual	24-hour	No. days > 246	Annual
Ambient objective / Assessment criterion		*320*	*n/a*	*62*	*320*	*n/a*	*62*
R127	Luddenham Uniting Church	168	0	17	172	0	18
R130	Hopewood Health Retreat	152	0	16	152	0	17
R131	Science of the Soul Study Centre	188	0	16	**327**	1	36
R132	Bringelly shops	**340**	1	17	**346**	1	23
R134	Kemps Creek shops	**334**	1	18	**343**	2	27
R135	Luddenham shops	205	0	26	209	0	28
R136	Mulgoa shops	251	1	18	258	1	19
R137	Rossmore shops	200	0	14	204	0	25
R138	Wallacia Shops	190	0	16	196	0	18
R140	Holy Family Catholic Primary and Church	175	0	27	186	0	30
R141	Edmund Rice Retreat and Conference Centre	189	0	17	191	0	18

Figure F55: NO_2 1-hour maximum Contour Plot during long term development – Cumulative

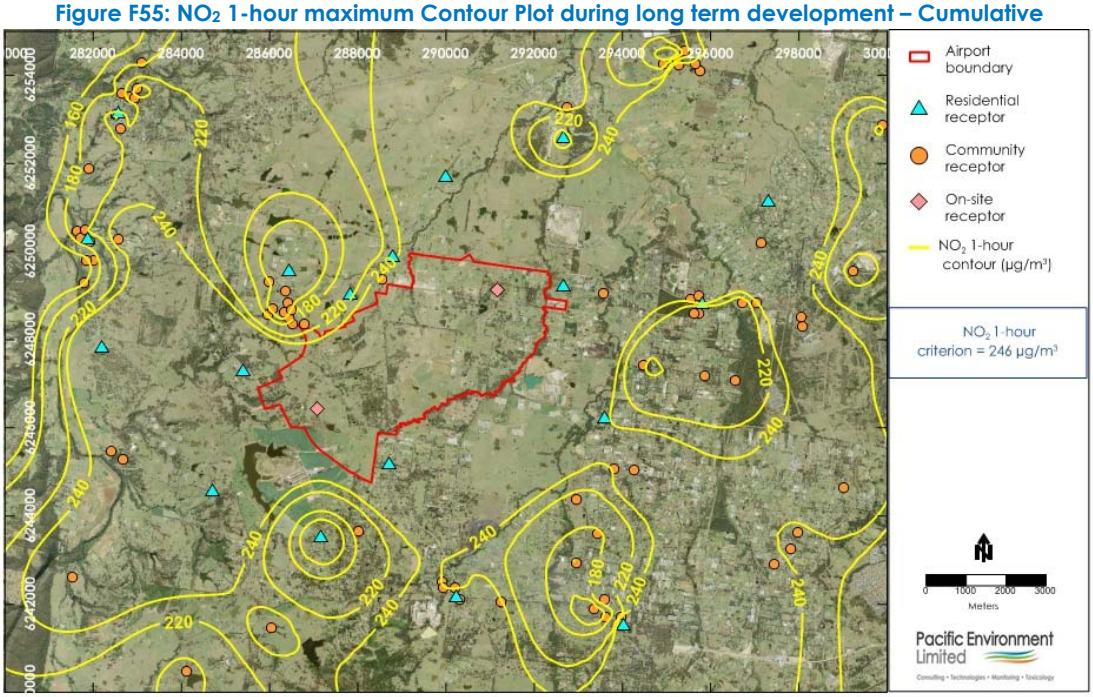
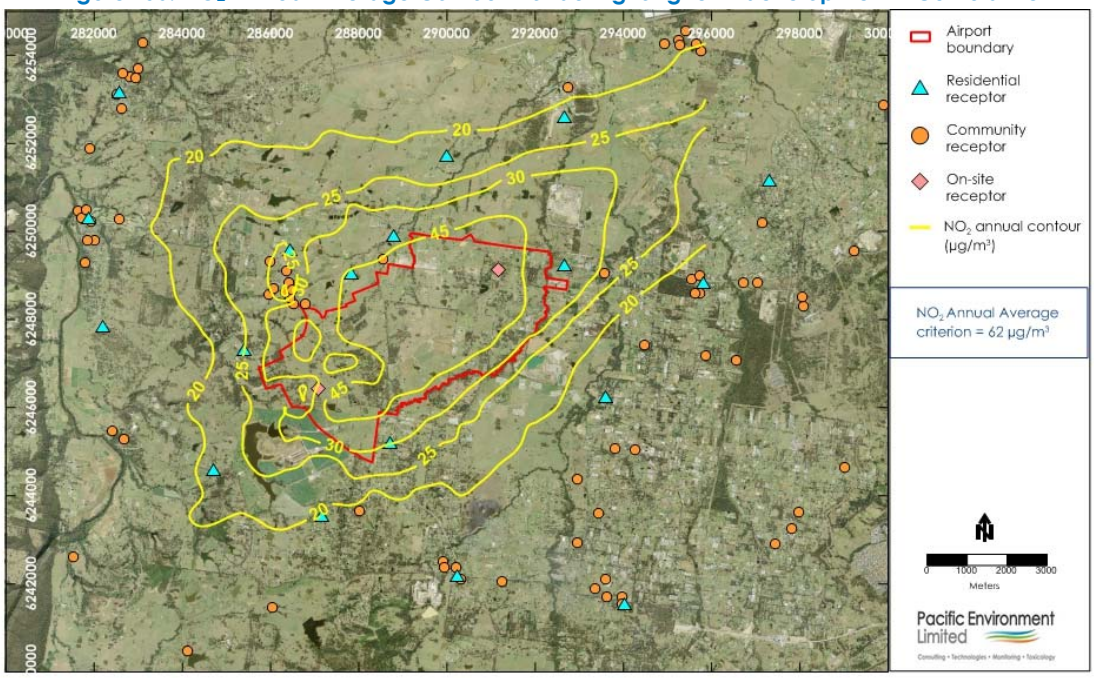


Figure F56: NO_2 Annual Average Contour Plot during long term development – Cumulative



F.2.2 Particulate matter PM_{10}

Table F10: Predicted incremental and cumulative PM_{10} concentrations during longer term development

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*50*	*30*
R1	Bringelly	3.7	0.1	13.7	1.9	46	19
R2	Luddenham	1.7	0.3	3.6	0.7	43	18
R3	Greendale, Greendale Road	5.7	0.3	7.3	0.6	43	18
R4	Kemps Creek	2.6	0.2	14.7	3.7	48	21
R6	Mulgoa	1.8	0.1	4.5	0.4	43	17
R7	Wallacia	1.3	0.1	2.6	0.4	43	17
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	2.2	0.2	4.4	1.2	45	18
R14	Lawson Road, Badgerys Creek	9.6	0.7	15.8	3.1	47	20
R15	Mersey Rd, Greendale	6.1	0.5	8.6	1.3	46	18
R17	Luddenham Road	3.4	0.2	6.9	1.2	45	18
R18	Cnr Adams & Elizabeth Drive	5.3	0.6	9.4	1.7	46	19
R19	Cnr Adams & Anton Road	5.3	0.8	6.9	1.4	45	18
R21	Cnr Willowdene Ave and Vicar Park Lane	5.9	0.3	6.9	0.9	44	18

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*50*	*30*
R22	Rossmore, Victor Ave	4.1	0.2	7.7	1.3	46	18
R23	Wallacia, Greendale Rd	2.3	0.1	3.7	0.4	43	17
R24	Badgerys Creek 1 NE	31.6	8.9	40.9	11.2	72	28
R25	Badgerys Creek 2 SW	3.6	0.5	5.1	1.2	43	18
R27	Greendale, Dwyer Rd	1.4	0.1	2.6	0.4	43	17
R30	Rossmore residential	1.7	0.1	24.0	5.0	49	22
R31	Mt Vernon residential	4.2	0.2	6.5	1.1	44	18
R34	Emmaus Residential Aged Care	2.3	0.2	6.9	1.7	44	19
R35	Mamre After School and Vacation Care	2.1	0.2	5.5	1.4	45	18
R36	Head Start After School Care	1.7	0.1	13.7	2.4	50	19
R37	Schoolies at Mulgoa	1.9	0.3	3.6	0.9	44	18
R38	Do-re-mi Day Care Centre	3.5	0.2	8.3	1.7	45	19
R39	Little Amigos Austral Early Learning Centre	3.9	0.1	7.5	1.2	45	18
R40	Little Smarties Childcare Centre	2.8	0.2	6.8	1.4	45	18
R41	The Grove Academy	2.9	0.1	6.9	1.2	45	18
R42	Horsley Kids	2.0	0.1	3.1	0.7	43	18
R44	Bringelly Child Care Centre	2.6	0.2	4.4	0.6	43	18
R46	Clementson Drive Early Educational Centre	4.1	0.1	9.1	1.4	46	18
R48	Kids Korner West Hoxton Early Learning Centre	1.8	0.1	8.2	1.1	45	18
R49	Luddenham Child Care Centre	1.5	0.2	3.4	0.7	43	18
R52	The Frogs Lodge	3.3	0.1	8.2	1.4	47	18
R53	Rossmore Community Preschool	1.6	0.1	17.2	2.9	47	20
R54	Mulgoa Preschool	2.2	0.1	3.9	0.5	43	17
R55	Jillys Educational Childcare Centre	3.2	0.1	6.9	1.1	46	18
R57	Wallacia Progress Hall	1.5	0.1	2.6	0.4	43	17
R59	Bringelly Community Centre	4.8	0.2	9.8	1.4	45	18
R63	Luddenham Progress Hall	1.2	0.2	2.5	0.5	43	18
R64	Mulgoa Hall	2.2	0.1	4.0	0.5	43	17
R65	Emmaus Catholic College	2.1	0.2	6.0	1.4	44	18
R66	University of Sydney Farms	3.8	0.1	6.7	0.5	43	17
R68	Christadelphian Heritage College Sydney	3.4	0.2	9.2	1.6	45	19
R69	Mamre Anglican School	2.1	0.2	5.4	1.4	45	18
R72	Irfan College	1.6	0.1	12.6	3.1	45	20
R73	Luddenham Public School	1.6	0.3	3.4	0.7	43	18
R74	Kemps Creek Public School	3.8	0.2	8.1	1.4	44	18
R75	Trinity Catholic Primary School	2.0	0.2	5.3	1.5	45	18

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*50*	*30*
R76	Bringelly Public School	3.9	0.2	16.4	2.6	49	20
R78	Mulgoa Public School	1.9	0.1	3.8	0.4	43	17
R79	Rossmore Public School	1.7	0.1	8.2	2.5	46	19
R80	Wallacia Public School	1.4	0.1	2.5	0.4	43	17
R82	Bellfield College - Junior Campus	2.4	0.1	6.4	1.5	45	18
R84	Bringelly Park	5.0	0.2	9.9	1.4	45	18
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	3.6	0.1	5.0	0.3	43	17
R86	Blaxland Crossing Reserve	1.2	0.1	2.4	0.4	43	17
R87	Bill Anderson Reserve	2.6	0.2	15.2	3.3	46	20
R88	Kemps Creek Nature Reserve	2.2	0.1	6.0	1.2	45	18
R91	Western Sydney Parklands	2.7	0.1	8.8	1.5	45	18
R93	Rossmore Grange	3.2	0.2	7.0	1.1	47	18
R94	Freeburn Park	1.8	0.3	3.8	0.7	43	18
R95	Overett Reserve	5.7	0.4	11.0	2.0	46	19
R97	Mulgoa Park	2.1	0.1	3.9	0.5	43	17
R98	Wallacia Bowling and Recreation Club	1.5	0.1	2.5	0.4	43	17
R99	Hubertus Country Club	7.2	0.8	9.6	1.6	45	19
R100	Sugarloaf Cobbitty Equestrian Club	4.0	0.1	6.0	0.4	43	17
R102	Panthers Wallacia	1.7	0.1	2.8	0.5	43	17
R103	Twin Creeks Golf and Country Club	2.1	0.2	4.7	1.1	45	18
R104	Sydney International Shooting Centre	2.8	0.1	12.9	1.6	45	19
R108	Luddenham Showground	1.6	0.2	3.7	0.7	44	18
R109	Kemps Creek Sporting and Bowling Club	2.2	0.1	29.7	5.5	**62**	22
R110	St James Luddenham	2.0	0.3	3.6	0.7	43	18
R111	Lin Ying temple	5.2	0.2	9.6	1.9	48	19
R112	Vat Ketanak Khmer Kampuchea Krom	2.7	0.1	6.3	1.2	46	18
R114	Anglican Church Sydney Diocese	2.0	0.1	6.0	1.4	45	18
R115	Anglican Parish of Mulgoa	2.4	0.1	4.2	0.5	43	17
R117	Bringelly Vineyard Church	2.2	0.1	12.2	2.6	48	20
R118	Free Church of Tonga	3.7	0.1	5.0	0.4	43	17
R120	Our Lady Queen of Peace	3.4	0.2	10.2	2.1	46	19
R122	St Anthony	4.2	0.1	8.7	1.4	47	18
R123	St Marys Church	1.6	0.1	4.8	0.4	43	17
R124	Wallacia Christian Church	1.3	0.1	2.6	0.4	43	17
R126	St Francis Xavier Church	3.3	0.1	5.8	0.4	43	17
R127	Luddenham Uniting Church	1.0	0.2	2.2	0.5	43	17

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*50*	*30*
R130	Hopewood Health Retreat	1.5	0.1	2.9	0.4	43	17
R131	Science of the Soul Study Centre	2.3	0.1	30.2	5.3	**61**	22
R132	Bringelly shops	3.3	0.1	12.4	1.7	46	19
R134	Kemps Creek shops	2.4	0.2	10.7	2.3	46	19
R135	Luddenham shops	2.0	0.3	3.5	0.7	43	18
R136	Mulgoa shops	1.8	0.1	4.7	0.4	43	17
R137	Rossmore shops	1.9	0.1	8.5	2.5	46	19
R138	Wallacia Shops	1.3	0.1	2.5	0.4	43	17
R140	Holy Family Catholic Primary and Church	2.1	0.3	5.3	1.3	45	18
R141	Edmund Rice Retreat and Conference Centre	1.2	0.1	2.9	0.4	43	17

Figure F57: PM_{10} 24-hours Contour Plot during long term development – Airport

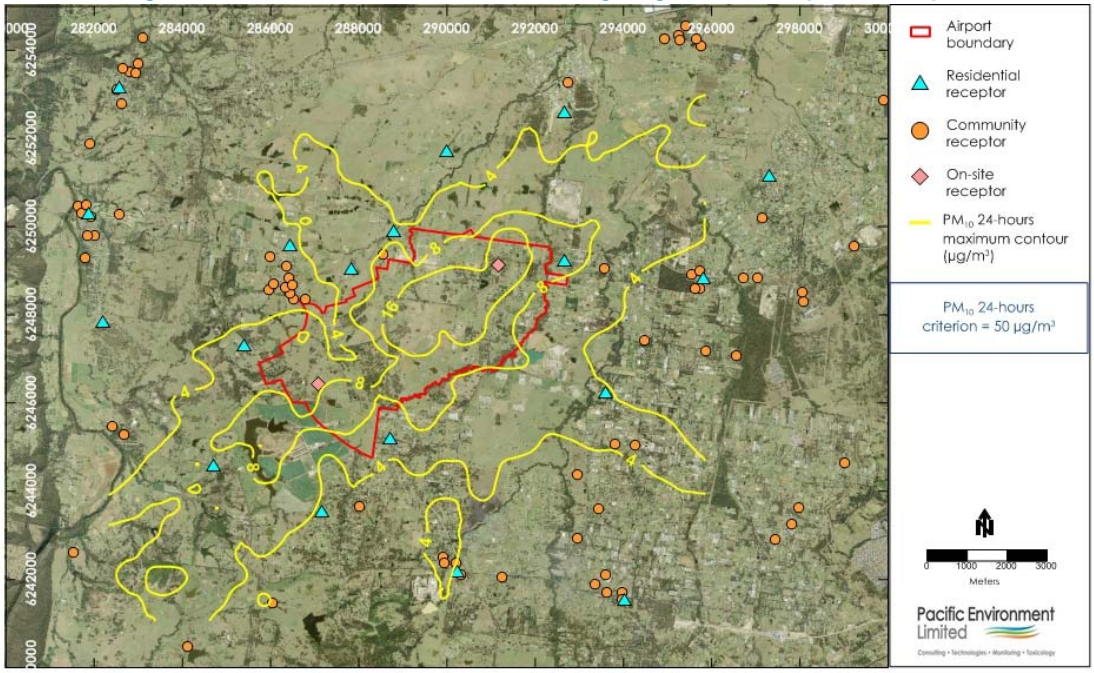


Figure F58: PM_{10} Annual Average Contour Plot during long term development – Airport

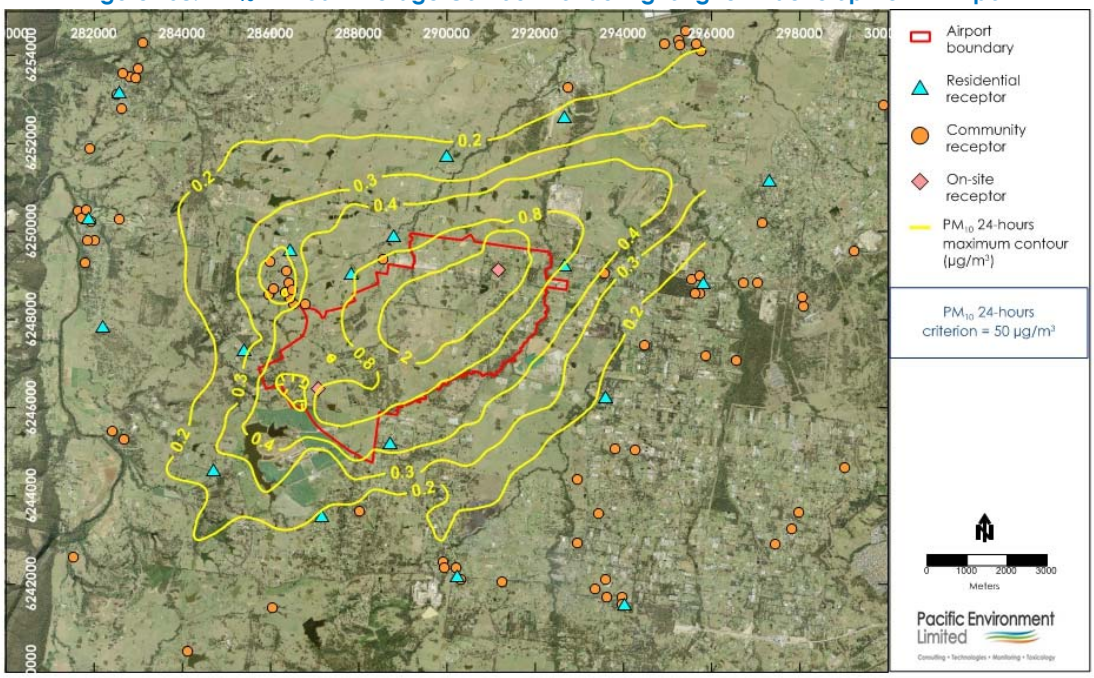


Figure F59: PM_{10} 24-hours Contour Plot during long term development – Airport + External Roadways

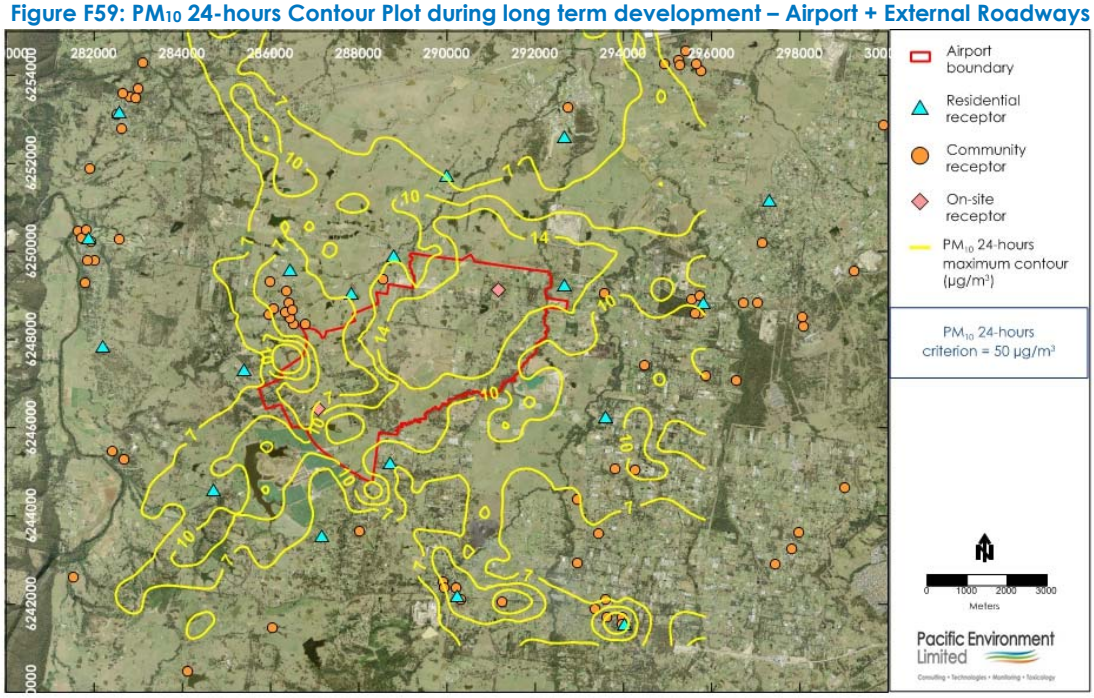


Figure F60: PM_{10} Annual Average Contour Plot during long term development – Airport + External Roadways

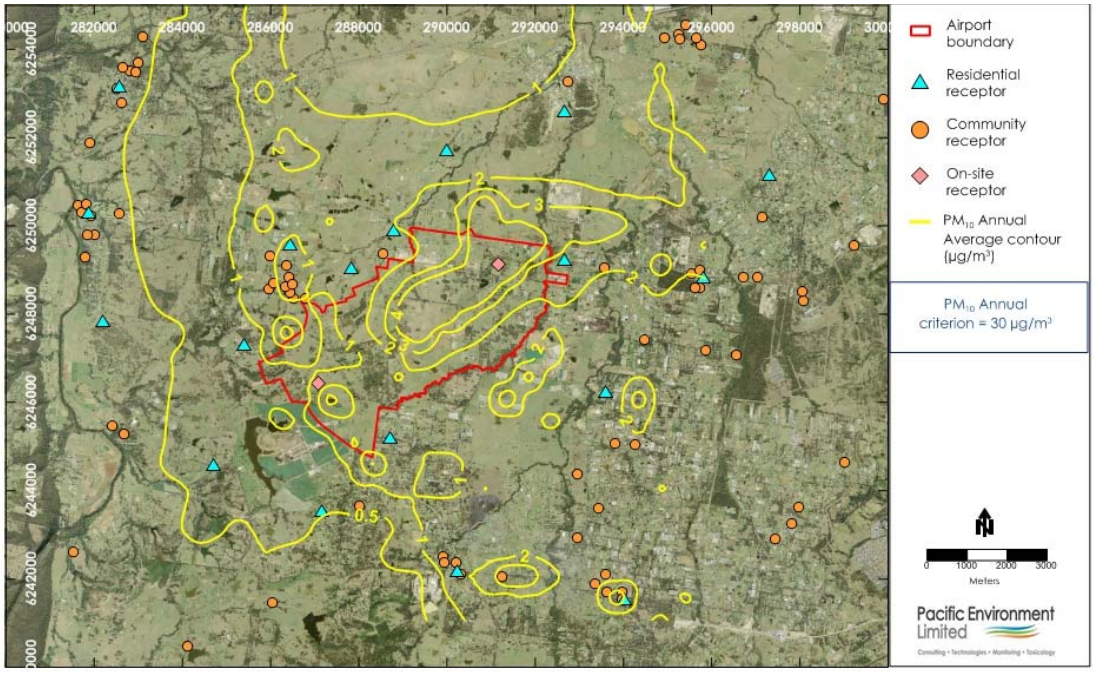


Figure F61: PM_{10} 24-hours Contour Plot during long term development – Cumulative

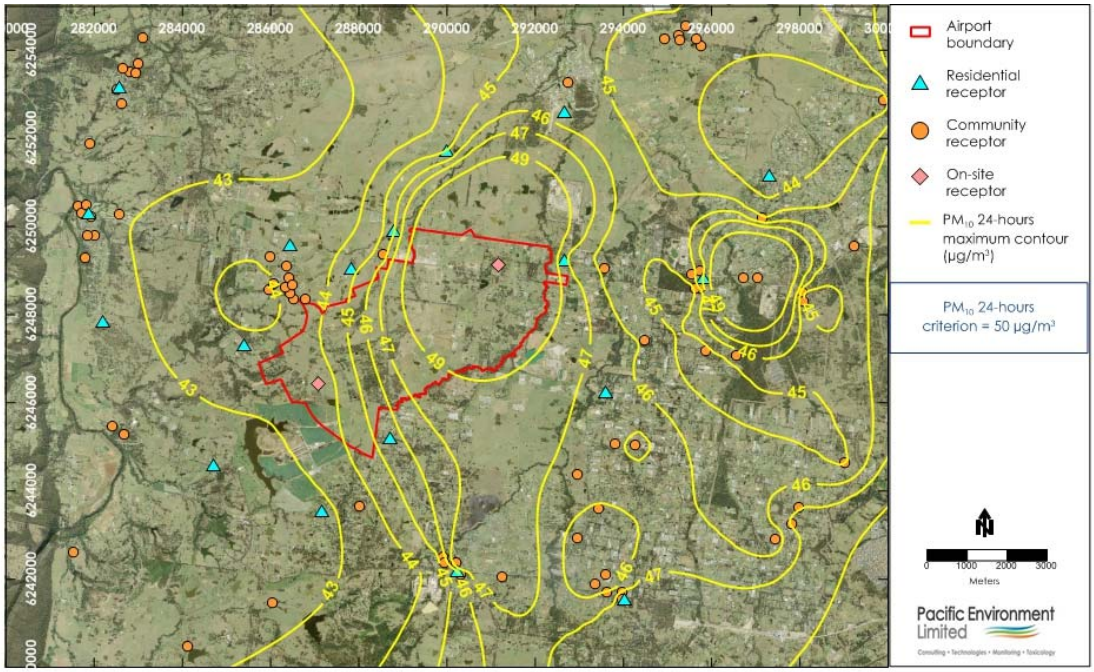
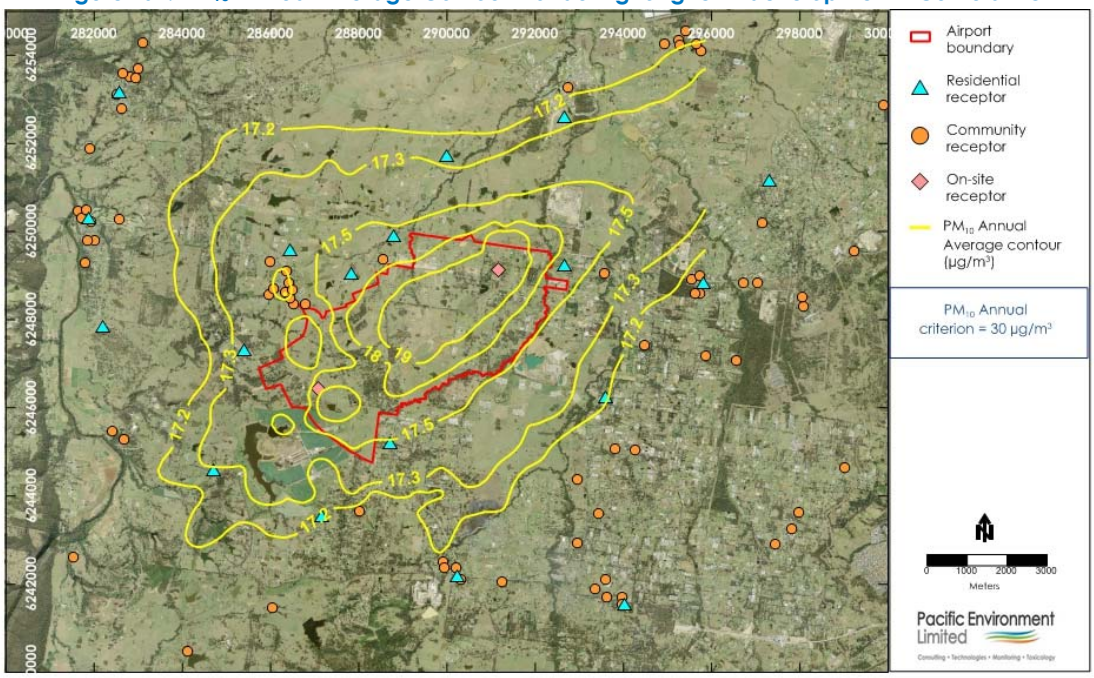


Figure F62: PM_{10} Annual Average Contour Plot during long term development - Cumulative



F.2.3 Particulate matter $PM_{2.5}$

Table F11: Predicted incremental and cumulative $PM_{2.5}$ concentrations during longer term development

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
NEPM-AAQ goal		*n/a*	*n/a*	*n/a*	*n/a*	*25*	*8*
R1	Bringelly	2.4	0.1	9.1	1.2	16	8
R2	Luddenham	1.5	0.2	2.4	0.5	14	8
R3	Greendale, Greendale Road	4.3	0.2	5.8	0.4	14	7
R4	Kemps Creek	2.0	0.1	8.4	2.1	18	9
R6	Mulgoa	1.6	0.1	3.2	0.3	13	7
R7	Wallacia	1.1	0.1	1.8	0.3	14	7
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	1.6	0.2	2.8	0.8	15	8
R14	Lawson Road, Badgerys Creek	6.8	0.6	11.3	2.1	18	9
R15	Mersey Rd, Greendale	4.6	0.5	6.6	1.0	16	8
R17	Luddenham Road	2.8	0.2	4.4	0.8	15	8
R18	Cnr Adams & Elizabeth Drive	3.8	0.5	6.6	1.1	16	8
R19	Cnr Adams & Anton Road	4.0	0.6	5.1	1.0	15	8
R21	Cnr Willowdene Ave and Vicar Park Lane	4.0	0.2	4.7	0.6	14	8
R22	Rossmore, Victor Ave	2.9	0.2	4.8	0.9	16	8

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
NEPM-AAQ goal		*n/a*	*n/a*	*n/a*	*n/a*	*25*	*8*
R23	Wallacia, Greendale Rd	1.7	0.1	2.5	0.3	14	7
R24	Badgerys Creek 1 NE	18.6	5.3	24.7	6.8	34	14
R25	Badgerys Creek 2 SW	2.3	0.4	3.3	0.9	14	8
R27	Greendale, Dwyer Rd	1.1	0.1	1.6	0.3	13	7
R30	Rossmore residential	1.2	0.1	15.9	3.4	23	10
R31	Mt Vernon residential	2.9	0.2	4.5	0.7	14	8
R34	Emmaus Residential Aged Care	1.5	0.2	4.4	1.1	14	8
R35	Mamre After School and Vacation Care	1.3	0.1	3.3	0.9	15	8
R36	Head Start After School Care	1.4	0.0	7.8	1.3	18	8
R37	Schoolies at Mulgoa	1.4	0.2	2.5	0.6	14	8
R38	Do-re-mi Day Care Centre	2.9	0.1	5.7	1.0	14	8
R39	Little Amigos Austral Early Learning Centre	2.9	0.1	5.0	0.8	15	8
R40	Little Smarties Childcare Centre	1.7	0.2	4.0	0.9	15	8
R41	The Grove Academy	2.2	0.1	4.6	0.8	15	8
R42	Horsley Kids	1.6	0.1	2.0	0.5	14	7
R44	Bringelly Child Care Centre	1.9	0.1	2.9	0.4	14	7
R46	Clementson Drive Early Educational Centre	3.0	0.1	5.6	0.9	16	8
R48	Kids Korner West Hoxton Early Learning Centre	1.4	0.1	5.0	0.7	15	8
R49	Luddenham Child Care Centre	1.3	0.2	2.5	0.4	14	7
R52	The Frogs Lodge	2.4	0.1	5.6	0.9	16	8
R53	Rossmore Community Preschool	1.1	0.1	11.4	2.0	19	9
R54	Mulgoa Preschool	1.9	0.1	3.0	0.3	13	7
R55	Jillys Educational Childcare Centre	2.5	0.1	4.7	0.7	16	8
R57	Wallacia Progress Hall	1.2	0.1	1.8	0.3	14	7
R59	Bringelly Community Centre	3.4	0.1	6.4	0.9	15	8
R63	Luddenham Progress Hall	1.0	0.2	1.8	0.4	14	7
R64	Mulgoa Hall	1.9	0.1	3.0	0.3	14	7
R65	Emmaus Catholic College	1.4	0.1	3.8	0.9	14	8
R66	University of Sydney Farms	2.8	0.1	4.6	0.3	14	7
R68	Christadelphian Heritage College Sydney	2.7	0.1	6.0	1.0	16	8
R69	Mamre Anglican School	1.5	0.2	3.3	0.9	15	8
R72	Irfan College	1.2	0.1	6.6	1.6	15	9
R73	Luddenham Public School	1.2	0.2	2.4	0.5	14	7
R74	Kemps Creek Public School	2.9	0.1	5.5	0.9	16	8
R75	Trinity Catholic Primary School	1.2	0.1	3.1	0.9	15	8
R76	Bringelly Public School	2.5	0.1	10.2	1.7	18	9

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
NEPM-AAQ goal		*n/a*	*n/a*	*n/a*	*n/a*	*25*	*8*
R78	Mulgoa Public School	1.6	0.1	2.8	0.3	13	7
R79	Rossmore Public School	1.3	0.1	5.5	1.7	16	9
R80	Wallacia Public School	1.2	0.1	1.8	0.3	14	7
R82	Bellfield College - Junior Campus	1.9	0.1	4.2	1.0	15	8
R84	Bringelly Park	3.6	0.1	6.4	0.9	15	8
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	2.6	0.1	3.4	0.2	13	7
R86	Blaxland Crossing Reserve	0.9	0.1	1.6	0.3	14	7
R87	Bill Anderson Reserve	1.9	0.1	8.7	1.8	18	9
R88	Kemps Creek Nature Reserve	1.7	0.1	4.0	0.8	15	8
R91	Western Sydney Parklands	2.2	0.1	5.7	0.9	16	8
R93	Rossmore Grange	2.6	0.1	4.8	0.7	16	8
R94	Freeburn Park	1.5	0.2	2.7	0.5	14	7
R95	Overett Reserve	4.1	0.3	7.6	1.4	16	8
R97	Mulgoa Park	1.8	0.1	3.0	0.3	14	7
R98	Wallacia Bowling and Recreation Club	1.1	0.1	1.8	0.3	14	7
R99	Hubertus Country Club	5.4	0.6	6.9	1.1	16	8
R100	Sugarloaf Cobbitty Equestrian Club	2.9	0.1	4.1	0.2	14	7
R102	Panthers Wallacia	1.4	0.1	2.1	0.3	14	7
R103	Twin Creeks Golf and Country Club	1.4	0.1	2.8	0.7	15	8
R104	Sydney International Shooting Centre	2.2	0.1	7.8	0.9	18	8
R108	Luddenham Showground	1.3	0.2	2.6	0.5	14	7
R109	Kemps Creek Sporting and Bowling Club	1.7	0.1	16.0	2.9	26	10
R110	St James Luddenham	1.6	0.2	2.5	0.5	14	8
R111	Lin Ying temple	4.0	0.1	6.0	1.2	17	8
R112	Vat Ketanak Khmer Kampuchea Krom	2.1	0.1	3.8	0.8	15	8
R114	Anglican Church Sydney Diocese	1.5	0.1	4.1	0.9	15	8
R115	Anglican Parish of Mulgoa	2.0	0.1	3.2	0.3	13	7
R117	Bringelly Vineyard Church	1.7	0.1	8.1	1.7	18	9
R118	Free Church of Tonga	2.6	0.1	3.4	0.3	13	7
R120	Our Lady Queen of Peace	2.4	0.1	6.6	1.4	16	8
R122	St Anthony	3.3	0.1	6.3	0.9	16	8
R123	St Marys Church	1.4	0.1	3.4	0.3	14	7
R124	Wallacia Christian Church	1.1	0.1	1.8	0.3	14	7
R126	St Francis Xavier Church	2.4	0.1	4.2	0.3	13	7
R127	Luddenham Uniting Church	0.8	0.1	1.5	0.3	14	7
R130	Hopewood Health Retreat	1.2	0.1	1.9	0.3	14	7

Receptor	Receptor location	Airport (µg/m³)		Airport + external roadways (µg/m³)		Cumulative (µg/m³)	
		24-hour	Annual	24-hour	Annual	24-hour	Annual
NEPM-AAQ goal		*n/a*	*n/a*	*n/a*	*n/a*	*25*	*8*
R131	Science of the Soul Study Centre	1.8	0.1	15.9	2.8	25	10
R132	Bringelly shops	2.1	0.1	8.2	1.1	16	8
R134	Kemps Creek shops	1.8	0.1	6.4	1.4	16	8
R135	Luddenham shops	1.6	0.3	2.4	0.5	14	8
R136	Mulgoa shops	1.5	0.1	3.3	0.3	13	7
R137	Rossmore shops	1.5	0.1	5.7	1.6	16	9
R138	Wallacia Shops	1.0	0.1	1.7	0.3	14	7
R140	Holy Family Catholic Primary and Church	1.6	0.2	3.1	0.8	15	8
R141	Edmund Rice Retreat and Conference Centre	1.0	0.1	1.8	0.3	13	7

Figure F63: $PM_{2.5}$ 24-hours Contour Plot during long term development – Airport

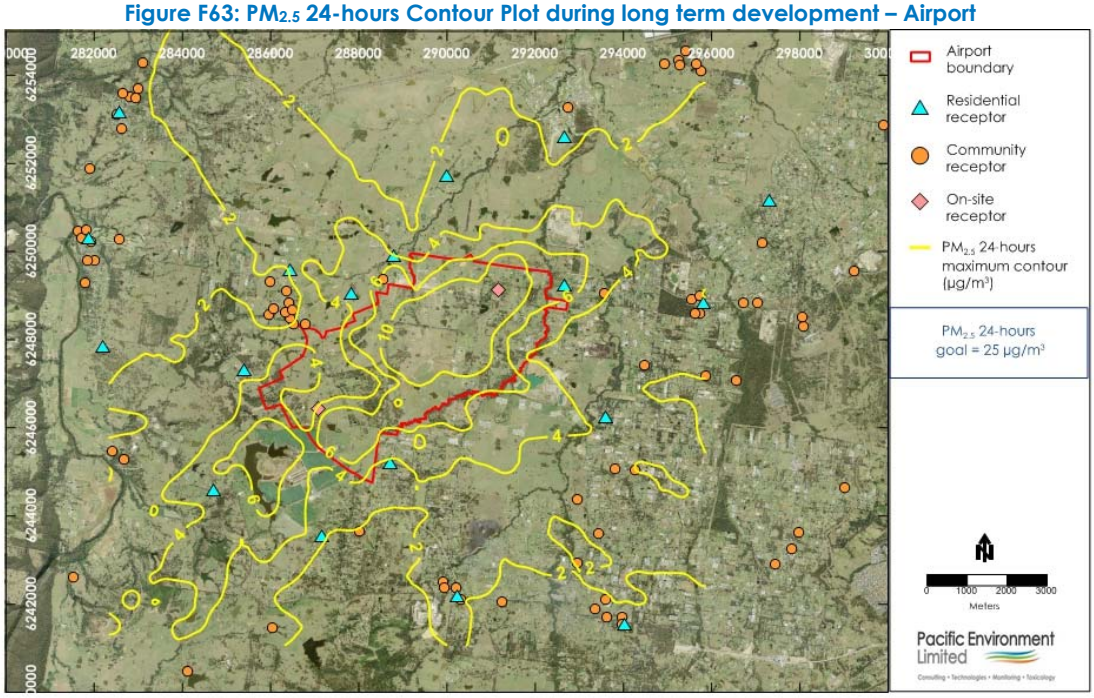


Figure F64: $PM_{2.5}$ Annual Average Contour Plot during long term development – Airport

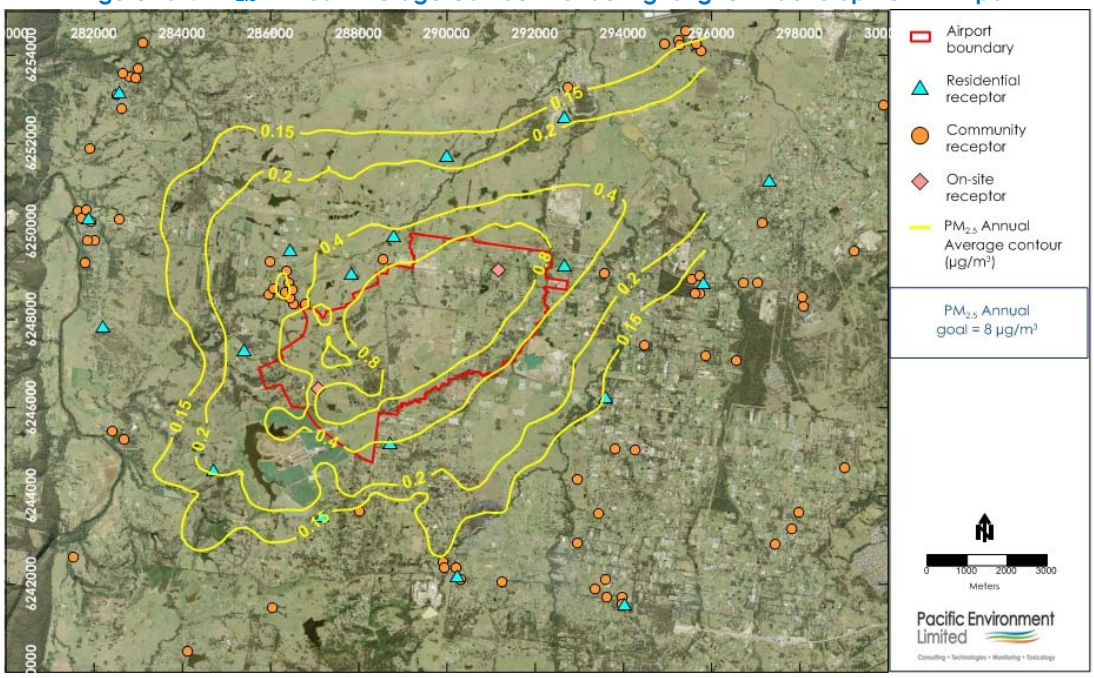


Figure F65: $PM_{2.5}$ 24-hours Contour Plot during long term development – Airport + External Roadways

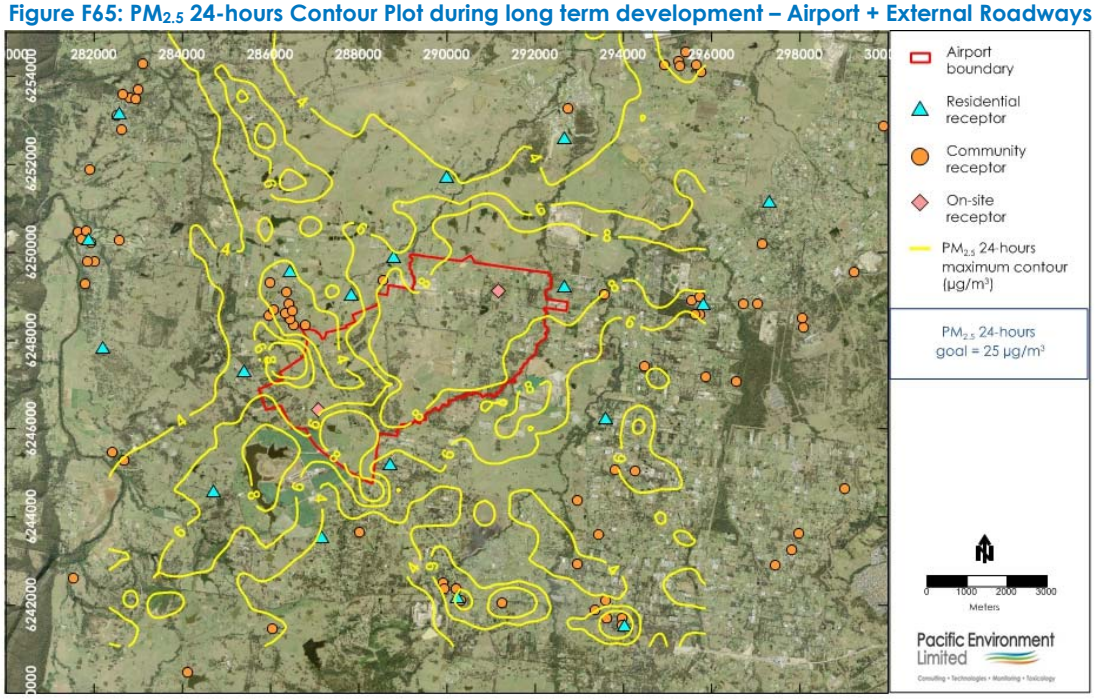


Figure F66: $PM_{2.5}$ Annual Average Contour Plot during long term development – Airport + External Roadways

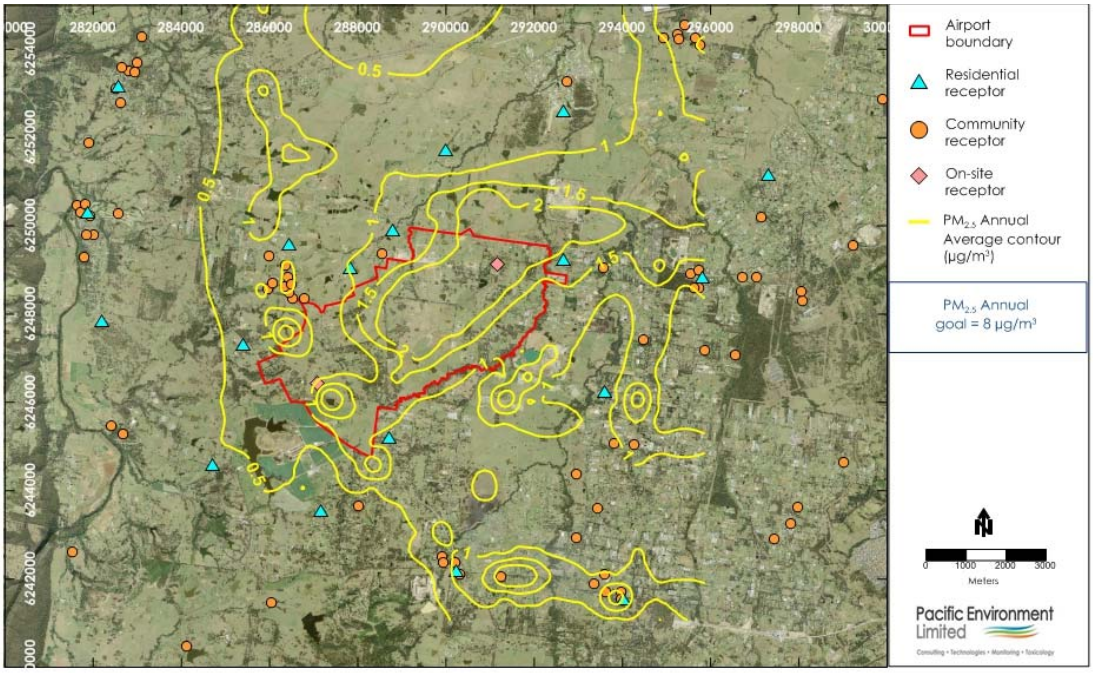


Figure F67: $PM_{2.5}$ 24-hours Contour Plot during long term development – Cumulative

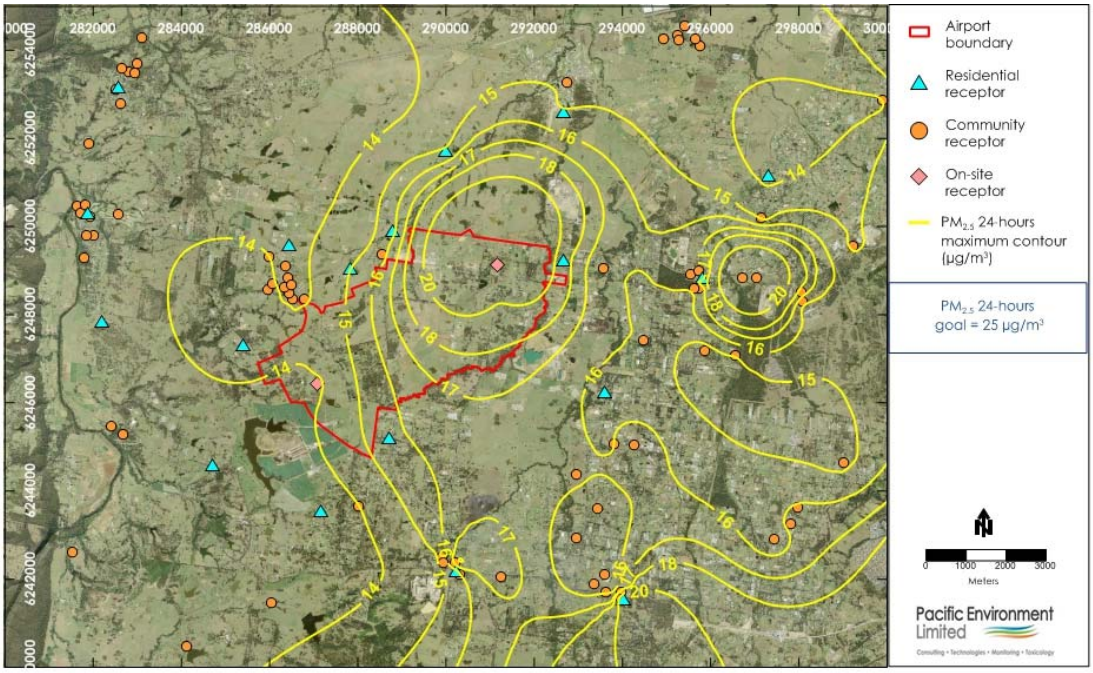
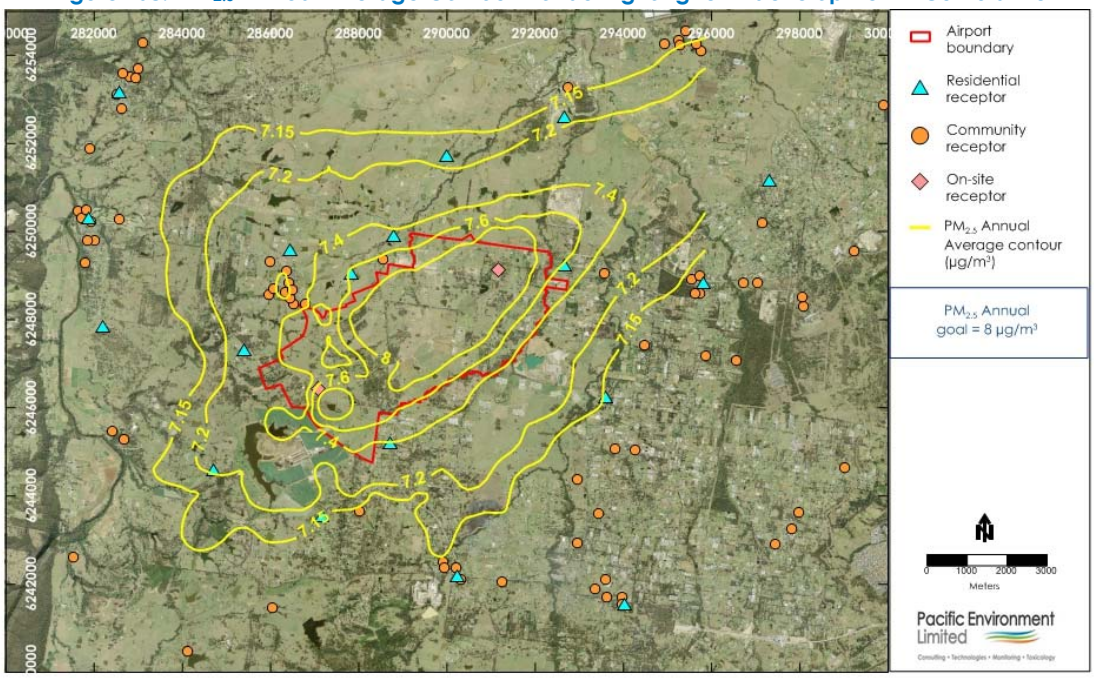


Figure F68: PM $_{2.5}$ Annual Average Contour Plot during long term development - Cumulative



Appendix G TABULATED RESULTS AND CONTOUR PLOTS DURING CONSTRUCTION

G.1.1 Bulk earthworks

Table G1: Predicted incremental results during bulk earthworks

Receptor ID	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	Annual	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*2*
R1	Bringelly	1.0	0.1	0.4	0.0	1.E-05
R2	Luddenham	2.1	0.3	0.5	0.1	7.E-05
R3	Greendale, Greendale Road	2.7	0.1	1.4	0.1	2.E-05
R4	Kemps Creek	1.3	0.1	0.8	0.0	2.E-05
R6	Mulgoa	0.4	0.1	0.2	0.0	1.E-05
R7	Wallacia	0.6	0.1	0.3	0.0	1.E-05
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	2.0	0.3	0.7	0.1	5.E-05
R14	Lawson Road, Badgerys Creek	4.8	0.6	2.0	0.2	1.E-04
R15	Mersey Rd, Greendale	3.3	0.4	1.2	0.1	5.E-05
R17	Luddenham Road	2.2	0.3	0.6	0.1	6.E-05
R18	Cnr Adams & Elizabeth Drive	6.5	1.0	1.8	0.2	2.E-04
R19	Cnr Adams & Anton Road	7.2	0.9	2.1	0.2	2.E-04
R21	Cnr Willowdene Ave and Vicar Park Lane	2.9	0.5	0.7	0.1	1.E-04
R22	Rossmore, Victor Ave	1.4	0.1	0.7	0.0	2.E-05
R23	Wallacia, Greendale Rd	0.8	0.1	0.3	0.0	2.E-05
R24	Badgerys Creek 1 NE	68.4	6.3	15.6	1.3	1.E-03
R25	Badgerys Creek 2 SW	39.4	3.8	5.0	0.6	8.E-04
R27	Greendale, Dwyer Rd	1.2	0.2	0.4	0.0	3.E-05
R30	Rossmore residential	0.7	0.1	0.3	0.0	7.E-06
R31	Mt Vernon residential	1.8	0.1	1.0	0.0	2.E-05
R34	Emmaus Residential Aged Care	1.3	0.2	0.6	0.1	3.E-05
R35	Mamre After School and Vacation Care	1.4	0.2	0.4	0.1	3.E-05
R36	Head Start After School Care	0.5	0.0	0.3	0.0	5.E-06
R37	Schoolies at Mulgoa	2.6	0.4	0.6	0.1	8.E-05
R38	Do-re-mi Day Care Centre	1.1	0.1	0.6	0.0	2.E-05
R39	Little Amigos Austral Early Learning Centre	0.4	0.0	0.3	0.0	6.E-06
R40	Little Smarties Childcare Centre	1.4	0.2	0.4	0.1	3.E-05
R41	The Grove Academy	1.0	0.1	0.4	0.0	1.E-05
R42	Horsley Kids	0.6	0.1	0.5	0.0	1.E-05
R44	Bringelly Child Care Centre	2.0	0.2	0.6	0.1	3.E-05
R46	Clementson Drive Early Educational Centre	1.0	0.1	0.5	0.0	2.E-05
R48	Kids Korner West Hoxton Early Learning Centre	0.4	0.0	0.3	0.0	6.E-06
R49	Luddenham Child Care Centre	2.8	0.4	0.7	0.1	8.E-05
R52	The Frogs Lodge	0.5	0.0	0.5	0.0	6.E-06
R53	Rossmore Community Preschool	0.7	0.1	0.3	0.0	7.E-06
R54	Mulgoa Preschool	0.4	0.1	0.2	0.0	1.E-05
R55	Jillys Educational Childcare Centre	0.9	0.1	0.5	0.0	1.E-05
R57	Wallacia Progress Hall	0.6	0.1	0.3	0.0	2.E-05
R59	Bringelly Community Centre	1.0	0.1	0.4	0.0	1.E-05
R63	Luddenham Progress Hall	3.6	0.5	1.0	0.1	1.E-04
R64	Mulgoa Hall	0.4	0.1	0.3	0.0	1.E-05
R65	Emmaus Catholic College	1.3	0.2	0.4	0.1	3.E-05
R66	University of Sydney Farms	0.8	0.1	0.4	0.0	2.E-05
R68	Christadelphian Heritage College Sydney	1.9	0.1	0.7	0.0	2.E-05
R69	Mamre Anglican School	1.4	0.2	0.5	0.1	3.E-05

Receptor ID	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	Annual	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*2*
R72	Irfan College	1.1	0.1	0.4	0.0	9.E-06
R73	Luddenham Public School	4.6	0.5	1.0	0.1	1.E-04
R74	Kemps Creek Public School	2.2	0.1	0.6	0.0	2.E-05
R75	Trinity Catholic Primary School	1.4	0.2	0.4	0.1	2.E-05
R76	Bringelly Public School	1.0	0.1	0.4	0.0	1.E-05
R78	Mulgoa Public School	0.3	0.1	0.2	0.0	1.E-05
R79	Rossmore Public School	0.6	0.1	0.3	0.0	7.E-06
R80	Wallacia Public School	0.5	0.1	0.3	0.0	1.E-05
R82	Bellfield College - Junior Campus	0.7	0.1	0.3	0.0	8.E-06
R84	Bringelly Park	1.0	0.1	0.4	0.0	1.E-05
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	0.8	0.0	0.5	0.0	8.E-06
R86	Blaxland Crossing Reserve	0.5	0.1	0.3	0.0	1.E-05
R87	Bill Anderson Reserve	1.4	0.1	0.9	0.0	2.E-05
R88	Kemps Creek Nature Reserve	0.9	0.1	0.3	0.0	1.E-05
R91	Western Sydney Parklands	1.0	0.1	0.6	0.0	9.E-06
R93	Rossmore Grange	1.0	0.1	0.6	0.0	1.E-05
R94	Freeburn Park	2.4	0.4	0.7	0.1	1.E-04
R95	Overett Reserve	2.9	0.3	1.4	0.1	5.E-05
R97	Mulgoa Park	0.4	0.1	0.3	0.0	1.E-05
R98	Wallacia Bowling and Recreation Club	0.6	0.1	0.3	0.0	2.E-05
R99	Hubertus Country Club	6.9	1.4	2.0	0.3	3.E-04
R100	Sugarloaf Cobbitty Equestrian Club	0.6	0.1	0.3	0.0	1.E-05
R102	Panthers Wallacia	0.7	0.1	0.3	0.0	2.E-05
R103	Twin Creeks Golf and Country Club	1.4	0.2	0.5	0.1	3.E-05
R104	Sydney International Shooting Centre	0.8	0.1	0.5	0.0	9.E-06
R108	Luddenham Showground	2.5	0.3	0.6	0.1	6.E-05
R109	Kemps Creek Sporting and Bowling Club	1.0	0.1	0.5	0.0	1.E-05
R110	St James Luddenham	6.0	0.7	1.1	0.1	1.E-04
R111	Lin Ying temple	1.3	0.1	0.5	0.0	1.E-05
R112	Vat Ketanak Khmer Kampuchea Krom	0.8	0.1	0.5	0.0	1.E-05
R114	Anglican Church Sydney Diocese	0.9	0.1	0.4	0.0	7.E-06
R115	Anglican Parish of Mulgoa	0.4	0.1	0.2	0.0	9.E-06
R117	Bringelly Vineyard Church	0.9	0.1	0.4	0.0	1.E-05
R118	Free Church of Tonga	1.5	0.1	0.6	0.0	1.E-05
R120	Our Lady Queen of Peace	1.4	0.2	0.5	0.1	2.E-05
R122	St Anthony	0.5	0.0	0.4	0.0	6.E-06
R123	St Marys Church	0.5	0.1	0.3	0.0	1.E-05
R124	Wallacia Christian Church	0.6	0.1	0.3	0.0	1.E-05
R126	St Francis Xavier Church	1.8	0.1	0.8	0.0	1.E-05
R127	Luddenham Uniting Church	3.7	0.5	0.9	0.1	1.E-04
R130	Hopewood Health Retreat	0.6	0.1	0.3	0.0	2.E-05
R131	Science of the Soul Study Centre	1.1	0.1	0.5	0.0	1.E-05
R132	Bringelly shops	1.0	0.1	0.4	0.0	1.E-05
R134	Kemps Creek shops	1.4	0.1	0.7	0.0	2.E-05
R135	Luddenham shops	5.1	0.8	1.0	0.2	2.E-04
R136	Mulgoa shops	0.4	0.1	0.2	0.0	1.E-05

Receptor ID	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	Annual	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*2*
R137	Rossmore shops	0.7	0.1	0.3	0.0	7.E-06
R138	Wallacia Shops	0.6	0.1	0.3	0.0	1.E-05
R140	Holy Family Catholic Primary and Church	2.9	0.4	0.8	0.1	9.E-05
R141	Edmund Rice Retreat and Conference Centre	0.3	0.1	0.2	0.0	1.E-05

Figure G1: Incremental PM_{10} 24-hours Contour Plot during bulk earthworks

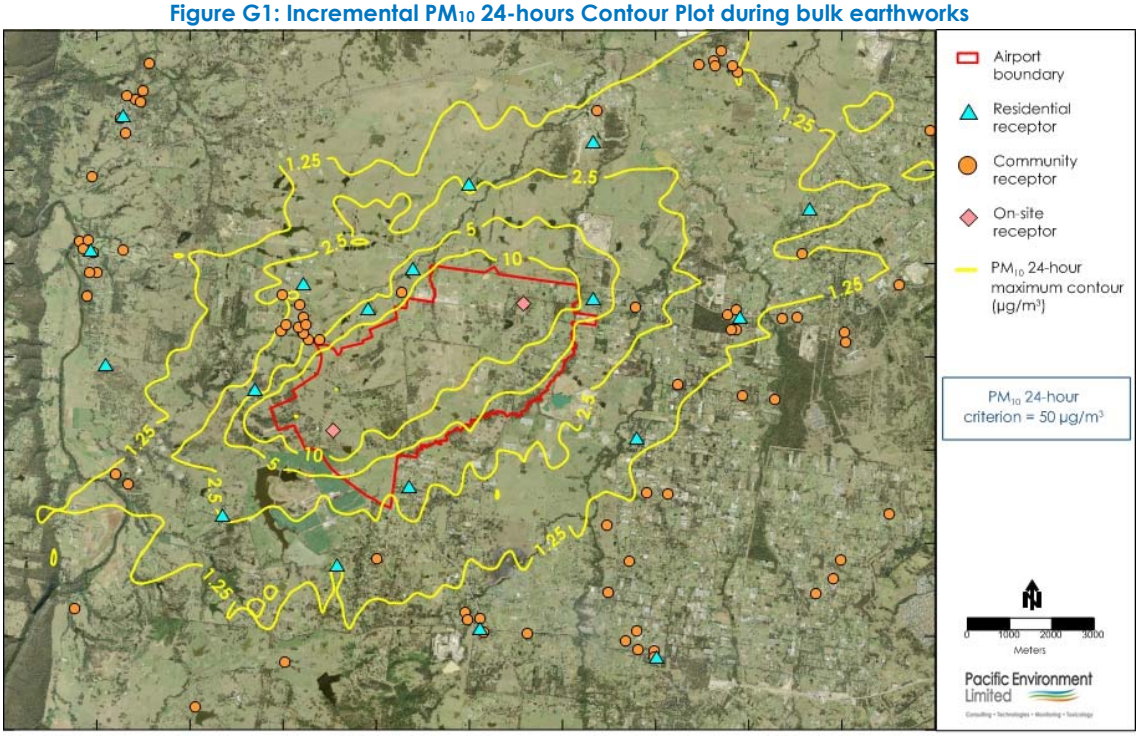


Figure G2: Incremental PM_{10} Annual Average Contour Plot during bulk earthworks

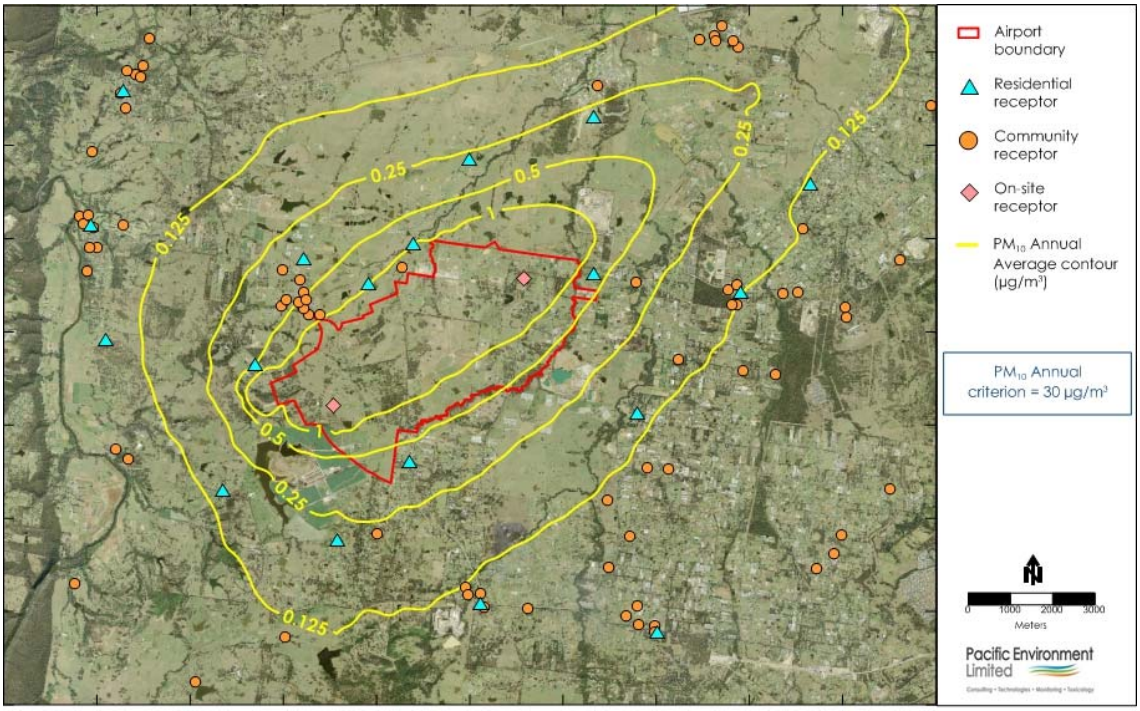


Figure G3: Incremental $PM_{2.5}$ 24-hours Contour Plot bulk earthworks

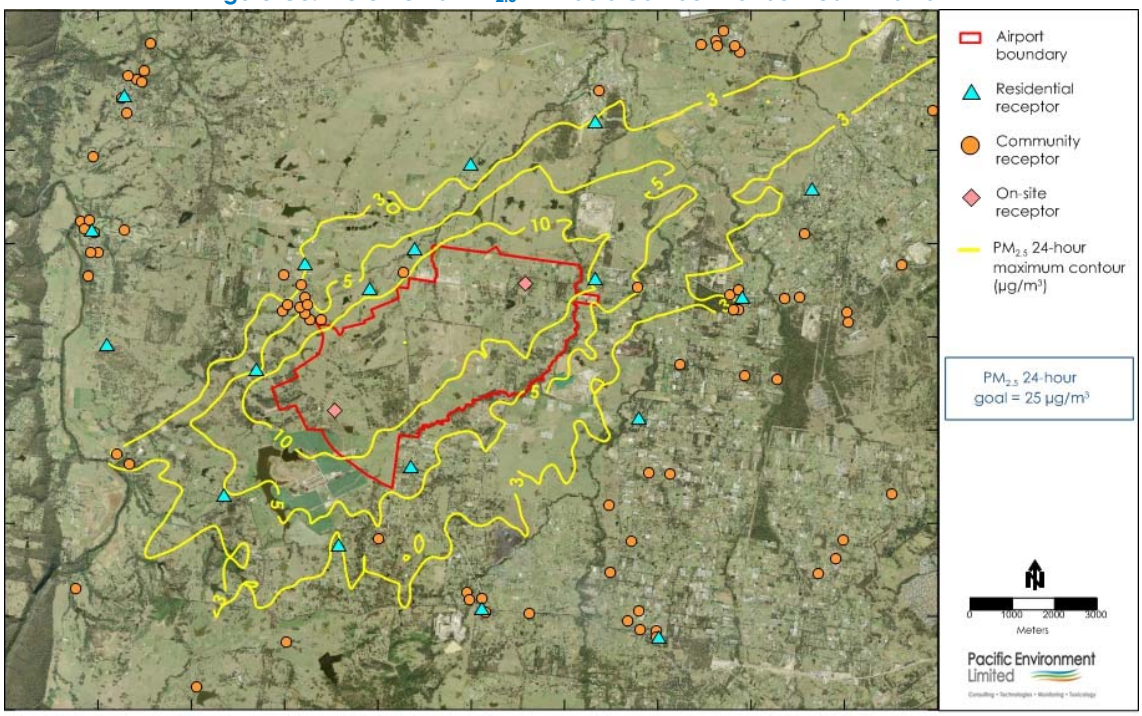


Figure G4: Incremental $PM_{2.5}$ Annual Average Contour Plot during bulk earthworks

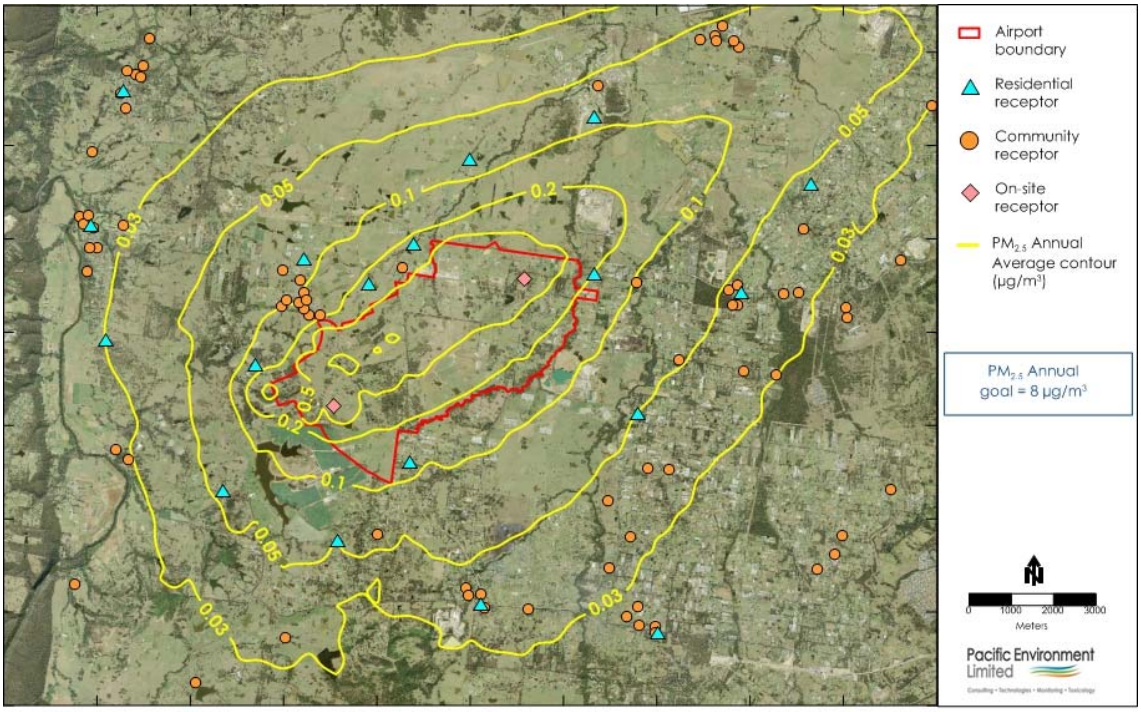


Figure G5: Incremental Dust deposition Annual Average Contour Plot during bulk earthworks

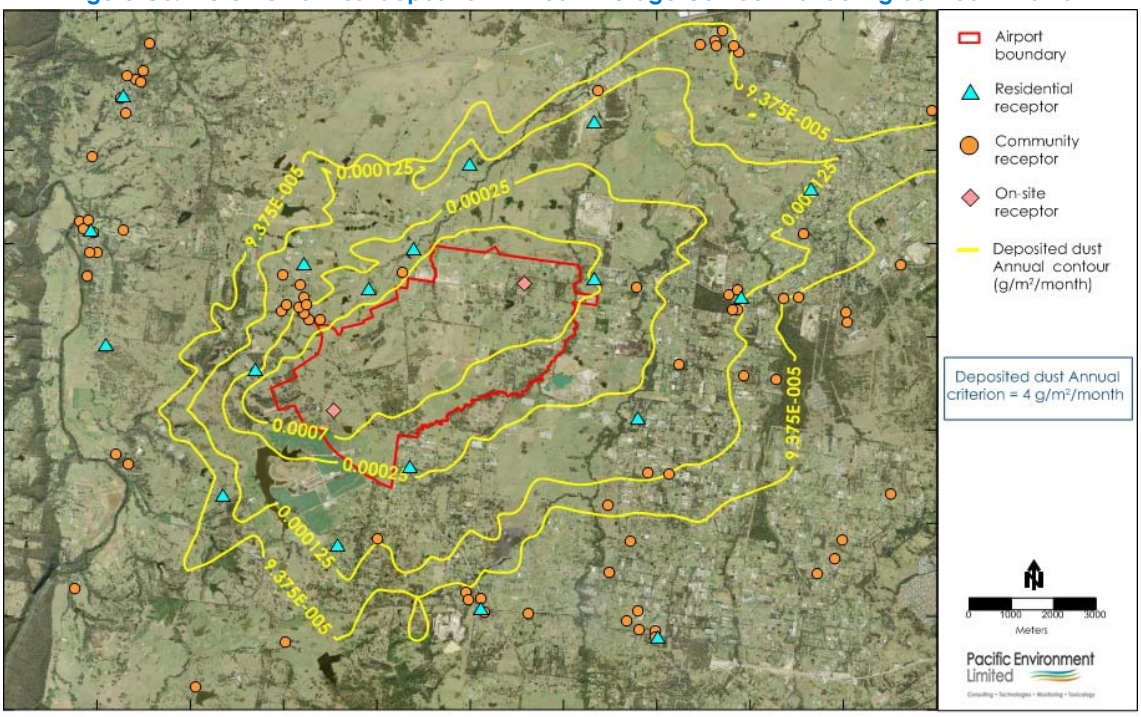


Table G2: Predicted cumulative results during site preparation works

Recept or ID	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	Annual	Annual
	Criterion	*50*	*30*	*25*	*8*	*4*
R1	Bringelly	43.0	17.1	13.5	7.0	2.0
R2	Luddenham	42.7	17.3	13.3	7.1	2.0
R3	Greendale, Greendale Road	42.7	17.1	13.3	7.1	2.0
R4	Kemps Creek	42.6	17.1	13.3	7.0	2.0
R6	Mulgoa	42.6	17.1	13.3	7.0	2.0
R7	Wallacia	42.6	17.1	13.3	7.0	2.0
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	43.4	17.3	13.5	7.1	2.0
R14	Lawson Road, Badgerys Creek	43.0	17.6	13.4	7.2	2.0
R15	Mersey Rd, Greendale	44.6	17.4	14.0	7.1	2.0
R17	Luddenham Road	44.2	17.3	13.7	7.1	2.0
R18	Cnr Adams & Elizabeth Drive	44.2	18.0	13.7	7.2	2.0
R19	Cnr Adams & Anton Road	43.9	17.9	13.6	7.2	2.0
R21	Cnr Willowdene Ave and Vicar Park Lane	42.9	17.5	13.4	7.1	2.0
R22	Rossmore, Victor Ave	42.7	17.1	13.3	7.0	2.0
R23	Wallacia, Greendale Rd	42.6	17.1	13.3	7.0	2.0
R24	Badgerys Creek 1 NE	90.4	23.3	22.5	8.3	2.0
R25	Badgerys Creek 2 SW	60.2	20.8	14.9	7.6	2.0
R27	Greendale, Dwyer Rd	43.0	17.2	13.4	7.0	2.0
R30	Rossmore residential	42.7	17.1	13.4	7.0	2.0
R31	Mt Vernon residential	42.6	17.1	13.3	7.0	2.0
R34	Emmaus Residential Aged Care	42.6	17.2	13.3	7.1	2.0
R35	Mamre After School and Vacation Care	42.6	17.2	13.3	7.1	2.0
R36	Head Start After School Care	42.6	17.0	13.3	7.0	2.0
R37	Schoolies at Mulgoa	42.7	17.4	13.3	7.1	2.0
R38	Do-re-mi Day Care Centre	42.6	17.1	13.3	7.0	2.0
R39	Little Amigos Austral Early Learning Centre	42.6	17.0	13.3	7.0	2.0
R40	Little Smarties Childcare Centre	42.6	17.2	13.3	7.1	2.0
R41	The Grove Academy	42.6	17.1	13.3	7.0	2.0
R42	Horsley Kids	42.6	17.1	13.3	7.0	2.0
R44	Bringelly Child Care Centre	44.0	17.2	13.9	7.1	2.0
R46	Clementson Drive Early Educational Centre	42.6	17.1	13.3	7.0	2.0
R48	Kids Korner West Hoxton Early Learning Centre	42.6	17.0	13.3	7.0	2.0
R49	Luddenham Child Care Centre	42.7	17.4	13.3	7.1	2.0
R52	The Frogs Lodge	42.6	17.0	13.3	7.0	2.0
R53	Rossmore Community Preschool	42.7	17.1	13.4	7.0	2.0
R54	Mulgoa Preschool	42.6	17.1	13.3	7.0	2.0
R55	Jillys Educational Childcare Centre	42.7	17.1	13.4	7.0	2.0
R57	Wallacia Progress Hall	42.6	17.1	13.3	7.0	2.0
R59	Bringelly Community Centre	43.0	17.1	13.5	7.0	2.0
R63	Luddenham Progress Hall	43.2	17.5	13.4	7.1	2.0
R64	Mulgoa Hall	42.6	17.1	13.3	7.0	2.0
R65	Emmaus Catholic College	42.6	17.2	13.3	7.1	2.0
R66	University of Sydney Farms	42.8	17.1	13.5	7.0	2.0
R68	Christadelphian Heritage College Sydney	42.6	17.1	13.3	7.0	2.0
R69	Mamre Anglican School	42.6	17.2	13.3	7.1	2.0
R72	Irfan College	42.6	17.1	13.3	7.0	2.0
R73	Luddenham Public School	44.7	17.5	13.6	7.1	2.0
R74	Kemps Creek Public School	42.6	17.1	13.3	7.0	2.0

Recept or ID	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	Annual	Annual
	Criterion	*50*	*30*	*25*	*8*	*4*
R75	Trinity Catholic Primary School	42.6	17.2	13.3	7.1	2.0
R76	Bringelly Public School	43.0	17.1	13.5	7.0	2.0
R78	Mulgoa Public School	42.6	17.1	13.3	7.0	2.0
R79	Rossmore Public School	42.7	17.1	13.4	7.0	2.0
R80	Wallacia Public School	42.6	17.1	13.3	7.0	2.0
R82	Bellfield College - Junior Campus	42.9	17.1	13.5	7.0	2.0
R84	Bringelly Park	43.0	17.1	13.6	7.0	2.0
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	42.6	17.0	13.3	7.0	2.0
R86	Blaxland Crossing Reserve	42.6	17.1	13.3	7.0	2.0
R87	Bill Anderson Reserve	42.6	17.1	13.3	7.0	2.0
R88	Kemps Creek Nature Reserve	42.6	17.1	13.3	7.0	2.0
R91	Western Sydney Parklands	42.6	17.1	13.3	7.0	2.0
R93	Rossmore Grange	42.8	17.1	13.5	7.0	2.0
R94	Freeburn Park	43.4	17.4	13.4	7.1	2.0
R95	Overett Reserve	42.7	17.3	13.3	7.1	2.0
R97	Mulgoa Park	42.6	17.1	13.3	7.0	2.0
R98	Wallacia Bowling and Recreation Club	42.6	17.1	13.3	7.0	2.0
R99	Hubertus Country Club	44.6	18.4	13.7	7.3	2.0
R100	Sugarloaf Cobbitty Equestrian Club	42.6	17.1	13.3	7.0	2.0
R102	Panthers Wallacia	42.6	17.1	13.3	7.0	2.0
R103	Twin Creeks Golf and Country Club	43.2	17.2	13.5	7.1	2.0
R104	Sydney International Shooting Centre	42.6	17.1	13.3	7.0	2.0
R108	Luddenham Showground	42.7	17.3	13.3	7.1	2.0
R109	Kemps Creek Sporting and Bowling Club	42.6	17.1	13.3	7.0	2.0
R110	St James Luddenham	42.9	17.7	13.4	7.1	2.0
R111	Lin Ying temple	42.6	17.1	13.3	7.0	2.0
R112	Vat Ketanak Khmer Kampuchea Krom	42.7	17.1	13.4	7.0	2.0
R114	Anglican Church Sydney Diocese	42.6	17.1	13.3	7.0	2.0
R115	Anglican Parish of Mulgoa	42.6	17.1	13.3	7.0	2.0
R117	Bringelly Vineyard Church	42.9	17.1	13.6	7.0	2.0
R118	Free Church of Tonga	42.6	17.1	13.3	7.0	2.0
R120	Our Lady Queen of Peace	42.7	17.2	13.3	7.1	2.0
R122	St Anthony	42.6	17.0	13.3	7.0	2.0
R123	St Marys Church	42.6	17.1	13.3	7.0	2.0
R124	Wallacia Christian Church	42.6	17.1	13.3	7.0	2.0
R126	St Francis Xavier Church	42.6	17.1	13.3	7.0	2.0
R127	Luddenham Uniting Church	44.0	17.5	13.5	7.1	2.0
R130	Hopewood Health Retreat	42.6	17.1	13.3	7.0	2.0
R131	Science of the Soul Study Centre	42.6	17.1	13.3	7.0	2.0
R132	Bringelly shops	43.0	17.1	13.5	7.0	2.0
R134	Kemps Creek shops	42.6	17.1	13.3	7.0	2.0
R135	Luddenham shops	42.9	17.8	13.4	7.2	2.0
R136	Mulgoa shops	42.6	17.1	13.3	7.0	2.0
R137	Rossmore shops	42.7	17.1	13.4	7.0	2.0
R138	Wallacia Shops	42.6	17.1	13.3	7.0	2.0
R140	Holy Family Catholic Primary and Church	42.7	17.4	13.4	7.1	2.0
R141	Edmund Rice Retreat and Conference Centre	42.6	17.1	13.3	7.0	2.0

Figure G6: Cumulative PM_{10} Annual Average Contour Plot during site preparation works.

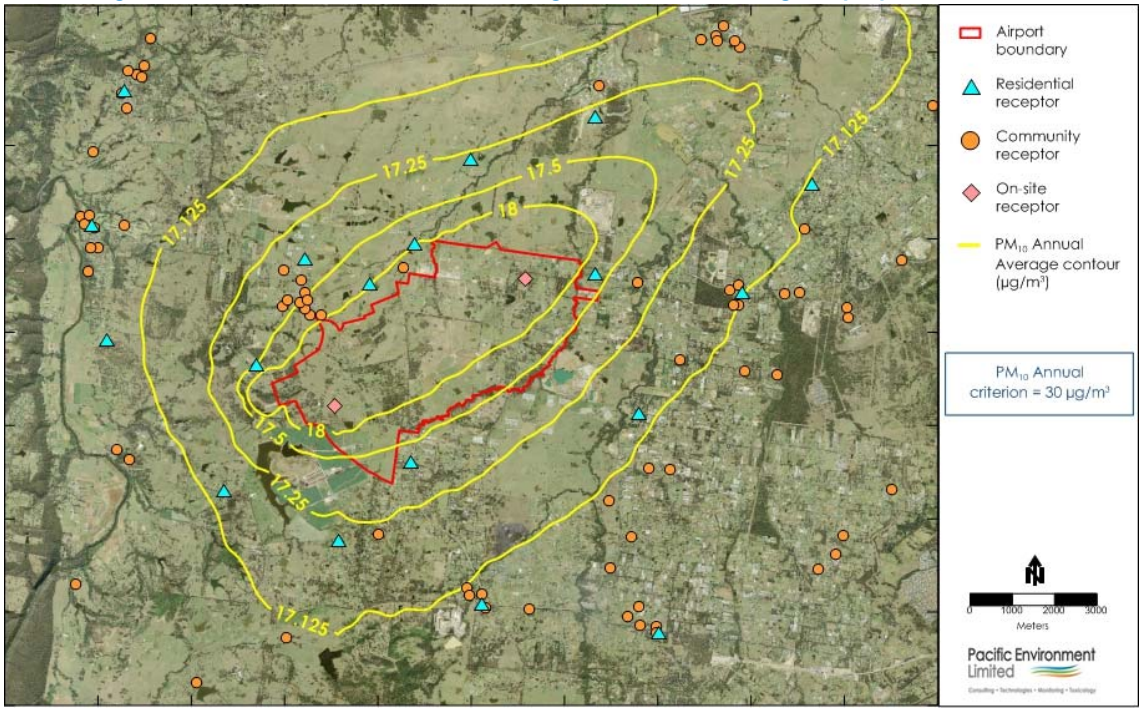


Figure G7: Cumulative $PM_{2.5}$ Annual Average Contour Plot during site preparation work

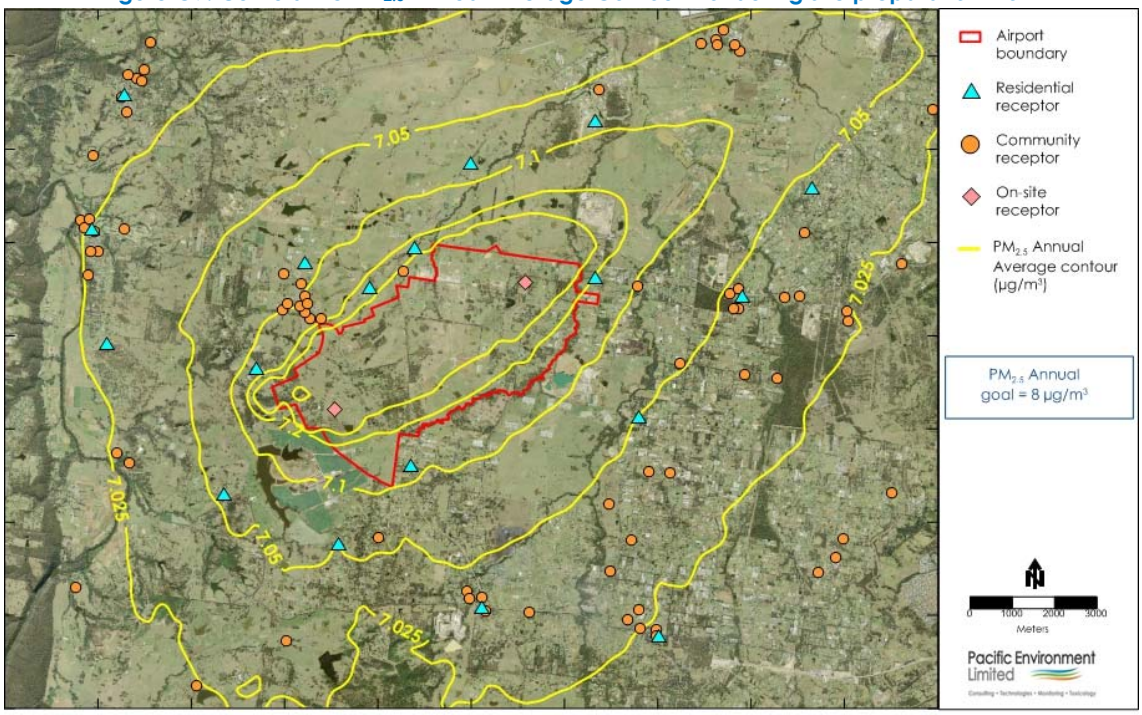
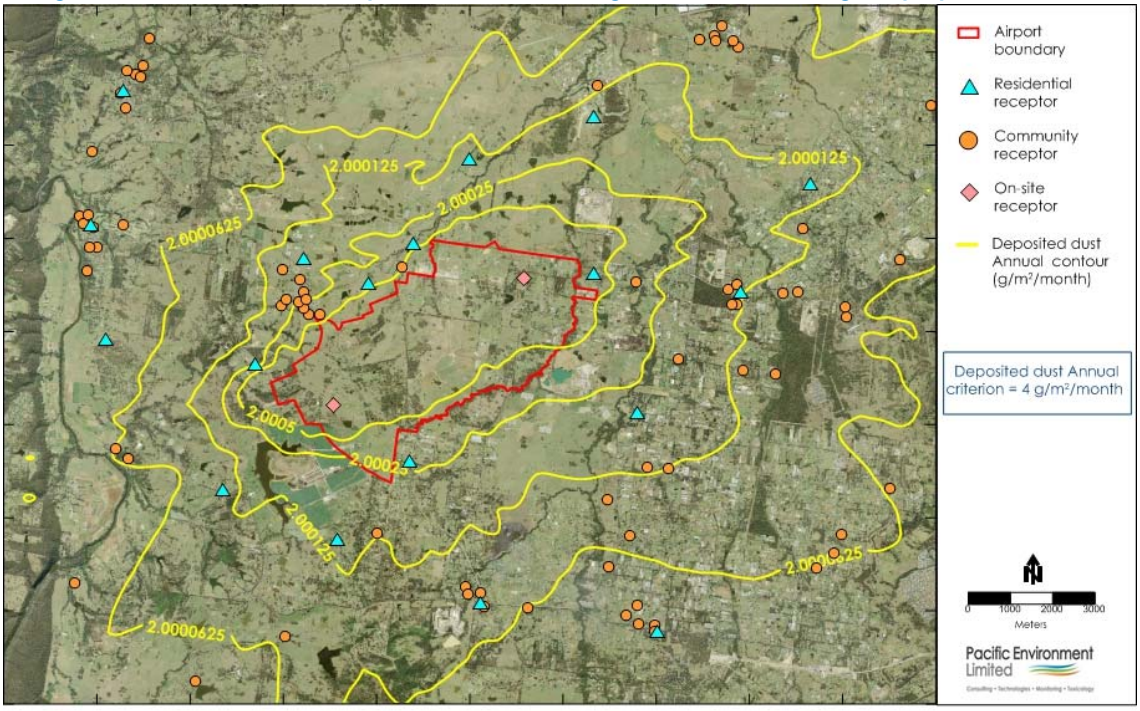


Figure G8: Cumulative Dust deposition Annual Average Contour Plot during site preparation works.



G.1.2 Aviation infrastructure

Table G3: Predicted incremental results during aviation infrastructure works

Receptor ID	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	24-hour	Annual
Criterion		*n/a*	*n/a*	*n/a*	*n/a*	*2*
R1	Bringelly	2.7	0.2	2.3	0.2	7.E-06
R2	Luddenham	2.7	0.4	2.4	0.3	4.E-05
R3	Greendale, Greendale Road	8.0	0.3	5.4	0.2	2.E-05
R4	Kemps Creek	11.0	0.2	2.8	0.2	1.E-05
R6	Mulgoa	1.3	0.1	0.7	0.1	7.E-06
R7	Wallacia	1.7	0.1	0.9	0.1	1.E-05
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	4.0	0.4	3.3	0.3	2.E-05
R14	Lawson Road, Badgerys Creek	25.4	1.2	6.6	0.7	5.E-05
R15	Mersey Rd, Greendale	7.3	0.6	5.9	0.5	3.E-05
R17	Luddenham Road	5.3	0.4	2.4	0.3	3.E-05
R18	Cnr Adams & Elizabeth Drive	11.0	1.1	7.8	1.0	1.E-04
R19	Cnr Adams & Anton Road	8.7	1.1	7.0	1.1	1.E-04
R21	Cnr Willowdene Ave and Vicar Park Lane	4.6	0.7	3.9	0.7	1.E-04
R22	Rossmore, Victor Ave	6.6	0.3	2.2	0.2	1.E-05
R23	Wallacia, Greendale Rd	2.1	0.2	1.2	0.2	1.E-05
R24	Badgerys Creek 1 NE	378.3	13.3	46.5	4.7	1.E-03
R25	Badgerys Creek 2 SW	38.7	4.3	29.0	5.4	9.E-04
R27	Greendale, Dwyer Rd	2.6	0.2	2.9	0.2	2.E-05
R30	Rossmore residential	2.3	0.1	1.5	0.1	4.E-06

Receptor ID	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	24-hour	Annual
	Criterion	*n/a*	*n/a*	*n/a*	*n/a*	*2*
R31	Mt Vernon residential	5.9	0.2	2.9	0.2	1.E-05
R34	Emmaus Residential Aged Care	2.6	0.3	2.4	0.2	1.E-05
R35	Mamre After School and Vacation Care	3.1	0.3	2.2	0.2	1.E-05
R36	Head Start After School Care	3.0	0.1	1.1	0.1	3.E-06
R37	Schoolies at Mulgoa	3.1	0.5	2.7	0.5	6.E-05
R38	Do-re-mi Day Care Centre	3.8	0.2	2.4	0.2	9.E-06
R39	Little Amigos Austral Early Learning Centre	2.7	0.1	0.9	0.1	4.E-06
R40	Little Smarties Childcare Centre	3.7	0.2	2.0	0.2	1.E-05
R41	The Grove Academy	6.5	0.2	1.4	0.1	8.E-06
R42	Horsley Kids	2.4	0.1	1.5	0.1	7.E-06
R44	Bringelly Child Care Centre	4.2	0.3	4.4	0.3	2.E-05
R46	Clementson Drive Early Educational Centre	2.4	0.2	1.9	0.1	8.E-06
R48	Kids Korner West Hoxton Early Learning Centre	3.2	0.1	0.8	0.1	4.E-06
R49	Luddenham Child Care Centre	3.9	0.4	2.6	0.4	6.E-05
R52	The Frogs Lodge	3.3	0.1	0.9	0.1	4.E-06
R53	Rossmore Community Preschool	2.2	0.1	1.5	0.1	4.E-06
R54	Mulgoa Preschool	1.6	0.1	0.6	0.1	6.E-06
R55	Jillys Educational Childcare Centre	4.4	0.2	1.9	0.1	6.E-06
R57	Wallacia Progress Hall	1.5	0.1	1.0	0.1	1.E-05
R59	Bringelly Community Centre	3.7	0.3	2.0	0.2	8.E-06
R63	Luddenham Progress Hall	5.8	0.5	4.4	0.6	8.E-05
R64	Mulgoa Hall	1.6	0.1	0.7	0.1	7.E-06
R65	Emmaus Catholic College	5.7	0.3	2.3	0.2	1.E-05
R66	University of Sydney Farms	2.8	0.2	2.1	0.2	1.E-05
R68	Christadelphian Heritage College Sydney	8.0	0.3	3.1	0.2	1.E-05
R69	Mamre Anglican School	4.2	0.3	2.3	0.2	1.E-05
R72	Irfan College	1.7	0.1	1.6	0.1	5.E-06
R73	Luddenham Public School	6.4	0.6	5.7	0.6	8.E-05
R74	Kemps Creek Public School	6.4	0.3	3.2	0.2	1.E-05
R75	Trinity Catholic Primary School	2.9	0.2	2.0	0.2	1.E-05
R76	Bringelly Public School	2.3	0.2	2.4	0.2	8.E-06
R78	Mulgoa Public School	1.4	0.1	0.7	0.1	6.E-06
R79	Rossmore Public School	3.3	0.1	1.3	0.1	4.E-06
R80	Wallacia Public School	1.5	0.1	0.9	0.1	9.E-06
R82	Bellfield College - Junior Campus	3.6	0.2	1.4	0.1	5.E-06
R84	Bringelly Park	5.2	0.3	2.2	0.2	9.E-06
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	2.8	0.1	2.1	0.1	5.E-06
R86	Blaxland Crossing Reserve	1.5	0.1	0.9	0.1	9.E-06
R87	Bill Anderson Reserve	13.3	0.3	3.1	0.2	1.E-05
R88	Kemps Creek Nature Reserve	2.6	0.2	1.2	0.1	7.E-06
R91	Western Sydney Parklands	3.7	0.1	1.9	0.1	5.E-06
R93	Rossmore Grange	4.3	0.3	1.6	0.2	8.E-06
R94	Freeburn Park	3.8	0.5	3.2	0.5	7.E-05
R95	Overett Reserve	21.2	0.6	5.3	0.4	3.E-05

Receptor ID	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	24-hour	Annual
	Criterion	*n/a*	*n/a*	*n/a*	*n/a*	*2*
R97	Mulgoa Park	1.5	0.1	0.7	0.1	7.E-06
R98	Wallacia Bowling and Recreation Club	1.5	0.1	1.0	0.1	1.E-05
R99	Hubertus Country Club	12.1	1.4	7.4	1.4	2.E-04
R100	Sugarloaf Cobbitty Equestrian Club	1.5	0.1	1.5	0.1	8.E-06
R102	Panthers Wallacia	1.8	0.2	1.0	0.1	1.E-05
R103	Twin Creeks Golf and Country Club	2.4	0.3	2.3	0.2	2.E-05
R104	Sydney International Shooting Centre	4.5	0.1	1.8	0.1	6.E-06
R108	Luddenham Showground	3.5	0.4	2.1	0.3	4.E-05
R109	Kemps Creek Sporting and Bowling Club	5.5	0.2	1.8	0.1	7.E-06
R110	St James Luddenham	6.8	0.8	7.6	0.9	1.E-04
R111	Lin Ying temple	5.4	0.2	2.1	0.1	8.E-06
R112	Vat Ketanak Khmer Kampuchea Krom	5.1	0.2	2.1	0.1	6.E-06
R114	Anglican Church Sydney Diocese	3.0	0.1	1.8	0.1	4.E-06
R115	Anglican Parish of Mulgoa	2.2	0.1	0.7	0.1	6.E-06
R117	Bringelly Vineyard Church	1.7	0.2	1.8	0.1	6.E-06
R118	Free Church of Tonga	3.7	0.1	3.3	0.1	1.E-05
R120	Our Lady Queen of Peace	8.4	0.3	1.6	0.2	1.E-05
R122	St Anthony	1.5	0.1	1.0	0.1	4.E-06
R123	St Marys Church	1.0	0.1	1.0	0.1	7.E-06
R124	Wallacia Christian Church	1.7	0.1	0.9	0.1	1.E-05
R126	St Francis Xavier Church	4.6	0.2	3.4	0.1	1.E-05
R127	Luddenham Uniting Church	5.0	0.5	4.2	0.6	1.E-04
R130	Hopewood Health Retreat	1.5	0.1	1.2	0.1	1.E-05
R131	Science of the Soul Study Centre	6.1	0.2	1.9	0.1	8.E-06
R132	Bringelly shops	2.8	0.2	2.3	0.2	7.E-06
R134	Kemps Creek shops	11.0	0.3	2.4	0.2	1.E-05
R135	Luddenham shops	6.4	0.9	5.3	1.0	2.E-04
R136	Mulgoa shops	1.3	0.1	0.7	0.1	7.E-06
R137	Rossmore shops	2.6	0.1	1.5	0.1	4.E-06
R138	Wallacia Shops	1.6	0.1	0.9	0.1	9.E-06
R140	Holy Family Catholic Primary and Church	4.5	0.5	4.0	0.6	6.E-05
R141	Edmund Rice Retreat and Conference Centre	1.7	0.1	0.6	0.1	7.E-06

Figure G9: Incremental PM_{10} 24-hours Contour Plot during aviation infrastructure works.

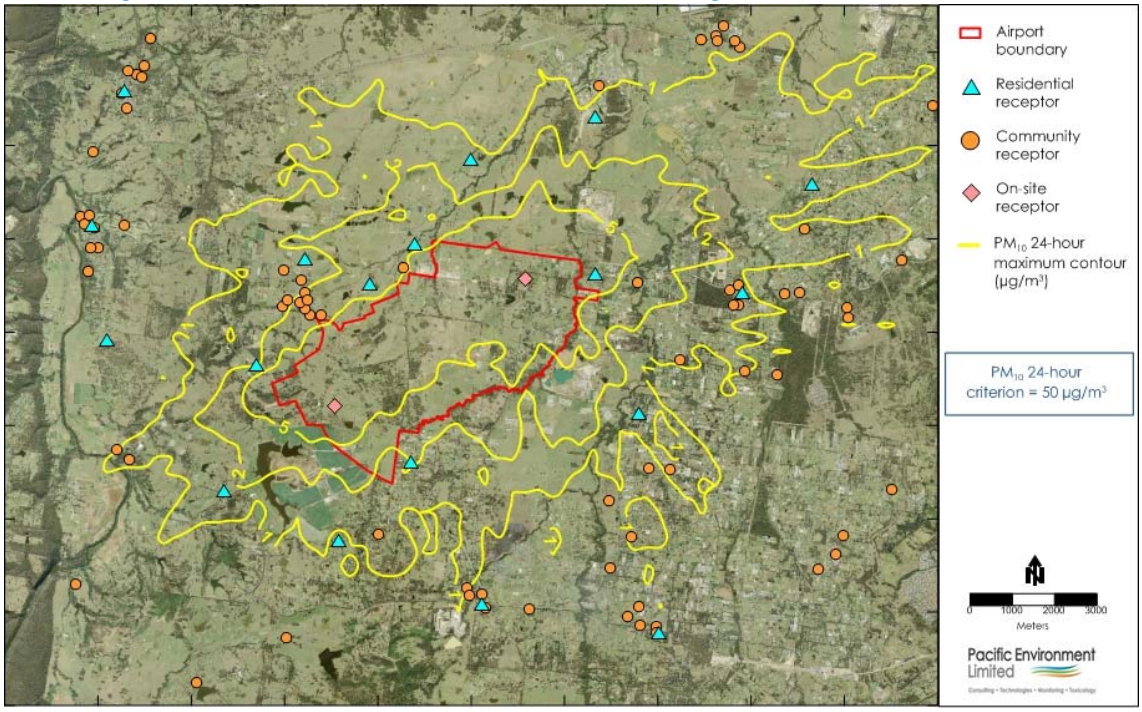


Figure G10: Incremental PM_{10} Annual Average Contour Plot during aviation infrastructure works

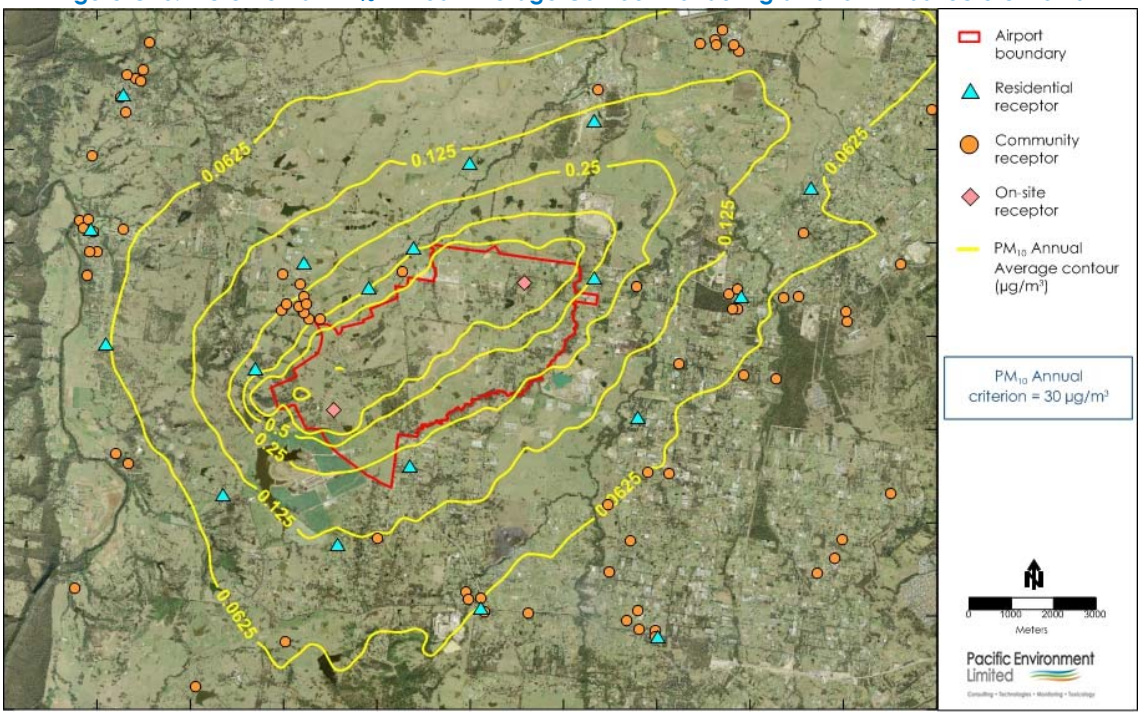


Figure G11: Incremental $PM_{2.5}$ 24-hours Contour Plot during aviation infrastructure works

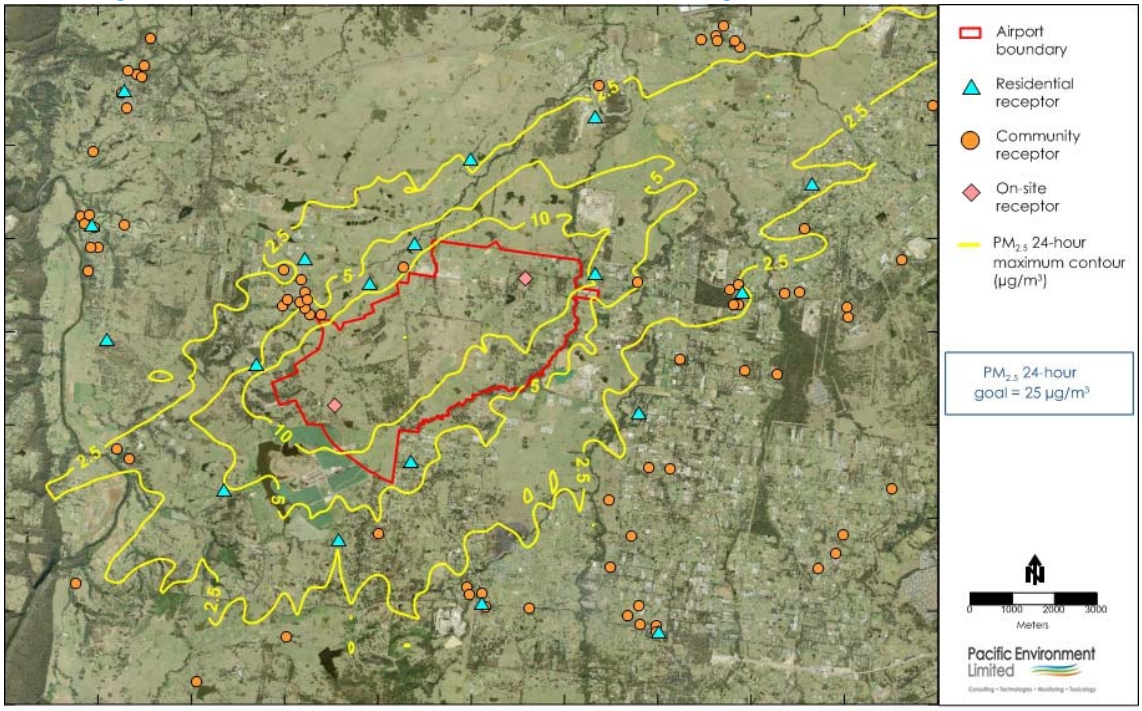


Figure G12: Incremental $PM_{2.5}$ Annual Average Contour Plot during aviation infrastructure works

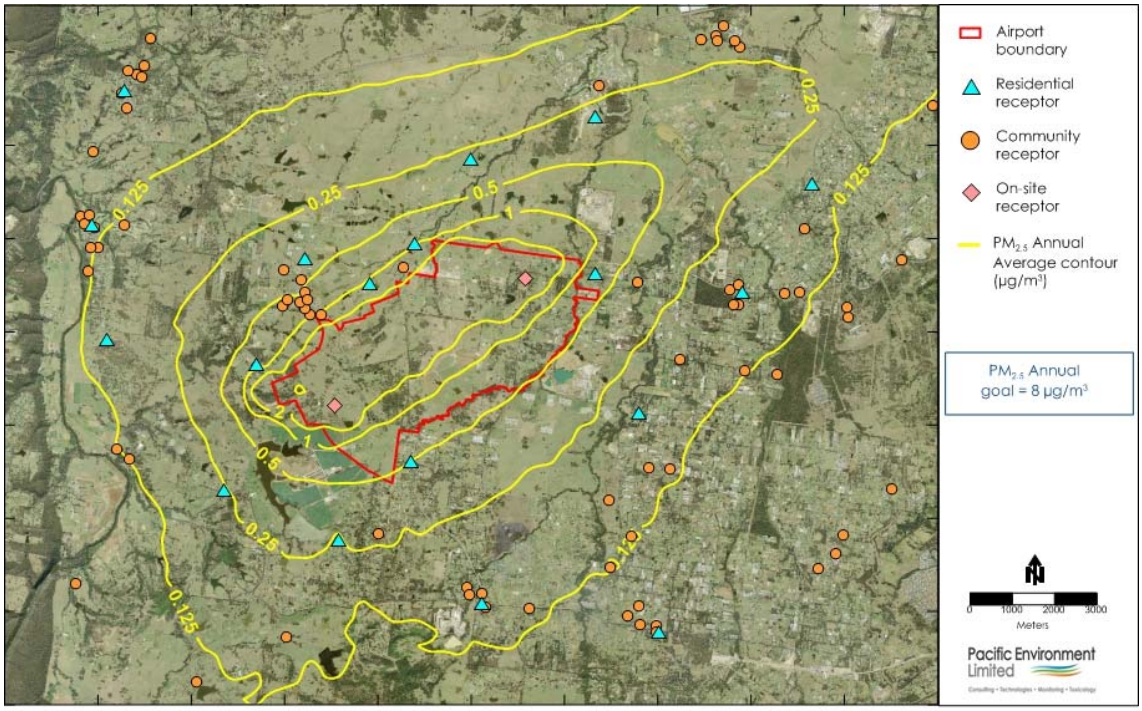


Figure G13: Incremental Dust deposition Annual Average Contour Plot during site preparation works

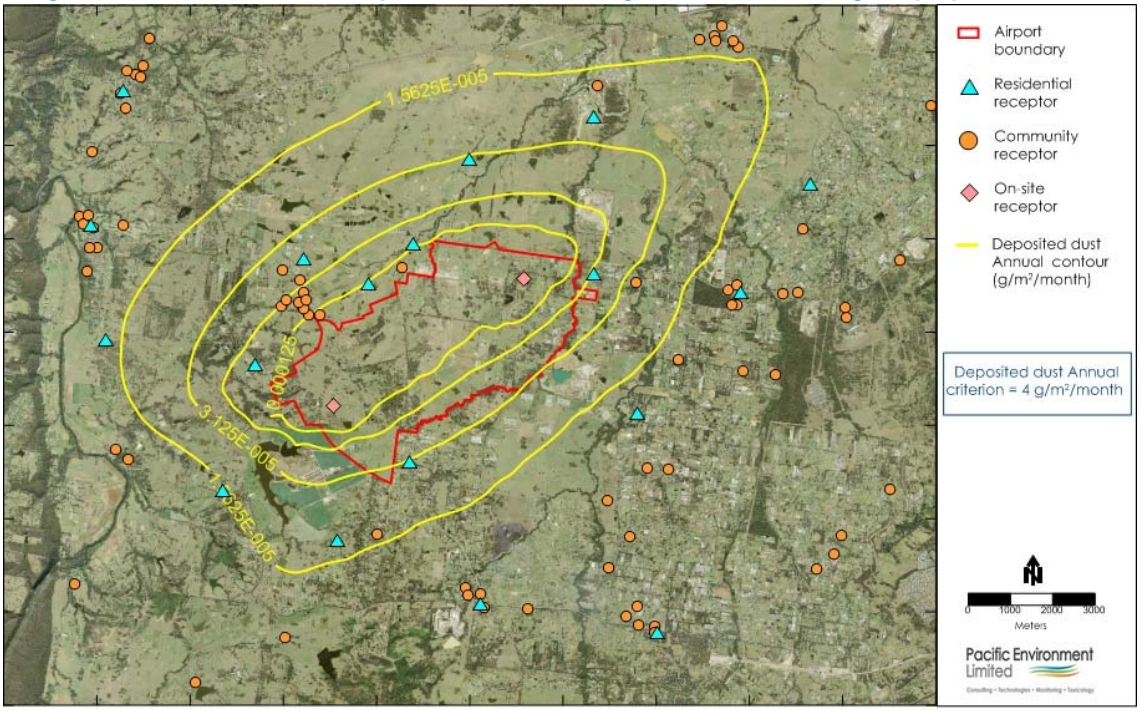


Table G4: Predicted cumulative results during aviation infrastructure works

Receptor	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	24-hour	Annual
Criterion		*50*	*30*	*25*	*8*	*4*
R1	Bringelly	45	17	14	7	2
R2	Luddenham	43	17	13	7	2
R3	Greendale, Greendale Road	43	17	13	7	2
R4	Kemps Creek	43	17	13	7	2
R6	Mulgoa	43	17	13	7	2
R7	Wallacia	43	17	13	7	2
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	47	17	14	7	2
R14	Lawson Road, Badgerys Creek	50	18	14	8	2
R15	Mersey Rd, Greendale	46	18	17	8	2
R17	Luddenham Road	44	17	15	7	2
R18	Cnr Adams & Elizabeth Drive	45	18	15	8	2
R19	Cnr Adams & Anton Road	44	18	15	8	2
R21	Cnr Willowdene Ave and Vicar Park Lane	43	18	14	8	2
R22	Rossmore, Victor Ave	43	17	13	7	2
R23	Wallacia, Greendale Rd	43	17	13	7	2
R24	Badgerys Creek 1 NE	400	30	53	12	2
R25	Badgerys Creek 2 SW	60	21	33	12	2
R27	Greendale, Dwyer Rd	43	17	14	7	2
R30	Rossmore residential	43	17	14	7	2
R31	Mt Vernon residential	43	17	13	7	2
R34	Emmaus Residential Aged Care	43	17	13	7	2

Receptor	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	24-hour	Annual
	Criterion	*50*	*30*	*25*	*8*	*4*
R35	Mamre After School and Vacation Care	43	17	13	7	2
R36	Head Start After School Care	43	17	13	7	2
R37	Schoolies at Mulgoa	43	18	14	8	2
R38	Do-re-mi Day Care Centre	43	17	13	7	2
R39	Little Amigos Austral Early Learning Centre	43	17	13	7	2
R40	Little Smarties Childcare Centre	43	17	13	7	2
R41	The Grove Academy	43	17	13	7	2
R42	Horsley Kids	43	17	13	7	2
R44	Bringelly Child Care Centre	46	17	17	7	2
R46	Clementson Drive Early Educational Centre	43	17	13	7	2
R48	Kids Korner West Hoxton Early Learning Centre	43	17	13	7	2
R49	Luddenham Child Care Centre	43	17	13	7	2
R52	The Frogs Lodge	43	17	13	7	2
R53	Rossmore Community Preschool	44	17	14	7	2
R54	Mulgoa Preschool	43	17	13	7	2
R55	Jillys Educational Childcare Centre	44	17	14	7	2
R57	Wallacia Progress Hall	43	17	13	7	2
R59	Bringelly Community Centre	44	17	15	7	2
R63	Luddenham Progress Hall	43	18	14	8	2
R64	Mulgoa Hall	43	17	13	7	2
R65	Emmaus Catholic College	43	17	13	7	2
R66	University of Sydney Farms	44	17	14	7	2
R68	Christadelphian Heritage College Sydney	43	17	13	7	2
R69	Mamre Anglican School	43	17	13	7	2
R72	Irfan College	43	17	13	7	2
R73	Luddenham Public School	45	18	15	8	2
R74	Kemps Creek Public School	43	17	13	7	2
R75	Trinity Catholic Primary School	43	17	13	7	2
R76	Bringelly Public School	45	17	14	7	2
R78	Mulgoa Public School	43	17	13	7	2
R79	Rossmore Public School	44	17	14	7	2
R80	Wallacia Public School	43	17	13	7	2
R82	Bellfield College - Junior Campus	46	17	14	7	2
R84	Bringelly Park	44	17	15	7	2
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	43	17	13	7	2
R86	Blaxland Crossing Reserve	43	17	13	7	2
R87	Bill Anderson Reserve	43	17	13	7	2
R88	Kemps Creek Nature Reserve	43	17	13	7	2
R91	Western Sydney Parklands	43	17	13	7	2
R93	Rossmore Grange	46	17	14	7	2
R94	Freeburn Park	43	17	14	8	2
R95	Overett Reserve	43	18	13	7	2

Receptor	Receptor location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	Dust deposition (g/m²/month)	
		24-hour	Annual	24-hour	24-hour	Annual
	Criterion	*50*	*30*	*25*	*8*	*4*
R97	Mulgoa Park	43	17	13	7	2
R98	Wallacia Bowling and Recreation Club	43	17	13	7	2
R99	Hubertus Country Club	45	18	16	8	2
R100	Sugarloaf Cobbitty Equestrian Club	43	17	13	7	2
R102	Panthers Wallacia	43	17	13	7	2
R103	Twin Creeks Golf and Country Club	45	17	14	7	2
R104	Sydney International Shooting Centre	43	17	13	7	2
R108	Luddenham Showground	43	17	13	7	2
R109	Kemps Creek Sporting and Bowling Club	43	17	13	7	2
R110	St James Luddenham	43	18	14	8	2
R111	Lin Ying temple	43	17	13	7	2
R112	Vat Ketanak Khmer Kampuchea Krom	43	17	14	7	2
R114	Anglican Church Sydney Diocese	43	17	13	7	2
R115	Anglican Parish of Mulgoa	43	17	13	7	2
R117	Bringelly Vineyard Church	44	17	15	7	2
R118	Free Church of Tonga	43	17	13	7	2
R120	Our Lady Queen of Peace	43	17	13	7	2
R122	St Anthony	43	17	13	7	2
R123	St Marys Church	43	17	13	7	2
R124	Wallacia Christian Church	43	17	13	7	2
R126	St Francis Xavier Church	43	17	13	7	2
R127	Luddenham Uniting Church	44	18	15	8	2
R130	Hopewood Health Retreat	43	17	13	7	2
R131	Science of the Soul Study Centre	43	17	13	7	2
R132	Bringelly shops	45	17	14	7	2
R134	Kemps Creek shops	43	17	13	7	2
R135	Luddenham shops	43	18	14	8	2
R136	Mulgoa shops	43	17	13	7	2
R137	Rossmore shops	44	17	14	7	2
R138	Wallacia Shops	43	17	13	7	2
R140	Holy Family Catholic Primary and Church	43	18	14	8	2
R141	Edmund Rice Retreat and Conference Centre	43	17	13	7	2

Figure G14: Cumulative PM_{10} Annual Average Contour Plot during aviation infrastructure works.

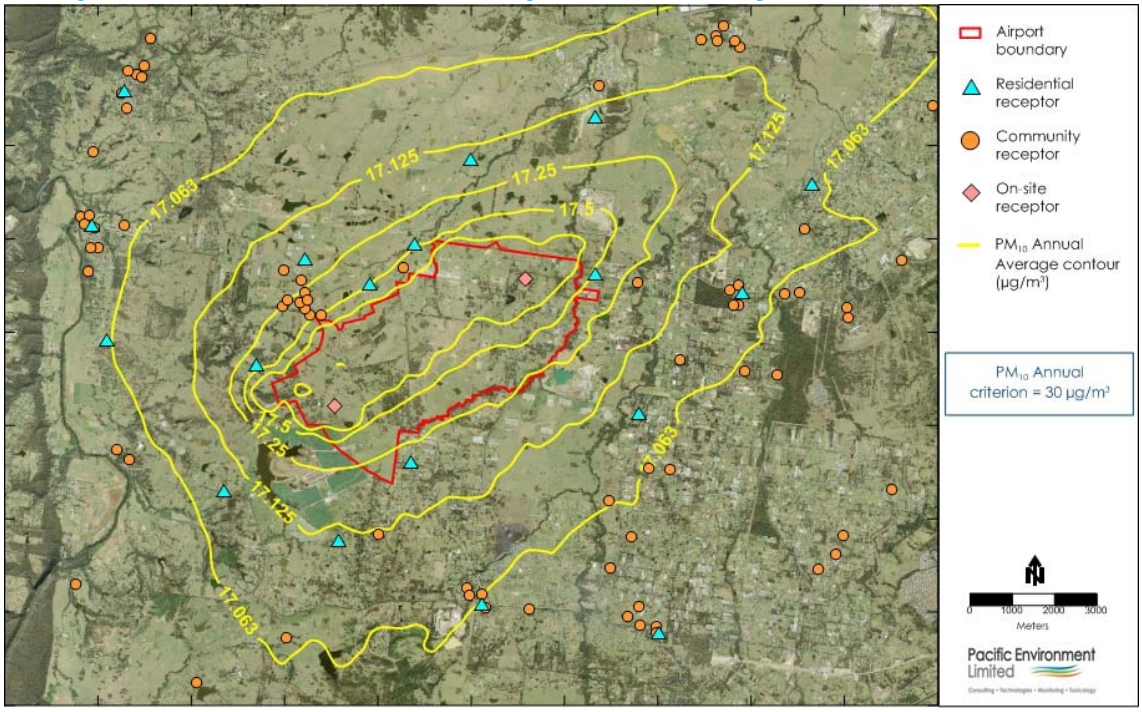


Figure G15: Cumulative $PM_{2.5}$ Annual Average Contour Plot during aviation infrastructure works

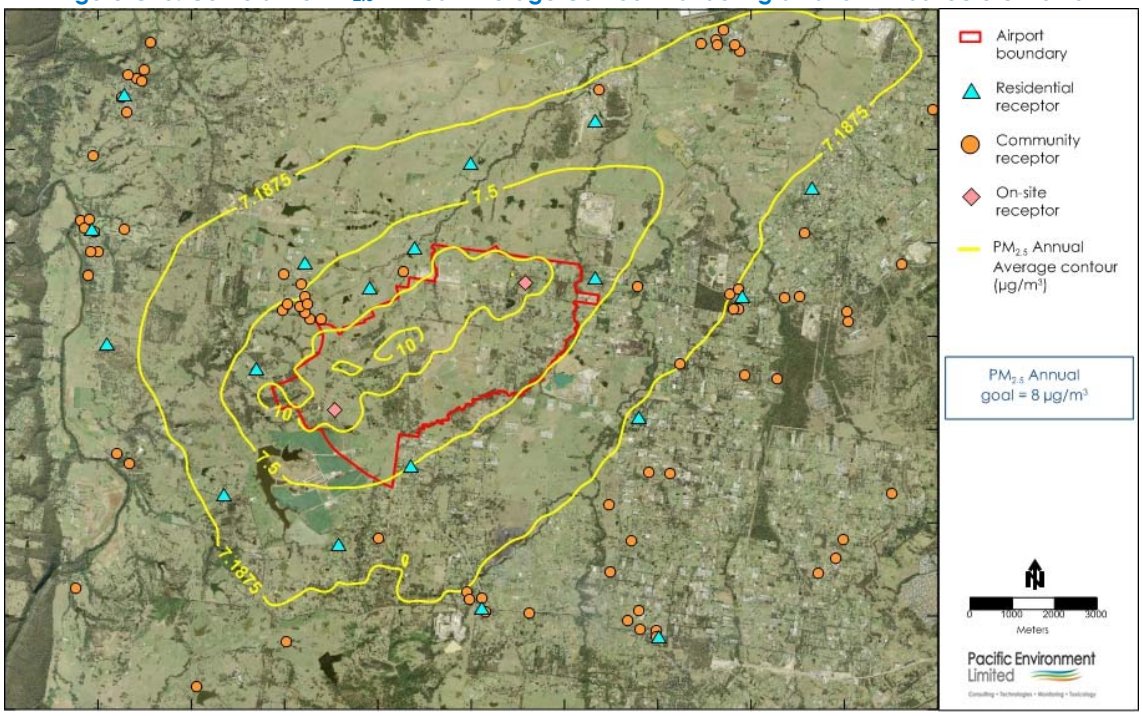
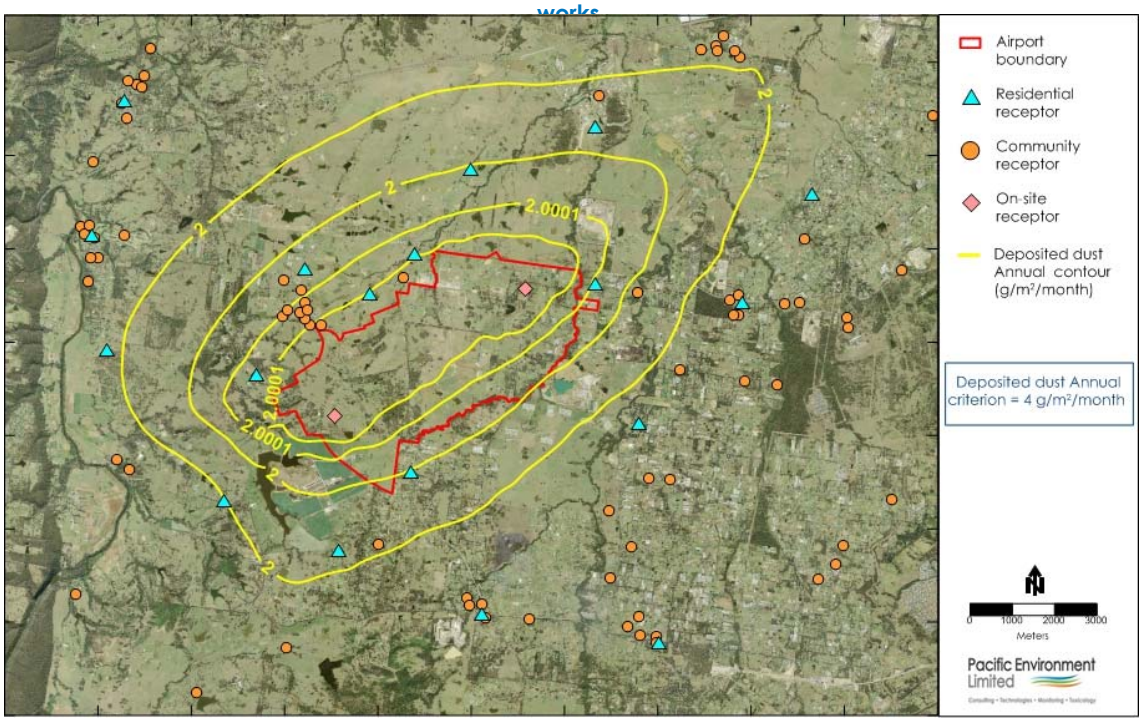


Figure G16: Cumulative Dust deposition annual Average Contour Plot during aviation infrastructure works



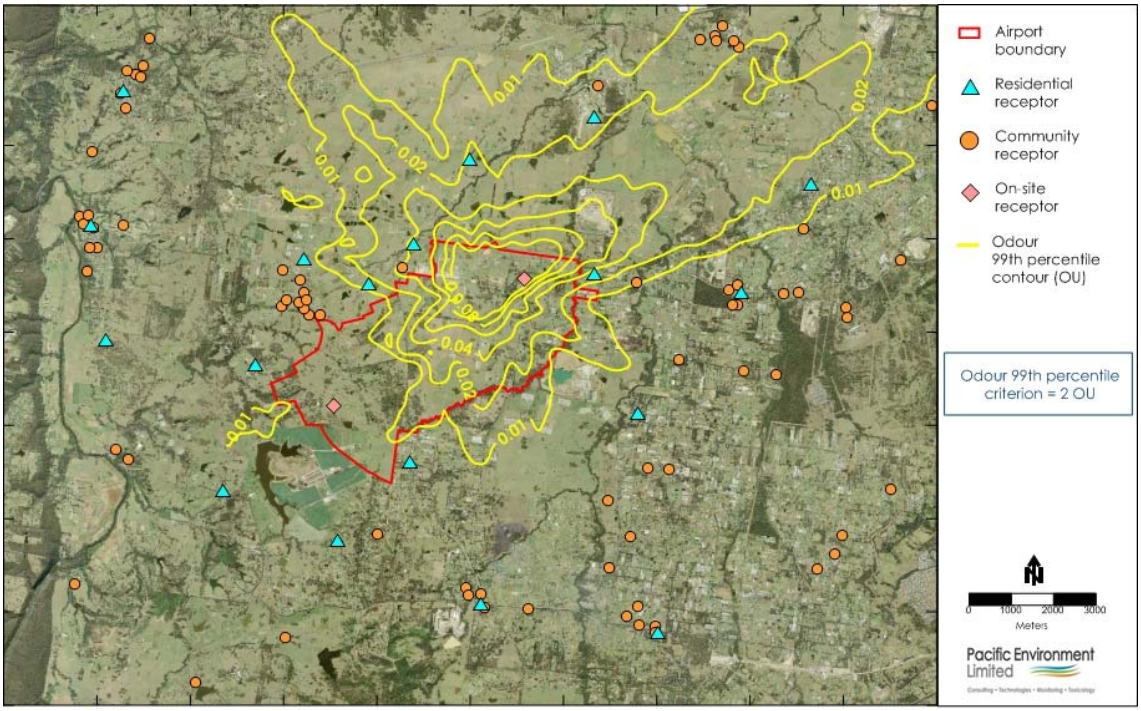
G.1.3 Asphalt plant

Table G5: Predicted 99th percentile odour concentration from asphalt plant

Receptor	Receptor location	1-hour 99th percentile
	Criterion	*2*
R1	Bringelly	<0.1
R2	Luddenham	<0.1
R3	Greendale, Greendale Road	<0.1
R4	Kemps Creek	<0.1
R6	Mulgoa	<0.1
R7	Wallacia	<0.1
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	<0.1
R14	Lawson Road, Badgerys Creek	1.7
R15	Mersey Rd, Greendale	0.1
R17	Luddenham Road	0.4
R18	Cnr Adams & Elizabeth Drive	0.5
R19	Cnr Adams & Anton Road	0.1
R21	Cnr Willowdene Ave and Vicar Park Lane	<0.1
R22	Rossmore, Victor Ave	0.2
R23	Wallacia, Greendale Rd	<0.1
R24	Badgerys Creek 1 NE	41.4
R25	Badgerys Creek 2 SW	<0.1
R27	Greendale, Dwyer Rd	<0.1
R30	Rossmore residential	0.0
R31	Mt Vernon residential	0.2
R34	Emmaus Residential Aged Care	0.4
R38	Do-re-mi Day Care Centre	0.2
R39	Little Amigos Austral Early Learning Centre	<0.1
R40	Little Smarties Childcare Centre	0.3
R41	The Grove Academy	<0.1
R44	Bringelly Child Care Centre	<0.1
R46	Clementson Drive Early Educational Centre	0.1
R48	Kids Korner West Hoxton Early Learning Centre	<0.1

R57	Wallacia Progress Hall	<0.1
R59	Bringelly Community Centre	<0.1
R64	Mulgoa Hall	0.1
R65	Emmaus Catholic College	0.4
R66	University of Sydney Farms	<0.1
R69	Mamre Anglican School	0.6
R72	Irfan College	<0.1
R73	Luddenham Public School	<0.1
R74	Kemps Creek Public School	<0.1
R75	Trinity Catholic Primary School	0.4
R78	Mulgoa Public School	0.1
R82	Bellfield College - Junior Campus	<0.1
R84	Bringelly Park	<0.1
R87	Bill Anderson Reserve	0.1
R88	Kemps Creek Nature Reserve	0.1
R92	Eugenie Byrne Park	<0.1
R94	Freeburn Park	<0.1
R95	Overett Reserve	0.3
R96	Horsley Park Reserve	0.4
R98	Wallacia Bowling and Recreation Club	<0.1
R99	Hubertus Country Club	0.4
R101	Treetop Adventure Park	<0.1
R104	Sydney International Shooting Centre	<0.1
R109	Kemps Creek Sporting and Bowling Club	0.1
R110	St James Luddenham	<0.1
R113	All Saints Anglican Church	<0.1
R115	Anglican Parish of Mulgoa	0.1
R116	Baptist Union Church and Manse	<0.1
R118	Free Church of Tonga	<0.1
R121	Sacred Heart Catholic Church Warragamba	<0.1
R124	Wallacia Christian Church	<0.1
R131	Science of the Soul Study Centre	0.1
R132	Bringelly shops	<0.1
R133	Horsley Park Shops	0.1
R135	Luddenham shops	<0.1
R137	Rossmore shops	<0.1
R138	Wallacia Shops	<0.1
R142	Mount Druitt Public School	<0.1

Figure G17: Predicted 99th percentile odour from asphalt plant contour Plot



Appendix H IMPACTS FROM DIESEL EMISSIONS

H.1 DIESEL EMISSIONS DURING CONSTRUCTION

H.1.1 Emissions calculations

A detailed description of the construction activities is presented in the *Construction Planning Report* **(GHD, 2015)**. Construction activities during the site preparation and aviation infrastructure works have been analysed and estimates of $PM_{2.5}$ emissions from diesel powered equipment. Emission factors have been sourced from available literature **(ASK Consulting Engineers 2013, Seabridge Gold 2012, ESA 2014, Heggies 2007, GHD 2011, CAT 2015)**. Where emissions were not available for $PM_{2.5}$ size particle fraction PM_{10} was used in place. This is considered a conservative assumption. It has been assumed that equipment will operate for 3,744 hours per year (6am – 6pm Monday to Saturday). The annual diesel emissions during construction are presented in **Table I1**.

Table H-1: Diesel emissions during construction

ACTIVITY	Annual $PM_{2.5}$ emissions (kg/yr)	
	Site preparation works	Av Infrastructure works
D11	3.5	-
D8	-	0.8
D6	0.1	-
657 Scraper	35.3	8.8
200t Excavator	26.4	-
30t Excavator	-	0.4
20,000L Water Cart	1.1	0.3
16' Grader	2.3	0.6
14' Grader	0.0	-
825 Compactor	3.1	0.9
Multi Tyre Roller	-	0.1
Smooth Drum Roller	0.4	0.3
Pad Foot Roller	0.4	0.1
966 Loader	-	1.1
Gravel Paver	-	0.2
Asphalt Paver	-	0.1
Concrete Placer Spreader	-	8.8
Concrete Slip Form Paver	-	8.8
Concrete Texture Cure Machine	-	8.8
50t dump truck	7.0	1.4
Dump truck (concrete and asphalt plants)	-	6.4
Total	*79.7*	*47.9*

H.1.2 Results

Table H-2: Predicted diesel $PM_{2.5}$ concentrations during bulk earthworks

Receptor	Receptor location	Diesel $PM_{2.5}$ ($\mu g/m^3$) Annual average
R1	Bringelly	0.00023
R2	Luddenham	0.00041
R3	Greendale, Greendale Road	0.00041
R4	Kemps Creek	0.00022
R6	Mulgoa	0.00012
R7	Wallacia	0.00015
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.00035
R14	Lawson Road, Badgerys Creek	0.00078
R15	Mersey Rd, Greendale	0.00073

Receptor	Receptor location	Diesel $PM_{2.5}$ ($\mu g/m^3$) Annual average
R17	Luddenham Road	0.00038
R18	Cnr Adams & Elizabeth Drive	0.00114
R19	Cnr Adams & Anton Road	0.00124
R21	Cnr Willowdene Ave and Vicar Park Lane	0.00085
R22	Rossmore, Victor Ave	0.00025
R23	Wallacia, Greendale Rd	0.00019
R24	Badgerys Creek 1 NE	0.00443
R25	Badgerys Creek 2 SW	0.00450
R27	Greendale, Dwyer Rd	0.00031
R30	Rossmore residential	0.00012
R31	Mt Vernon residential	0.00020
R34	Emmaus Residential Aged Care	0.00026
R35	Mamre After School and Vacation Care	0.00024
R36	Head Start After School Care	0.00009
R37	Schoolies at Mulgoa	0.00061
R38	Do-re-mi Day Care Centre	0.00020
R39	Little Amigos Austral Early Learning Centre	0.00009
R40	Little Smarties Childcare Centre	0.00023
R41	The Grove Academy	0.00018
R42	Horsley Kids	0.00013
R44	Bringelly Child Care Centre	0.00040
R46	Clementson Drive Early Educational Centre	0.00022
R48	Kids Korner West Hoxton Early Learning Centre	0.00009
R49	Luddenham Child Care Centre	0.00048
R52	The Frogs Lodge	0.00009
R53	Rossmore Community Preschool	0.00012
R54	Mulgoa Preschool	0.00012
R55	Jillys Educational Childcare Centre	0.00018
R57	Wallacia Progress Hall	0.00016
R59	Bringelly Community Centre	0.00025
R63	Luddenham Progress Hall	0.00061
R64	Mulgoa Hall	0.00012
R65	Emmaus Catholic College	0.00025
R66	University of Sydney Farms	0.00023
R68	Christadelphian Heritage College Sydney	0.00023
R69	Mamre Anglican School	0.00025
R72	Irfan College	0.00011
R73	Luddenham Public School	0.00068
R74	Kemps Creek Public School	0.00023
R75	Trinity Catholic Primary School	0.00022
R76	Bringelly Public School	0.00024
R78	Mulgoa Public School	0.00011
R79	Rossmore Public School	0.00014
R80	Wallacia Public School	0.00015
R82	Bellfield College - Junior Campus	0.00015
R84	Bringelly Park	0.00026
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	0.00012
R86	Blaxland Crossing Reserve	0.00014
R87	Bill Anderson Reserve	0.00024
R88	Kemps Creek Nature Reserve	0.00015
R91	Western Sydney Parklands	0.00014
R93	Rossmore Grange	0.00023

Receptor	Receptor location	Diesel $PM_{2.5}$ ($\mu g/m^3$) Annual average
R94	Freeburn Park	0.00058
R95	Overett Reserve	0.00043
R97	Mulgoa Park	0.00012
R98	Wallacia Bowling and Recreation Club	0.00016
R99	Hubertus Country Club	0.00155
R100	Sugarloaf Cobbitty Equestrian Club	0.00016
R102	Panthers Wallacia	0.00017
R103	Twin Creeks Golf and Country Club	0.00026
R104	Sydney International Shooting Centre	0.00014
R108	Luddenham Showground	0.00043
R109	Kemps Creek Sporting and Bowling Club	0.00016
R110	St James Luddenham	0.00090
R111	Lin Ying temple	0.00020
R112	Vat Ketanak Khmer Kampuchea Krom	0.00019
R114	Anglican Church Sydney Diocese	0.00015
R115	Anglican Parish of Mulgoa	0.00011
R117	Bringelly Vineyard Church	0.00020
R118	Free Church of Tonga	0.00017
R120	Our Lady Queen of Peace	0.00025
R122	St Anthony	0.00009
R123	St Marys Church	0.00012
R124	Wallacia Christian Church	0.00016
R126	St Francis Xavier Church	0.00018
R127	Luddenham Uniting Church	0.00060
R130	Hopewood Health Retreat	0.00016
R131	Science of the Soul Study Centre	0.00017
R132	Bringelly shops	0.00022
R134	Kemps Creek shops	0.00023
R135	Luddenham shops	0.00107
R136	Mulgoa shops	0.00012
R137	Rossmore shops	0.00013
R138	Wallacia Shops	0.00015
R140	Holy Family Catholic Primary and Church	0.00064
R141	Edmund Rice Retreat and Conference Centre	0.00013

H.2 DIESEL EMISSIONS DURING OPERATION

H.2.1 Emissions calculations

Emission for diesel PM2.5 were calculated by isolating the diesel emissions in EDMS.

H.2.2 Results

Table H-3: Predicted diesel $PM_{2.5}$ concentrations during stage 1 and longer term development

Receptor	Receptor location	Diesel $PM_{2.5}$ ($\mu g/m^3$) Annual average	
		Stage 1	Longer term
R1	Bringelly	0.3	0.5
R2	Luddenham	0.1	0.2
R3	Greendale, Greendale Road	0.1	0.2
R4	Kemps Creek	0.5	1.0
R6	Mulgoa	0.1	0.1

Receptor	Receptor location	Diesel $PM_{2.5}$ (µg/m³) Annual average	
		Stage 1	Longer term
R7	Wallacia	0.1	0.1
R8	Twin Creeks, Cnr Twin Ck Drive & Humewood Place	0.2	0.4
R14	Lawson Road, Badgerys Creek	0.4	0.8
R15	Mersey Rd, Greendale	0.2	0.5
R17	Luddenham Road	0.2	0.3
R18	Cnr Adams & Elizabeth Drive	0.2	0.5
R19	Cnr Adams & Anton Road	0.2	0.5
R21	Cnr Willowdene Ave and Vicar Park Lane	0.1	0.3
R22	Rossmore, Victor Ave	0.2	0.4
R23	Wallacia, Greendale Rd	0.1	0.1
R24	Badgerys Creek 1 NE	0.4	1.2
R25	Badgerys Creek 2 SW	0.2	0.5
R27	Greendale, Dwyer Rd	0.1	0.1
R30	Rossmore residential	0.3	1.1
R31	Mt Vernon residential	0.2	0.4
R34	Emmaus Residential Aged Care	0.3	0.5
R35	Mamre After School and Vacation Care	0.3	0.4
R36	Head Start After School Care	0.6	0.8
R37	Schoolies at Mulgoa	0.1	0.3
R38	Do-re-mi Day Care Centre	0.3	0.5
R39	Little Amigos Austral Early Learning Centre	0.2	0.3
R40	Little Smarties Childcare Centre	0.3	0.4
R41	The Grove Academy	0.2	0.3
R42	Horsley Kids	0.2	0.3
R44	Bringelly Child Care Centre	0.1	0.2
R46	Clementson Drive Early Educational Centre	0.2	0.4
R48	Kids Korner West Hoxton Early Learning Centre	0.2	0.3
R49	Luddenham Child Care Centre	0.1	0.2
R52	The Frogs Lodge	0.2	0.4
R53	Rossmore Community Preschool	0.3	0.7
R54	Mulgoa Preschool	0.1	0.1
R55	Jillys Educational Childcare Centre	0.2	0.3
R57	Wallacia Progress Hall	0.1	0.1
R59	Bringelly Community Centre	0.2	0.4
R63	Luddenham Progress Hall	0.1	0.2
R64	Mulgoa Hall	0.1	0.1
R65	Emmaus Catholic College	0.3	0.4
R66	University of Sydney Farms	0.1	0.1
R68	Christadelphian Heritage College Sydney	0.3	0.5
R69	Mamre Anglican School	0.3	0.4
R72	Irfan College	0.8	0.9
R73	Luddenham Public School	0.1	0.2
R74	Kemps Creek Public School	0.2	0.4
R75	Trinity Catholic Primary School	0.3	0.4
R76	Bringelly Public School	0.4	0.8
R78	Mulgoa Public School	0.1	0.1
R79	Rossmore Public School	0.4	0.6
R80	Wallacia Public School	0.1	0.1
R82	Bellfield College - Junior Campus	0.2	0.4
R84	Bringelly Park	0.2	0.4
R85	Bents Basin State Conservation Reserve and Gulguer Nature Reserve	0.1	0.1
R86	Blaxland Crossing Reserve	0.1	0.1

Receptor	Receptor location	Diesel $PM_{2.5}$ (µg/m³) Annual average	
		Stage 1	Longer term
R87	Bill Anderson Reserve	0.4	0.9
R88	Kemps Creek Nature Reserve	0.2	0.4
R91	Western Sydney Parklands	0.3	0.5
R93	Rossmore Grange	0.2	0.3
R94	Freeburn Park	0.1	0.2
R95	Overett Reserve	0.3	0.5
R97	Mulgoa Park	0.1	0.1
R98	Wallacia Bowling and Recreation Club	0.1	0.1
R99	Hubertus Country Club	0.2	0.5
R100	Sugarloaf Cobbitty Equestrian Club	0.1	0.1
R102	Panthers Wallacia	0.1	0.1
R103	Twin Creeks Golf and Country Club	0.2	0.3
R104	Sydney International Shooting Centre	0.3	0.5
R108	Luddenham Showground	0.1	0.2
R109	Kemps Creek Sporting and Bowling Club	0.5	1.5
R110	St James Luddenham	0.1	0.2
R111	Lin Ying temple	0.3	0.5
R112	Vat Ketanak Khmer Kampuchea Krom	0.2	0.3
R114	Anglican Church Sydney Diocese	0.2	0.3
R115	Anglican Parish of Mulgoa	0.1	0.1
R117	Bringelly Vineyard Church	0.3	0.6
R118	Free Church of Tonga	0.1	0.1
R120	Our Lady Queen of Peace	0.3	0.5
R122	St Anthony	0.2	0.4
R123	St Marys Church	0.1	0.1
R124	Wallacia Christian Church	0.1	0.1
R126	St Francis Xavier Church	0.1	0.1
R127	Luddenham Uniting Church	0.1	0.1
R130	Hopewood Health Retreat	0.1	0.1
R131	Science of the Soul Study Centre	0.5	1.4
R132	Bringelly shops	0.3	0.4
R134	Kemps Creek shops	0.4	0.6
R135	Luddenham shops	0.1	0.2
R136	Mulgoa shops	0.1	0.1
R137	Rossmore shops	0.4	0.6
R138	Wallacia Shops	0.1	0.1
R140	Holy Family Catholic Primary and Church	0.2	0.4
R141	Edmund Rice Retreat and Conference Centre	0.1	0.1

VOLUME 4

Appendix F2
Regional air quality

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WESTERN SYDNEY AIRPORT EIS
REGIONAL AIR QUALITY ASSESSMENT



RAMBOLL ENVIRON

WESTERN SYDNEY AIRPORT EIS
REGIONAL AIR QUALITY ASSESSMENT

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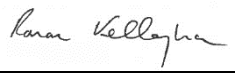
Final	6/10/2015	R. Kellaghan	G. Yarwood	R. Kellaghan	

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EXECUTIVE SUMMARY

Introduction

Regional air quality considers the formation of secondary pollutants (such as ozone) through photochemical reactions from primary emissions of precursor gases. The primary emissions of precursor gases considered in this assessment include nitrogen oxides (NOx), volatile organic compounds (VOCs) and carbon monoxide (CO), and the assessment focuses on the regional impacts from ozone formation. The regional assessment complements the local air quality impact assessment, prepared by Pacific Environment Limited, which is concerned with air quality impacts within a 5 km radius of the airport site (including impacts on the airport site) due to the Stage 1 construction phase, and the operation of the Stage 1 airport development and the longer term development.

Study approach

Ozone air quality impacts from the airport were evaluated using the Comprehensive Air quality Model with extensions (CAMx) (ENVIRON, 2015). CAMx is a three-dimensional, gridded, atmospheric dispersion model with photochemistry that allows for assessments of gaseous and particulate air pollution over spatial scales ranging from sub-urban to continental. The assessment follows the modelling approach used for the New South Wales (NSW) Environment Protection Agency (EPA) tiered procedure for ozone assessment, developed for estimating ground level ozone impacts from stationary sources in NSW (ENVIRON, 2011).

Air quality standards

The National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) (NEPC, 1998), establishes national standards for six criteria pollutants, including ozone. The AAQ NEPM seeks to attain '*ambient air quality that allows for the adequate protection of human health and wellbeing*'.

Modelling results for all sources are compared against NEPM standards for maximum 1-hour and 4-hour ozone concentrations. The predicted maximum change in ozone concentration, from the operation of the proposed airport, is compared against the maximum allowable increment of 1 part per billion (ppb), prescribed by the NSW EPA's tiered procedure for ozone assessment.

Existing environment

The relationship between ozone formation and emissions of precursor gases is not linear, for example NO_x emissions can lead to both formation and destruction of ozone, depending on the local quantities of NO_x, VOCs and sunlight (US EPA, 2014).

Peak ozone concentrations in Sydney tend to occur in the afternoon and during summer months. All areas of the Sydney region are currently classified as non-attainment, meaning they are not meeting an "acceptance limit" expressed as 82% of the NEPM standards (ENVIRON, 2011).

A review of the most recent 10 years of monitoring data reveals exceedances of the 1-hour and 4-hour ozone standard in 8 of the previous 10 years. Analysis of long term trends indicates that there is some evidence of decreasing monthly maximum ozone concentrations at Bringelly, near the airport site, and other areas of Sydney.

Emissions scenarios

The ozone modelling assessment considered emissions data for the following scenarios:

- 2008/2009 Base Case - for model evaluation.
- 2030 Future Base Case - for comparison with future airport operations.
- 2030 Airport Case – for Stage 1 airport emissions.
- 2063 Airport Case – for longer term airport emissions.

Gridded emissions inventory data for 2008 were provided by NSW EPA, as monthly weekday and weekend files (NSW EPA, 2012). The 2008 emissions data are used for the 2008 / 2009 Base Case, which models an ozone season from November 2008 to February 2009. This is the ozone season with the highest number of exceedances in the previous 10 years. The 2008 monthly files are considered suitable for modelling January and February 2009, without the need for adjustment. The GMR air

emissions inventory includes point source emissions from commercial and industrial sources and area source emissions for on-road mobile, commercial, industrial, domestic and off-road sources.

To assess the impact of airport operations for a future scenario, it was necessary to apply projections to the 2008 emissions. The NSW EPA also provided annual future year emissions projections for 2031, which were used to scale baseline emissions for the 2030 Future Base Case, to allow direct comparison with the Stage 1 airport development year (2030).

Emissions data for airport operations scenarios (Stage 1 and longer term development) were developed in the local air quality assessment, using the US Federal Aviation Administration Emissions and Dispersion Modeling System (EDMS), and have been provided for use in this assessment. A number of adjustments were made to the EDMS data for regional modelling, including chemical speciation of VOC and NOx emissions. Adjustments were also necessary for traffic emissions. The EDMS emissions data for roadways in the local air quality assessment includes all future traffic. For regional modelling, further processing of the traffic emissions was needed to disaggregate the change in traffic emissions attributed to the airport from all other 2030 Base Case roadway emissions for the links included in the EDMS modelling.

Model evaluation

TAPM was used to simulate meteorology within the study area using surface observation data from all suitable Bureau of Meteorology (BoM) and Office of Environment and Heritage (OEH) stations located in the modelling domain. The performance of the model for the Sydney region was evaluated. General wind patterns in the observation data were reflected reasonably well in the TAPM predictions. Statistical evaluation shows good correlation for wind speed and temperature with low bias and error.

The 2008/2009 Base Case emissions scenario was used to assess CAMx model performance by comparing predicted ozone concentrations against ambient monitoring data for the same period. Scatter plots presented for the evaluation demonstrate that modelled-observed data pairs are clustered around the 1:1 line showing that the model tends to correctly predict variability in ozone concentration. The model exhibits very little bias at the Bringelly and St Marys monitoring sites with normalised mean bias for 1-hour ozone less than 2% and for 4-hour ozone less than 7%.

Assessment of ozone impact – Stage 1 airport development (2030)

To assess the impact of Stage 1 airport development, modelling predictions are compared against a 2030 Future Base Case. A number of days were selected for detailed analysis, representing days when peak ozone impacts may be expected. Days with high observed ozone (1-hour ozone concentrations greater than 70 ppb and 4-hour ozone concentrations greater than 65 ppb) and good model performance (bias within ±15% in peak values) were selected for analysis. The selection of days for analysis follows guidance provided in the NSW EPA's tiered procedure for ozone assessment. The selection of historical dates in January and February 2009 may appear counter intuitive for the modelling future emissions in 2030 and 2063. However, these dates simply represent the meteorological conditions that have historically led to peak ozone formation and which the model has effectively captured for peak ozone formation in the context of future emission scenarios.

For each day of analysis, peak predicted 1-hour ozone concentrations were unchanged between the 2030 Base Case and the 2030 Airport Case. This is because the predicted ozone concentrations from the proposed airport occur in different locations to where ozone peaks occur. Both the 2030 Base Case and the 2030 Airport Case peak ozone concentrations were above the NEPM criterion of 100 ppb for all but one day of analysis.

The largest difference in daily maximum 1-hour ozone concentration, from the addition of airport emissions, was 5.5 ppb. However, reliance on a single model result (e.g., the largest ozone change) could accentuate the influence of uncertainties in model input data or model formulation, therefore the average of the 2nd to 4th highest ozone change (1.1 ppb) is used to describe ozone impacts. This approach is similar to the use of a 99th percentile to describe maximum ozone impacts. When compared to the maximum allowable increment level of 1 ppb, a marginal impact is predicted for the 2030 Airport Case.

The peak predicted 4-hour ozone concentrations were unchanged between the 2030 Airport Case and the 2030 Base Case on eight days and increased on four days, by a maximum of 0.1 ppb. The highest change in daily maximum 4-hour ozone concentration, from the addition of airport emissions, was 2.4 ppb, while the second highest was 1.2 ppb. The average of the 2nd to 4th highest change in daily maximum 4-hour ozone was 0.9 ppb, which is below the maximum allowable increment of 1 ppb.

Locations of ozone differences due to 2030 airport emissions are shown in spatial plots. Decreases in daily maximum ozone occur in the vicinity of the airport for 2030 and are attributable to ozone suppression by NOx emissions. Increases in ozone occur downwind of the airport which, on most days, is to the south and southwest.

Assessment of ozone impact – Longer term airport development (2063)

Future projected emissions for sources other than the proposed airport (commercial, industrial, on-road mobile, etc.) are not available for the 2063 Airport Case and there was no reasonable way of projecting out to 2063. Therefore the longer term development scenario becomes a hypothetical scenario of the longer term airport development occurring within the context of 2030 Base Case emissions.

The maximum predicted 1-hour ozone concentration was unchanged between the 2030 Base Case and the 2063 Airport Case for eight of the analysis days. On four days, the peak predicted 1-hour ozone concentration increased, by a maximum of 0.2 ppb. Both the 2030 Base Case and the 2063 Airport Case were above the NEPM criterion of 100 ppb for all but one day of analysis.

Larger ozone increases were predicted for the 2063 Airport Case than the 2030 Airport Case. The average of the 2nd to 4th highest increases in daily maximum 1-hour ozone rose from 1.1 ppb for the 2030 Airport Case to 4.5 ppb for the 2063 Airport Case. This is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

The peak predicted 4-hour ozone concentration was unchanged on seven days and increased on five days, by a maximum of 0.2 ppb. The highest change in daily maximum 4-hour ozone concentration, from the addition of 2063 Airport Case emissions, was 6.3 ppb, while the second highest was 5.8 ppb. The average of the 2nd to 4th highest increases in daily maximum 4-hour ozone is 3.7 ppb, which is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

Decreases in daily maximum ozone, due to ozone suppression by NOx emissions, occur in the vicinity of the proposed airport and on some days extend to the aircraft flight corridor and areas downwind of the airport for 2063. Areas of ozone decrease are more expansive for the 2063 Airport Case than for the 2030 Airport Case because NO_x emissions from the airport are higher in 2063. Increases in ozone occur downwind of the airport and also are larger for 2063 than for 2030.

It is noted that emission data provided for airport operations assumes worst case operations, for example by including emissions from Auxiliary Power Units (APUs) rather than the use of mains powered APUs at the airport gates. Furthermore, for the longer term airport development, we have not accounted for changes in emissions from all other sources (commercial, industrial, on-road mobile, etc.), some of which may increase and some of which may decrease. The modelling predictions for the longer term development should therefore be viewed in this context.

Mitigation

Mitigation for ozone impacts should be considered for both the Stage 1 and longer term development and should focus primarily on measures which result in reductions in NO_x emissions. The NSW tiered procedure for ozone assessment requires that the best management practice (BMP) determination for facilities located within ozone non-attainment areas should consider best available techniques (BAT) and/or emission offsets. As recommended in the local air quality assessment, the proposed airport operator would implement BAT where it can, for example through the use of mains powered APUs at the airport gates. When assessing the effectiveness of any proposed mitigation measures, it is recommended that an evaluation is done of the sensitivity of ozone concentrations to reduction in NO_x and VOCs (i.e., ppb ozone per tonne of emissions) for future years.

WESTERN SYDNEY AIRPORT EIS
REGIONAL AIR QUALITY ASSESSMENT

CONTENTS

1.	**INTRODUCTION**	**1**
1.1	Background	1
1.2	Purpose of this report	2
1.3	Structure of this report	2
2.	**INTRODUCTION TO REGIONAL AIR QUALITY EFFECTS**	**3**
2.1	Introduction to regional air quality	3
2.2	Effects of ground level concentrations of ozone	4
2.3	Effects of ground level concentrations of ozone on vegetation	5
3.	**LEGISLATIVE SETTING AND AMBIENT OZONE STANDARDS**	**7**
3.1	Introduction	7
3.2	Ambient air quality standards	7
3.3	Ozone standards for the protection of vegetation and ecosystems	8
3.4	Airports (Environment Protection) Regulations 1997	8
3.5	NSW Tiered procedure for ozone assessment	8
4.	**OVERVIEW OF ASSESSMENT APPROACH**	**9**
4.1	Meteorological Model	9
4.1.1	Modelling domain	11
4.1.2	Modelling period	13
4.2	Overview of the Chemical Transport Model	13
4.2.1	Chemical Mechanism	13
4.3	Emissions scenarios	14
4.3.1	Baseline model evaluation	14
4.3.2	Future baseline emissions	15
4.3.3	Stage 1 Airport Development (2030)	16
4.3.3.1	Adjustments for roadway emissions	17
4.3.4	Longer term airport development (2063)	17
4.4	Biogenic emissions	18
4.5	Boundary conditions	18
5.	**EXISTING ENVIRONMENT**	**19**
5.1	Defining areas of ozone attainment and nonattainment	19
5.2	Annual exceedances of 1-hour and 4-hour ozone standards	21
5.3	Temporal patterns in ozone concentration	22
5.4	Long term trends in ozone concentration	22
6.	**EVALUATION OF METEOROLOGICAL MODELLING**	**25**
6.1	Evaluation of model performance near the airport site	26
6.2	Evaluation of model performance in Southwest Sydney	29
6.3	Evaluation of model performance in Northwest Sydney	31
6.4	Evaluation of model performance in Western Sydney	34
6.5	Summary	36
7.	**MODEL EVALUATION BASE CASE SCENARIO**	**37**
7.1	Introduction	37
7.2	Graphical evaluation	37
7.3	Statistical evaluation	43
8.	**EVALUATION OF OZONE IMPACTS**	**44**
8.1	Selecting days for detailed analysis	44
8.2	Approach to Evaluating Ozone Impacts	45

8.3 Stage 1 airport development 45
8.3.1 Spatial variation in peak ozone concentrations 47
8.4 Longer term airport development 61
8.4.1 Spatial variation in peak ozone concentrations 62
9. MITIGATION MEASURES 76
10. CONCLUSION 77
10.1 Results for Stage 1 airport development 77
10.2 Results for longer term airport development 78
10.3 Mitigation 78
11. GLOSSARY OF TERMS AND ACONYMNS 80
12. REFERENCES 82

TABLE OF FIGURES

Figure 4-1: TAPM inner grid domain (GMR), grid spacing and monitoring sites 12
Figure 5-1: OEH monitoring sites in the Sydney Region 19
Figure 5-2: Polar plot of maximum hourly and monthly ozone concentration (ppb) by wind direction at Bringelly (2004 to 2014) 23
Figure 5-3: Trend in monthly max ozone and NO_x concentrations (ppb) at Bringelly (2004-2014) (% change per year with 95% confidence limits) 24
Figure 6-1: Wind rose comparison for proposed airport..... 27
Figure 6-2: Time variation of observed and predicted wind speed and temperature for proposed airport..... 27
Figure 6-3: Scatter plot of observed and predicted wind speed for proposed airport..... 28
Figure 6-4: Scatter plot of observed and predicted temperature for proposed airport..... 28
Figure 6-5: Wind rose comparison for Southwest Sydney..... 29
Figure 6-6: Time variation plot of observed and predicted wind speed and temperature for Southwest Sydney 30
Figure 6-7: Scatter plot of observed and predicted wind speed for Southwest Sydney 30
Figure 6-8: Scatter plot of observed and predicted temperature for Southwest Sydney 31
Figure 6-9: Wind rose comparison for Northwest Sydney 32
Figure 6-10: Time variation plot of observed and predicted wind speed and temperature for Northwest Sydney 32
Figure 6-11: Scatter plot of observed and predicted wind speed for Northwest Sydney 33
Figure 6-12: Scatter plot of observed and predicted temperature for Northwest Sydney 33
Figure 6-13: Wind rose comparison for Western Sydney 34
Figure 6-14: Time variation plot of observed and predicted wind speed and temperature for Western Sydney 35
Figure 6-15: Scatter plot of observed and predicted wind speed for Western Sydney 35
Figure 6-16: Scatter plot of observed and predicted temperature for Western Sydney 36
Figure 7-1: Scatter plot of modelled and observed ozone concentration for all sites..... 38
Figure 7-2: Scatter plots of modelled and observed 1-hour ozone concentration at Bringelly, Oakdale and St Marys..... 39
Figure 7-3: Scatter plots of modelled and observed 4-hour ozone concentration at Bringelly, Oakdale and St Marys..... 40
Figure 7-4: Timeseries of modelled and observed 1-hour ozone concentration at Bringelly, Oakdale and St Marys 41

Figure 7-5: Timeseries of modelled and observed 4-hour ozone concentration at Bringelly, Oakdale and St Marys 42
Figure 8-1: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 January 48
Figure 8-2: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 14 and 29 January..... 49
Figure 8-3: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 30 and 31 January..... 50
Figure 8-4: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 4 and 5 February..... 51
Figure 8-5: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 February..... 52
Figure 8-6: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 8 and 20 February..... 53
Figure 8-7: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 January 54
Figure 8-8: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 14 and 29 January..... 55
Figure 8-9: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 30 and 31 January..... 56
Figure 8-10: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 4 and 5 February..... 57
Figure 8-11: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 February..... 58
Figure 8-12: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 8 and 20 February..... 59
Figure 8-13: Maximum predicted 1-hour and 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for all days 60
Figure 8-14: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 January 63
Figure 8-15: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 14 and 29 January..... 64
Figure 8-16: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 30 and 31 January..... 65
Figure 8-17: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 4 and 5 February..... 66
Figure 8-18: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 February..... 67
Figure 8-19: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 8 and 20 February..... 68
Figure 8-20: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 January 69
Figure 8-21: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 14 and 29 January..... 70
Figure 8-22: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 30 and 31 January..... 71
Figure 8-23: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 4 and 5 February..... 72
Figure 8-24: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 February..... 73
Figure 8-25: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 8 and 20 February..... 74
Figure 8-26: Maximum predicted 1-hour and 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for all days 75
Figure 12-1: Tiered procedure for ozone assessment in NSW 2

TABLE OF TABLES

Table 2-1: Proportion of emissions from existing airports as a percentage of total emissions for the Sydney Region 3
Table 2-2: Human health effects of ambient ozone pollution..... 4
Table 2-3: Summary of causal determination of human health outcomes for ozone 5
Table 2-4: Summary of vegetation and ecosystem effects for ozone..... 6
Table 3-1: National (NEPM) standards for ozone 7
Table 3-2: NSW EPA Impact Assessment criteria for ozone..... 7
Table 3-3: EPP (Air) ozone goals for vegetation 8
Table 4-1: CAMx meteorological input data requirements..... 9
Table 4-2: Data assimilation sites included in the meteorological model..... 10
Table 4-3: Summary of annual emissions for NSW GMR in 2008 15
Table 4-4: Summary of annual emissions for Sydney Region in 2008 15
Table 4-5: Summary of annual emissions for airport operations in 2008 15
Table 4-6: Summary of estimated annual baseline emissions for 2031 for the GMR..... 16
Table 4-7: Scaling factors used to scale 2008 baseline emissions for 2030 16
Table 4-8: Stage 1 airport development emissions (2030) 16
Table 4-9: Disaggregated traffic emissions for regional modelling 17
Table 4-10: Longer term airport development emissions (2063) 18
Table 5-1: Classification of ozone nonattainment based on 1-hour average ozone concentrations 20
Table 5-2: Classification of ozone nonattainment based on 4-hour average ozone concentrations 20
Table 5-3: Number of annual exceedances of the 1-hour ozone standard..... 21
Table 5-4: Number of annual exceedances of the 4-hour ozone standard..... 21
Table 6-1: Locations and observations sites for model evaluation..... 25
Table 6-2: Statistical evaluation for model performance..... 26
Table 6-3: Evaluation of TAPM wind speed and temperature against observations for Western Sydney Airport 29
Table 6-4: Evaluation of TAPM wind speeds against observations for Southwest Sydney 31
Table 6-5: Evaluation of TAPM wind speed and temperature against observations for Northwest Sydney 34
Table 6-6: Evaluation of TAPM wind speeds against observations for Western Sydney 36
Table 7-1: Statistical metrics for model evaluation 37
Table 7-2: Performance statistics for predicted 1-hour ozone concentration .. 43
Table 7-3: Performance statistics for predicted 4-hour ozone concentration .. 43
Table 8-1: Date selection for detailed analysis..... 44
Table 8-2: Maximum daily predicted 1-hour ozone concentration (ppb) - 2030 46
Table 8-3: Maximum daily predicted 4-hour ozone concentration (ppb) - 2030 47
Table 8-4: Maximum daily predicted 1-hour ozone concentration (ppb) - 2063 61
Table 8-5: Maximum daily predicted 4-hour ozone concentration (ppb) - 2063 62

APPENDICES

Appendix 1
NSW EPA tiered procedure for ozone Assessment

Appendix 2
Speciation Profiles for VOC emissions

Appendix 3
Spatial Allocation of Emissions

1. INTRODUCTION

Ramboll Environ Australia Pty Ltd (Ramboll Environ) has been engaged by GHD, on behalf of the Australian Government (Department of Infrastructure and Regional Development), to assess regional air quality impacts associated with the proposed Western Sydney Airport (the airport). The regional air quality assessment forms part of the environmental impact statement (EIS) being prepared by GHD.

The regional air quality assessment considers impacts from emissions associated with the airport forming secondary pollutants (principally ozone) through atmospheric reactions on a regional scale.

The regional assessment complements the local air quality impact assessment, prepared by Pacific Environment Limited, which is concerned with impacts on a local scale, for primary pollutants that are emitted directly from the airport.

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and

companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Purpose of this report

The 1997 EIS considered the potential impacts on local and regional air quality, however since this report was published, there are more extensive air quality monitoring data available to describe background conditions and ambient air quality goals have changed.

This report has been prepared in accordance with the EIS guidelines. In particular, the EIS Guidelines for the project (Reference: EPBC 2014/7391) indicate the following is required to be included in the EIS:

> (section 5c)
>
> *"The EIS should address the potential for facilitated impacts upon MNES at the local, regional, state, national and international scale"*
>
> (section 5g)
>
> *"…changes to air quality during construction and operation (including consideration of seasonal and meteorological variations that influence local air quality)"*

The primary objective of the regional air quality assessment is to therefore update the previous assessment, consistent with best science and contemporary modelling and assessment techniques. It should be noted that a separate report considering the impact on local air quality and greenhouse gases has also been prepared and included in the EIS. The regional air quality report has used consistent assumptions on aircraft and ground fleet use, including airport vehicles on external roadways and meteorology to ensure consistency of the results.

1.3 Structure of this report

The remainder of this report is structured as follows:

- Section 2 – provides an introduction to regional air quality effects.
- Section 3 – considers and documents the relevant legislation and guidelines in relation to ozone impact assessment.
- Section 4 – presents the methodology used to undertake the regional modelling assessment.
- Section 5 – outlines the existing environment.
- Section 6 – evaluates the meteorology used for modelling.
- Section 7 – presents the results of the Base Case model evaluation.
- Section 8 – presents the impact assessment of both the Stage 1 and longer term airport development.
- Section 9 – outlines recommended mitigation measures.
- Section 10 – provides the summary and conclusions of the report.
- Section 11 – provides a glossary of terms and acronyms.
- Section 12 – presents a list of references drawn on by this report.

2. INTRODUCTION TO REGIONAL AIR QUALITY EFFECTS

2.1 Introduction to regional air quality

Regional air quality considers the formation of secondary pollutants (such as ozone (O_3)) through photochemical reactions from primary emissions of precursor gases. The primary emissions of precursor gases considered in this assessment include nitrogen oxides (NO_x), volatile organic compounds (VOCs) and carbon monoxide (CO). The direct impacts from these precursor gases is considered in the local air quality assessment within 5 km of the airport site boundary.

International studies have shown that emissions from airport operations are small when compared in the context of regional emission inventories (Ratliff et al., 2009). This is supported by data presented in the Air emissions inventory for the Greater Metropolitan Region (GMR) in New South Wales (NSW EPA, 2012a) which shows that emissions from existing airport operations in Sydney are less than 3% of total emissions for the Sydney Region (refer **Table 2-1)**.

Notwithstanding the relatively small contribution to regional emissions, impacts on a local and regional scale need to be assessed.

Table 2-1: Proportion of emissions from existing airports as a percentage of total emissions for the Sydney Region

Activity	NO_x	VOCs	CO
Flight operations	2.37%	0.19%	0.32%
Ground Operations	0.34%	0.1%	0.2%

Note: Does not include emissions associated with airport traffic

Regional ozone is affected both by local formation and the transport of ozone and its precursors from upwind areas. As a secondary pollutant, ozone concentrations are generally more regionally homogeneous than concentrations of primary pollutants emitted directly from stationary and mobile sources (US EPA, 2013).

The relationship between ozone formation and emissions of precursor gases is not linear. NO_x emissions can lead to both formation and destruction of ozone, depending on the local quantities of NO_x, VOCs and sunlight (US EPA, 2014). For example, a study in the US found that near some urban centres, aircraft emissions reduced ozone, whereas in suburban and rural areas, aircraft emissions increased ambient ozone levels (Ratliff et al., 2009).

Scavenging of ozone by reaction with NO ("titration") can result in localised reduction in ozone concentrations. However, the resulting NO_2 can then contribute to subsequent ozone formation further downwind. Ozone titration is most pronounced in urban areas that have high NO_x emissions from vehicles and other sources. In areas with relatively low NO_x concentrations ozone formation typically increases monotonically with increasing NO_x emissions (US EPA, 2014).

Meteorology and seasonality also play an important role in ozone formation. Elevated ground level concentrations of ozone in Sydney occur during the warmer seasons because of the greater availability of sunlight and higher temperatures. Also, the largest source of VOC precursor emissions in the Sydney GMR is from vegetation and the highest emissions occur from the tree canopy during the warmer months (November to February) (NSW EPA, 2012a; NSW EPA, 2012b).

Elevated ground-level ozone concentrations are also associated with slow moving high pressure systems during the warmer seasons, associated with generally cloudless skies, light winds and the development of stable conditions near the surface that inhibit or reduce the vertical mixing of ozone precursors. The combination of inhibited vertical mixing and light winds minimises the dispersal of pollutants, allowing their concentrations to build up (US EPA, 2014).

Exceedances of the ambient ozone standards in Sydney are therefore generally limited to the summer months (December to February). In some years exceedances occur in the months of

October, November and March, however outside the core summer periods, exceedances often coincide with bushfires events (for example October 2013 and November 2009). Further discussion on ambient ozone concentrations for Sydney is provided in **Section 4**.

2.2 Effects of ground level concentrations of ozone

In 2012, the Council of Australian Governments (COAG) identified air quality as an issue of national priority (COAG, 2012), and agreed that its Standing Council on Environment and Water would implement a strategic approach to air quality management in the form of a National Plan for Clean Air. One of the first deliverables identified for the first stage of the National Plan for Clean Air was a health risk assessment (HRA) of air pollution (including ozone) and a summary report for policy makers that outlined the key findings of the HRA (Morgan et al, 2013).

A range of health effects associated with exposure to ozone pollution were outlined in Morgan et al (2013) and are summarised in **Table 2-2**. Morgan et al (2013) also reported that current short-term ozone exposure above background is estimated be responsible for 3.7% of annual deaths and 3.4% of annual childhood hospital emergency department attendances for the Sydney region.

Table 2-2: Human health effects of ambient ozone pollution

Exposure period	Health effects
Short-term Exposure	Adverse effects on lung function
	Lung inflammatory reactions
	Adverse effects on the respiratory system
	Increased medication use
	Increased hospitalisations
	Increased mortality
Long-term Exposure	Reduced lung function development

Source: Morgan et al (2013)

The US EPA's Integrated Science Assessment for Ozone and Related Photochemical Oxidants (ISA) assessed a large body of peer reviewed literature to draw conclusions on the causal relationships between pollution and health and welfare effects (US EPA, 2013). A summary of the human health effects associated with ozone exposure are summarised in **Table 2-3**, based on the US EPA ISA review of exposures studies, toxicology and epidemiology evidence. The strongest evidence for health effects is from studies on respiratory effects, however there is also a significant body of evidence to suggest that short term exposure to ozone, directly or indirectly, contributes to cardiopulmonary-related mortality (US EPA, 2013).

Table 2-3: Summary of causal determination of human health outcomes for ozone

Exposure period	Health outcome	Conclusion from ISA[1]
Short-term Exposure	Respiratory effects	Causal Relationship
	Cardiovascular effects	Likely to be a Causal Relationship
	Central nervous system effects	Suggestive of a Causal Relationship
	Total mortality	Likely to be a Causal Relationship
Long-term Exposure	Respiratory effects	Likely to be a Causal Relationship
	Cardiovascular effects	Suggestive of a Causal Relationship
	Reproductive and developmental effects	Suggestive of a Causal Relationship
	Central nervous system effects	Suggestive of a Causal Relationship
	Cancer	Inadequate to Infer a Causal Relationship
	Total mortality	Suggestive of a Causal Relationship

Source: US EPA (2013)

2.3 Effects of ground level concentrations of ozone on vegetation

Effects related to impacts on vegetation and ecosystems are also outlined in the US EPA ISA review. Based on over 40 years of research in the US, a clear causal link has been established between ambient ozone concentrations and visible foliar injury, decreased photosynthesis, changes in plant reproduction, and decreased growth.

A summary of vegetation and ecosystem effects from the ISA are presented in **Table 2-4**.

[1] The health effects are characterised by the strength of evidence for causality. The classification of a causal relationship means the evidence is sufficient to show that a pollutant causes health effects. For the "likely to be causal" group, the evidence is also sufficient, however important uncertainties remain (for example chance or bias). Where evidence is "suggestive", evidence is limited.

Table 2-4: Summary of vegetation and ecosystem effects for ozone

Vegetation and ecosystem effects	Conclusions from 2006 NAAQS review	Conclusion from ISA
Visible Foliar Injury Effects on Vegetation	Data published since the 1996 O_3 review strengthen previous conclusions that there is strong evidence that current ambient O_3 concentrations cause impaired aesthetic quality of many native plants and trees by increasing foliar injury.	Causal Relationship
Reduced Vegetation Growth	Data published since the 1996 O_3 review strengthen previous conclusions that there is strong evidence that current ambient O_3 concentrations cause decreased growth and biomass accumulation in annual, perennial and woody plants, including agronomic crops, annuals, shrubs, grasses, and trees.	Causal Relationship
Reduced Productivity in Terrestrial Ecosystems	There is evidence that O_3 is an important stressor of ecosystems and that the effects of O_3 on individual plants and processes are scaled up through the ecosystem, affecting net primary productivity.	Causal Relationship
Reduced Carbon (C) Sequestration in Terrestrial Ecosystems	Limited studies from the 2006 O_3 review.	Likely to be a Causal Relationship
Reduced Yield and Quality of Agricultural Crops	Data published since the 1996 O_3 review strengthen previous conclusions that there is strong evidence that current ambient O_3 concentrations cause decreased yield and/or nutritive quality in a large number of agronomic and forage crops.	Causal Relationship
Alteration of Terrestrial Ecosystem Water Cycling	Ecosystem water quantity may be affected by O_3 exposure at the landscape level.	Likely to be a Causal Relationship
Alteration of Belowground Biogeochemical Cycles	Ozone-sensitive species have well known responses to O_3 exposure, including altered carbon (C) allocation to below-ground tissues, and also altered rates of leaf and root production, turnover, and decomposition. These shifts can affect overall C and nitrogen (N) loss from the ecosystem in terms of respired C, and leached aqueous dissolved organic and inorganic C and N.	Causal Relationship
Alteration of Terrestrial Community Composition	Ozone may be affecting above- and below –ground community composition through impacts on both growth and reproduction. Significant changes in plant community composition resulting directly from O_3 exposure have been demonstrated.	Likely to be a Causal Relationship

Source: US EPA (2013)

3. LEGISLATIVE SETTING AND AMBIENT OZONE STANDARDS

3.1 Introduction

In 1998, Australia adopted a National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM) (NEPC, 1998), establishing national standards for six criteria pollutants, including ozone. The goal of the AAQ NEPM is to attain *'ambient air quality that allows for the adequate protection of human health and wellbeing'*. The AAQ NEPM standards are described in **Section 3.2**. Guidance for air quality impact assessment in NSW is outlined in the *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales* (the Approved Methods) (NSW EPA, 2005). The guidance typically relates to local air quality assessment and when detailed regional modelling of ozone is required, the Approved Methods recommends that advice is sought from the Air Technical Advisory Services Unit of the NSW EPA.

The NSW EPA have also recently released a tiered procedure for ozone assessment, developed for estimating ground level ozone impacts from stationary sources in NSW (ENVIRON, 2011). Aspects of the guidance that are relevant to this assessment are discussed in **Section 3.4**.

In addition, it is important to note that a future airport operator will be under an obligation to monitor air quality under the *Airports (Environment Protection) Regulations 1997* and to include details of the proposed monitoring arrangements in its environment strategy as part of the master planning process under the *Airports Act 1996*.

3.2 Ambient air quality standards

The NEPM ambient air quality standards for ozone are summarised in **Table 3-1**, expressed as ppm (parts per million), by volume. The NEPM standards are identical to the impact assessment criteria prescribed by the NSW EPA in the Approved Methods, although the impact assessment criteria are expressed as pphm (parts per hundred million) and in micrograms per cubic metre of air (µg/m³) (refer **Table 3-2**). The form of the NEPM standard also allows for 1 day a year for the goal to be exceeded.

Table 3-1: National (NEPM) standards for ozone

Averaging period	Maximum concentration	Maximum allowable exceedances
1 hour	0.10 ppm	1 day a year
4 hours	0.08 ppm	1 day a year

Table 3-2: NSW EPA Impact Assessment criteria for ozone

Averaging period	Concentration	
	pphm	µg/m³[a]
1 hour	10	214
4 hours	8	171

Note: [a] referenced to a temperature of 0 degrees Celsius and an absolute pressure of 101.325 kilopascals

The ambient ozone monitoring data and ozone modelling results presented in this report use ppb (parts per billion) as the preferred reporting unit. The NEPM standard of 0.10 ppm for 1-hour ozone is equivalent to the NSW EPA criteria of 10 pphm and the criterion of 100 ppb used in this report. Similarly, the NEPM standard of 0.08 ppm for 4-hour ozone is equivalent to the NSW EPA criterion of 8 pphm, which is likewise equivalent to 80 ppb, which is used in this report.

3.3 Ozone standards for the protection of vegetation and ecosystems

Ozone standards for vegetation are not prescribed by the NSW EPA, however under the Queensland Environment Protection (Air) Policy (EPP (Air)) 2008, air quality objectives are listed for both human health and ecosystems damage. The EPP (Air) adopts the NEPM health based standards (**Table 3-1**). The EPP (Air) ecosystem goals are presented in **Table 3-3**.

Table 3-3: EPP (Air) ozone goals for vegetation

Indicator	Environmental value	Air Quality Objective	Period
Ozone (measured as accumulated exposure over a threshold of 40 ppb during daylight hours)	Protecting agriculture	0.2 ppm-hr	5 days
	Health and biodiversity of ecosystems (for semi-natural vegetation)	3 ppm-hr	3 months
	Health and biodiversity of ecosystems (for natural or uncultivated area)	10 ppm-hr	3 months

3.4 Airports (Environment Protection) Regulations 1997

The Airport (Environment Protection) Regulations 1997 (specifically Clause 2.01 and Schedule 1) outline the requirements for preventing or minimising air pollution. Schedule 1 outlines the accepted limits for emissions from stationary sources, which are defined as plant and equipment that "*is not a vehicle*" and is "*fixed to a particular location*". Stationary sources at an airport that would be subject to the limits in Schedule 1 include, for example, boilers and gas fired stationary engines.

Schedule 1 also outlines the ambient air quality objectives, which reflect the NEPM goals listed in **Section 3.2**.

3.5 NSW Tiered procedure for ozone assessment

The NSW EPA's tiered procedure for ozone assessment was developed for estimating ground level ozone impacts from stationary sources in NSW (ENVIRON, 2011). Stationary sources are defined as scheduled activities listed in Schedule 1 of the Protection of the Environment Operations (POEO) Act (1997) (NSW).

The most significant sources at the proposed airport (e.g. aircraft in flight) would not be designated as scheduled activity under the POEO Act and, as such, the tiered procedure for ozone assessment is only applicable to minor emissions sources such as boilers.

Notwithstanding, the tiered procedure provides guidance on how ozone assessment should be conducted in NSW and there are aspects of the guidance that are relevant and applicable to this assessment, described as follows:

- The assessment approach described in **Section 4** follows the modelling approach used to derive the tiered procedure and screening tool (ENVIRON, 2011).
- The tiered procedure describes a process to define areas as "attainment" or "non-attainment" for ozone. This process is useful to provide context for the existing environment and the analysis is presented in **Section 5.1**.
- The tiered procedure provides criteria for selecting days for detailed analysis, for a Level 2 assessment. These criteria are used in this assessment as discussed in **Section 8.1**.
- The tiered procedure provides a maximum allowable increment level of 1 ppb for ozone assessment. This is a useful metric to compare the modelled change in ozone concentrations attributable to emissions from the airport.

An overview of the tiered procedure framework is provided in **Appendix 1**.

4. OVERVIEW OF ASSESSMENT APPROACH

Ozone air quality impacts from the proposed airport were evaluated using the Comprehensive Air Quality Model with extensions (ENVIRON, 2015). CAMx is a three-dimensional, gridded, atmospheric dispersion model with photochemistry that allows for assessments of gaseous and PM air pollution (e.g. ozone, $PM_{2.5}$, PM_{10} and air toxics) over spatial scales ranging from sub-urban to continental. CAMx was used to assess ozone impacts in the Sydney GMR in a study for NSW EPA to develop the tiered assessment procedure for ozone (ENVIRON, 2011). CAMx is used around the world and is one of two models used by the US EPA to develop air quality regulations for ozone and PM (US EPA, 2011).

CAMx requires numerous input data including the following:

- An emissions inventory that specifies emissions of all ozone precursors from all sources contained within the CAMx modelling domain.
- Meteorological input data that determine how pollutants are transported within the CAMx modelling domain and the atmospheric conditions under which ozone is formed.
- Boundary conditions define pollutant concentrations that enter the CAMx modelling domain with prevailing winds that cross into domain boundaries.

This section describes how the CAMx input data were prepared.

4.1 Meteorological Model

CAMx requires meteorological input data for the parameters shown in **Table 4-1**.

Table 4-1: CAMx meteorological input data requirements

Input Parameter	Description
Winds (m/s)	3-D gridded wind vectors (u,v) for the start and end of each hour
Temperature (K)	3-D gridded temperature and 2-D gridded surface temperature for the start and end of each hour
Pressure (mb)	3-D gridded pressure for the start and end of each hour
Vertical Diffusivity (m^2/s)	3-D gridded vertical exchange coefficients for each hour
Water Vapor (ppm)	3-D gridded water vapor mixing ratio for each hour
Clouds and Rainfall (g/m^3)	3-D gridded cloud and rain liquid water content for each hour
Layer interface height (m)	3-D gridded time-varying layer heights for the start and end of each hour

TAPM has been used to simulate meteorology within the study area. TAPM is a three-dimensional meteorological and air pollution model developed by the CSIRO Division of Atmospheric Research. A detailed description of TAPM and its performance can be found in Hurley (2008) and Hurley et al. (2009). TAPM has been extensively used as a meteorological modelling tool, both in Australia and internationally (Wang et al., 2008; Soriano et al.; 2003; Mahmud, 2009; Mocioaca et al., 2009).

TAPM uses fundamental fluid dynamics and scalar transport equations to predict meteorology and (optionally) pollutant concentrations. The model predicts airflows that are important to local-scale air pollution, such as sea breezes and terrain induced flows, against a background of larger scale meteorology provided by synoptic analyses.

The modelling approach in this study reflects the modelling approach used in previous ozone modelling assessment for the GMR, consistent with ENVIRON (2011). TAPM is used to generate gridded three-dimensional meteorological data for each hour of the model run period, for input into the chemical transport model.

Surface observation data from all suitable Bureau of Meteorology (BoM) and Office of Environment and Heritage (OEH) meteorological stations located in the modelling domain are included in the meteorological modelling. The inclusion of these data (referred to as "data assimilation") provides real-world observations to improve the accuracy of the wind field, provided that the measurement is located so as to represent the surrounding area (e.g., clear of wind obstructions).

The observation sites included in the modelling are listed in **Table 4-2** and the locations are shown in **Figure 4-1**. The radius of influence (ROI) for each station is selected on the basis of the surrounding terrain and land use. For example, a small ROI is applied where a monitoring site is influenced by local terrain or obstructions.

Table 4-2: Data assimilation sites included in the meteorological model

BoM Site	Radius of influence (km)	NSW OEH Site	Radius of influence (km)
Albion Park (Wollongong Airport)	5	Albion Park South	2.5
Badgerys Creek	10	Bargo	2.5
Bankstown Airport	7	Bringelly	10
Bellambi AWS	2.5	Chullora	0.5
Camden Airport AWS	7	Earlwood	2.5
Canterbury Racecourse AWS	2.5	Londfield	2.5
Cessnock Airport AWS	10	MacArthur	5
Gosford (Narara) AWS	2.5	Newcastle	2.5
Holsworth Control Range	2.5	Oakdale	2.5
Horsley Park Equestrian Centre AWS	5	Prospect	5
Kiama (Bomb Headland)	2.5	Randwick	5
Moss Vale AWS	10	Rozelle	0.5
Mount Boyce AWS	10	St Marys	5
Nora Head AWS	2.5	Vineyard	7
Nullo Mountain	10	Wollongong	2.5
Patterson (Tocal AWS)	5		
Penrith Lakes AWS	2.5		
Richmond RAFF AWS	7		
Sydney Airport AWS	5		
Sydney Olympic Park	5		
Terry Hills AWS	5		
AWS	2.5		
Williamtowm RAFF	7		

4.1.1 Modelling domain

TAPM was run in three nested grids with grid spacing of 10km x 10km, 4km x 4km and 3km x 3km with 25 vertical levels (up to 8,000m). The number of grid points (70 x 90) was selected to ensure that the inner most grid (3km x 3km) covers an area of 210km x 270km; that is, the Greater Metropolitan Region (GMR) of NSW.

The outer grid spacing is limited to a 10km spacing, to remain within the maximum domain size recommended for TAPM. As outlined in Hurley (2008), domains larger than 1500km x 1500km should be avoided as the model does not account for curvature of the earth.

Hurley (2008) also recommends that the ratio of grid spacing from one nest to another be in the range 2 to 4, as this has been found to optimise both model run time and numerical noise generated in the nesting regions. The ratio of grid spacing selected between the outer grid and grid 2 was 2.5 and between grid 2 and the inner grid was 1.3. Although the grid 2 to inner grid ratio is lower than the recommended range, this is not expected to significantly influence the wind field for the areas of interest in this study, which are located at a distance from the edge of this nesting region. It is also noted that the meteorological modelling conducted by the EPA, for the tiered ozone assessment procedure, used similar small grid spacing ratios for the innermost grid.

The inner grid modelling domain, grid spacing and observation sites are shown in **Figure 4-1**.

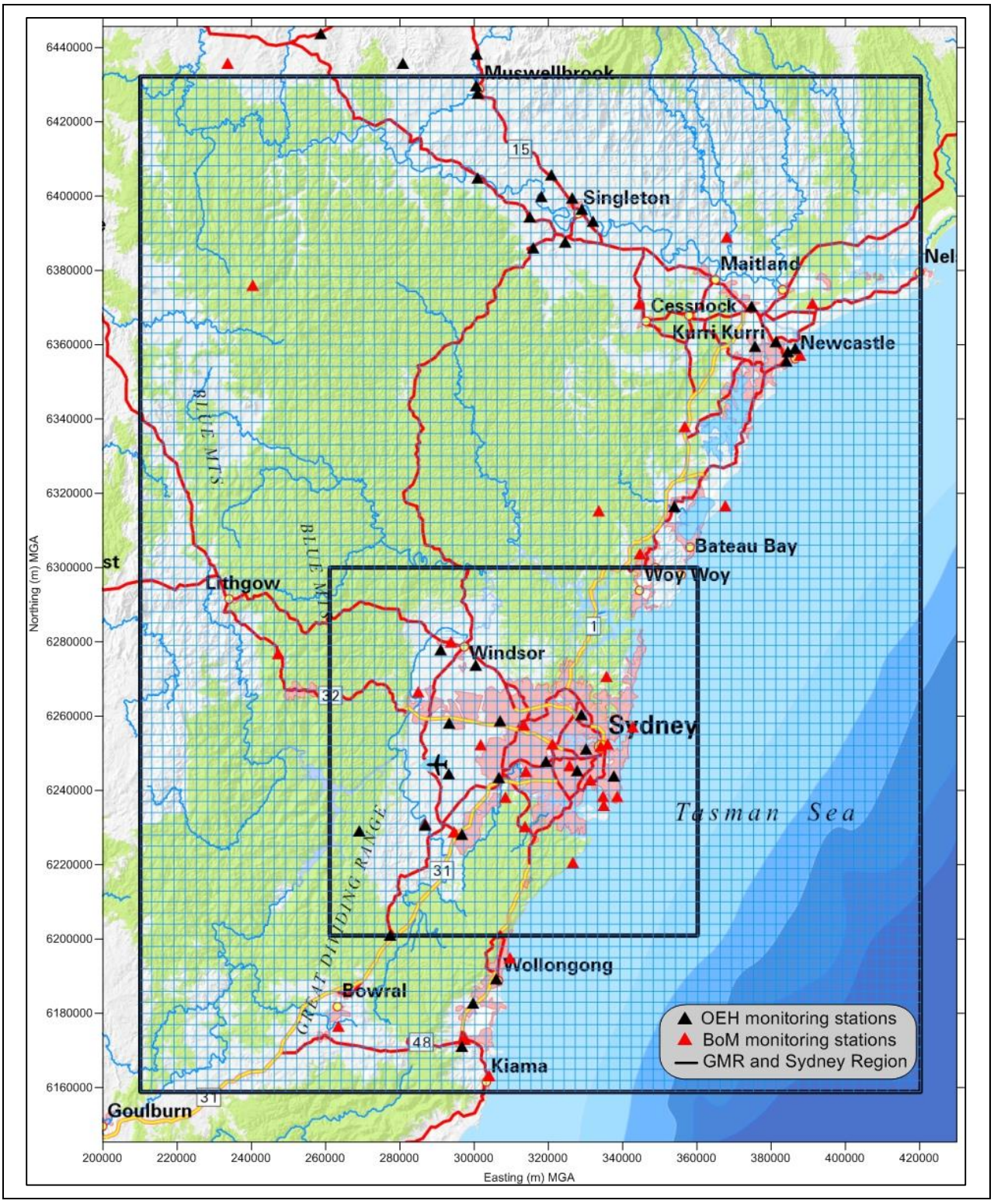


Figure 4-1: TAPM inner grid domain (GMR), grid spacing and monitoring sites

4.1.2 Modelling period

To provide confidence in the ozone modelling for a new emission source (in this case the proposed airport), it was necessary to select a suitable baseline period for modelling, which is used to evaluate model performance and make model refinements if they are needed.

The evaluation of model performance was based on a comparison against historical ozone monitoring data and the most suitable periods for evaluation are when peak ozone impacts occur (when exceedances of the 1-hour and 4-hour ozone standards occur frequently on consecutive days).

A review of ozone concentration data for the most recent 10 years indicates that the greatest number of exceedances of the 1-hour and 4-hour ozone standard occurred during summer 2008/2009. Peak ozone events also occurred during the summer 2006/2007, 2005/2006, 2007, 2011 and 2013, however analysis of the Geoscience Australia Sentinel Hotspots database for these periods indicates that significant bushfire activity may have contributed to some of these ozone episodes.

For example, during the summer of 2006/2007 there was significant bushfires to the northwest of Sydney and on the Central coast, in November 2009 there were bushfires on the northern outskirts of Sydney and in October 2013 there was a significant bushfire event in the Blue Mountains.

During the summer of 2008/2009 some isolated fires were recorded on the Sentinel Hotspots database, however no significant bushfire events were recorded. Considering the high number of exceedances of both the 1-hour and 4-hour ozone concentrations in the summer of 2008-2009, this period was selected for model evaluation.

The extended 2008/2009 summer period was modelled, from November 2008 to February 2009.

4.2 Overview of the Chemical Transport Model

The model selected for this assessment is consistent with the NSW EPA's tiered procedure for ozone assessment in NSW (ENVIRON, 2011). The Comprehensive Air quality Model with extensions (CAMx), developed by Ramboll Environ (ENVIRON, 2015), is an Eulerian photochemical dispersion model that allows for integrated "one-atmosphere" assessments of gaseous and particulate air pollution (e.g. ozone, $PM_{2.5}$, PM_{10} and air toxics) over a wide range of spatial scales ranging from sub-urban to continental. CAMx is one of two photochemical grid models that accounts for virtually all of the ozone assessment modelling currently performed in the US.

CAMx is a publicly available, open-source computer modelling system that can be downloaded from the CAMx home page at http://www.camx.com/. This site also provides a comprehensive User's Guide and other technical documentation (including journal publications), as well as pre- and post-processing utilities. The model is actively maintained and updated by Ramboll Environ, and the latest version of the model was used for this assessment (Version 6.2), released in March 2015.

4.2.1 Chemical Mechanism

Photochemical models incorporate atmospheric chemistry modules to describe the conversion of emitted pollutants to secondary pollutants such as ozone. The 2005 version of the Carbon Bond chemical mechanism (CB05) was selected for this study (Yarwood et al., 2005).

CB05 supersedes the CB4 mechanism and should be used rather than CB4. CB05 has been evaluated against smog chamber data and has been used in multiple photochemical models (e.g. CAMx and CMAQ).

The Air Emission Inventory for the GMR has been compiled for the CB4 mechanism. However, CB4 emission inventories can be used with CB05 without causing any problems because CB05 is backwards compatible with CB4.

4.3 Emissions scenarios

Emissions data for modelling are required for the following scenarios:

- 2008/2009 Base Case – for model evaluation.
- 2030 Future Base Case – for comparison with airport operations.
- 2030 Airport Case – for the Stage 1 airport development emissions.
- 2063 Airport Case – for the longer term airport development emissions.

4.3.1 Baseline model evaluation

The 2008/2009 Base Case model evaluation assesses model performance by modelling existing emissions sources for 2008/2009 and comparing results against monitoring data for the same period. The 2008/2009 Base Case was used to evaluate and calibrate the model and provides confidence in the model's ability to predict the future air quality impact from the addition of the airport. As previously discussed, the 2008/2009 period was selected because it has the greatest number of exceedances of the 1-hour and 4-hour ozone standard for the past 10 years.

Gridded emissions inventory data were provided by NSW EPA for 2008 (NSW EPA, 2012). The GMR air emissions inventory data includes point source emissions from commercial and industrial sources, area source emissions for on-road mobile, commercial, industrial, domestic and off-road sources for the entire GMR.

The following emissions files were provided by the NSW EPA:

- Areas source files (aems), including fugitive area source emissions from commercial, domestic, industrial and off-road sources. In extracting the data, the control factor for biogenic sources (bushfires, prescribed burning, soil and vegetation) is set to zero, to exclude these sources (refer **Section 4.4** for details on how biogenic emissions were modelled).
- Vehicle emission files (mvems), including area source emissions for on-road mobile sources.
- Point source files (pems), including elevated point source emission files for commercial and industrial premises.

Gridded emissions inventory data were received as weekday and weekend files by month, at a grid resolution of 1km x 1km and speciated for the CB4 chemical mechanism.

From these data, time-varying emissions are generated for the modelling period (November 2008 to February 2009) for input into CAMx by aggregating emissions into a 3km x 3km grid. The resulting emission files were ready for use with CAMx but required merging with emissions from biogenic sources and the airport.

Annual emission totals for the NSW GMR and the Sydney Region are presented in **Table 4-3** and **Table 4-4**, for ozone precursor emissions considered in the modelling. For some sources the majority of emissions occur within the Sydney region. For example. 74% of NO_x emissions for on-road mobile sources occur in Sydney. For others source groups, such as industrial, the majority of emissions occur outside of the Sydney region.

As described in **Section 2.1**, emissions from existing airport operations in Sydney are less than 3% of total emissions for the Sydney Region (NSW EPA, 2012a). A summary of the annual emissions for existing airports in the Sydney Region (e.g. Sydney Airport, Bankstown Airport, Camden Airport and Richmond RAAF) is presented in **Table 4-5**, to provide context with emissions estimates presented for the proposed airport. It is noted that airport related traffic is not included in the emission totals.

Table 4-3: Summary of annual emissions for NSW GMR in 2008

Source	Tonnes per year		
	Carbon Monoxide	**Oxides of Nitrogen**	**Total VOCs**
Commercial	389	501	9,176
Domestic-Commercial	109,377	3,290	68,809
Industrial	613,365	191,411	11,519
Off-Road Mobile	53,817	53,210	17,950
On-Road Mobile	153,812	60,932	29,504
Total	**930,759**	**309,344**	**136,957**

Table 4-4: Summary of annual emissions for Sydney Region in 2008

Source	Tonnes per year		
	Carbon Monoxide	**Oxides of Nitrogen**	**Total VOCs**
Commercial	335	344	6,652
Domestic-Commercial	82,186	2,531	53,178
Industrial	14,173	8,921	8,205
Off-Road Mobile	20,801	16,238	7,341
On-Road Mobile	123,712	45,392	23,512
Total	**241,208**	**73,427**	**98,889**

Table 4-5: Summary of annual emissions for airport operations in 2008

Source	Tonnes per year		
	Carbon Monoxide	**Oxides of Nitrogen**	**Total VOCs**
Aircraft (flight operations)	2,407	1,771	253
Aircraft (ground operations)	1,823	255	99
Total	**4,230**	**2,026**	**352**

4.3.2 Future baseline emissions

To assess the impact of airport operations for a future scenario, it was necessary to apply projections to the 2008 baseline emission estimates. The NSW EPA have developed future year annual emissions projections for 2031, which have been used to scale baseline emissions for the Stage 1 airport development, which is nominally assessed in 2030.

The NSW EPA emission projections are consistent with the business as usual (BAU) scenario presented in the Economic Analysis which supports the Impact Statement for the proposed variation to the Ambient Air Quality NEPM[2]. The emission projections assume economic growth and also (importantly) emission factor development to account for improvements in emission standards and increased regulation. For example, despite projected growth in vehicle kilometres travelled (VKT) vehicle emissions are assumed to decrease as a result of improvements in emission standards.

A summary of the emissions projections for 2031 are presented in **Table 4-6** and used to derive scaling factors for the 2008 gridded emissions, as shown in **Table 4-7**.

[2] http://www.environment.gov.au/protection/nepc/nepms/ambient-air-quality/variation-2014/impact-statement

Table 4-6: Summary of estimated annual baseline emissions for 2031 for the GMR

Source	Tonnes per year		
	Carbon Monoxide	Oxides of Nitrogen	Total VOCs
Commercial	461	599	7,635
Domestic-Commercial	119,461	4,069	81,860
Industrial	649,605	231,049	15,353
Off-Road Mobile	73,757	70,469	23,381
On-Road Mobile	38,453	18,889	10,446
Total	**881,736**	**325,074**	**138,675**

Table 4-7: Scaling factors used to scale 2008 baseline emissions for 2030

Source	Tonnes per year		
	Carbon Monoxide	Oxides of Nitrogen	Total VOCs
Area source emissions (fugitive commercial, domestic, non-road emissions)	1.216	1.252	1.108
Point source emissions	1.059	1.207	1.333
Vehicle emissions	0.250	0.310	0.354

4.3.3 Stage 1 Airport Development (2030)

Aircraft are typically the largest contributor to airport emissions, however the majority of aircraft emissions occur in flight and are released at high altitude (Masiol & Harrison, 2014). Local and regional emission inventories for aircraft are therefore typically limited to emissions generated during the Landing/Take-Off (LTO) cycle, which includes idle, taxi, take off, climb-out and approach. These emissions are released near the ground and can be brought to ground level by turbulent mixing in the atmosphere. Emissions generated during the LTO cycle are generally considered in airport emission inventories up to 3,000 feet (~1,000 m). Other airport emissions sources include ground support equipment (GSE), aircraft auxiliary power units (APU) and other stationary sources on the ground (boilers, generators, training fires, maintenance).

Emissions estimates for the Stage 1 airport development (nominally 2030) have been made using the US Federal Aviation Administration Emissions and Dispersion Modeling System (EDMS). The EDMS emissions data are developed for the local air quality assessment and have been provided for use in this assessment. Emissions are estimated for all airport operations and also for surrounding roadways out to radius of approximately 10 km, including the proposed M12 motorway and upgrades to the Northern Road and Bringelly Road. The emissions estimates for roadways are based on future projected traffic volumes, taking into account the operation of the airport. Details of the roadways included are provided in the local air quality assessment.

A summary of the annual airport emissions from EDMS are presented in **Table 4-8**.

Table 4-8: Stage 1 airport development emissions (2030)

Source	Tonnes per year		
	Carbon Monoxide	Oxides of Nitrogen	Total VOCs
Aircraft	126.5	335.9	26.5
GSE	48.6	4.5	2.0
APUs	4.7	17.3	0.5
Parking Facilities	9.4	0.4	1.0
Roadways	2,141.0	1,355.3	239.4
Stationary Sources	2.4	4.4	62.0
Training Fires	3.1	0.0	0.1
Total	**2,335.7**	**1,717.9**	**331.6**

Adjustments have been made to the EDMS data for regional modelling. EDMS emissions were processed using the Emissions Processing System version 3 (EPS3) to generate CAMx model-ready emissions. Several EPS3 modules were used to perform the following tasks:

- Gridding.
- Temporal allocation.
- Chemical speciation of VOC and NOx.
- Adjusting emissions for growth and controls.
- Merging emissions from different sectors.
- Tabulating emissions for quality assurance and reporting.

Speciation profiles have been assigned for each source group to convert total VOC to individual VOC species needed for modelling. The speciation profiles used are listed in **Appendix 2**.

4.3.3.1 Adjustments for roadway emissions

The roadway emissions prepared for the local air quality assessment included all future traffic on the roads within 10 km of the airport, not just the incremental traffic attributable to the airport development. For regional modelling, only the incremental traffic emissions were needed because non-airport traffic is already accounted for in the 2030 Base Case emissions inventory for the GMR.

The traffic emissions attributed to the airport were disaggregated from the roadway emissions prepared for the local air quality assessment by using the change in daily traffic volumes between the "Do Minimum" (no airport) and the "Do Something" (airport) traffic modelling scenarios. The airport traffic emissions were separated independently for each roadway segment (link) included in the local scale air quality assessment. For most links, traffic increases with the airport but on some links traffic decreases when a road is used less in response to new roads being built. It is noted that the approach of scaling based on daily traffic is a simplification and doesn't, for example, account for traffic fleet changes by link (e.g., more cars and fewer trucks in the Do Something scenario).

The estimated airport roadway emissions are presented in **Table 4-9**. The NOx emissions attributed to the airport are estimated as 1.2% of the total traffic emissions for the EDMS road links. As a comparison, the percentage change in daily traffic, between the "Do Minimum" and the "Do Something", over all roadway links combined is 1.6%. The spatial allocation of emissions data for 2030 is presented in **Appendix 3**.

Table 4-9: Disaggregated traffic emissions for regional modelling

	Tonnes per year		
Source	**Carbon Monoxide**	**Oxides of Nitrogen**	**Total VOCs**
Roadways in EMDS	2,141.0	1,355.3	239.4
Estimated emissions attributed to the airport	37.1	15.7	4.4

4.3.4 Longer term airport development (2063)

Emissions estimates for the longer term airport development (nominally 2063) have been developed for the local air quality assessment. A summary of the annual airport emissions from EDMS are presented in **Table 4-10**. The 2063 Airport Case presents a hypothetical scenario, as it has the longer term airport development from 2063 operating in the year 2030. This is necessary because there are no projections of emissions for other sources (commercial, industrial etc.) for the year 2063.

Similar to 2030, traffic emissions attributed to the airport were disaggregated from the total roadway emissions for 2063 modelling. The EDMS roadway emissions for 2063 decrease from 2030 despite increase in airport passengers, due to a combination of lower per-vehicle emissions in 2063 and the introduction of a train line for the longer term development. As previously discussed, there are no adjustments applied for 2063 for all other roadways within the modelling domain and emissions are assumed to be the same as 2030.

Incremental traffic emissions attributable to the airport in 2063 were also assumed to be the same as for 2030, which represents 2.1% of the total traffic emissions for the EDMS road links in 2063. The longer term airport development emissions presented in **Table 4-10**.

Table 4-10: Longer term airport development emissions (2063)

Source	Tonnes per year		
	Carbon Monoxide	**Oxides of Nitrogen**	**Total VOCs**
Aircraft	728.6	1,756.4	131.9
GSE	159.2	15.0	7.2
APUs	17.8	64.4	1.8
Parking Facilities	126.8	5.7	13.7
Roadways	2,885.1	761.7	283.3
Stationary Sources	15.3	21.6	507.0
Training Fires	61.1	0.5	2.0
Total	**3,993.9**	**2,625.3**	**946.9**

4.4 Biogenic emissions

Vegetation is present throughout the Sydney GMR, even in urban and suburban environments, and the modelling domain includes areas of dense eucalypt forest that form part of the Blue Mountains national parklands. VOCs from these biogenic sources are an important component of the modelling. The biogenic emission data in the GMR air emissions inventory are provided as diurnal emission profiles averaged by month (based on monthly average temperature) and so do not take into account day-to- day variation in temperature.

To obtain date-specific and hourly varying gridded biogenic emissions, the Model of Emissions of Gases and Aerosols from Nature (MEGAN) is used, driven by temperature fields from TAPM.

MEGAN was developed by the Biological-Atmospheric Interactions (BAI) group of the Atmospheric Chemistry Division (ACD) at the US National Center for Atmospheric Research (NCAR). MEGAN estimates net emission of gases and aerosols from terrestrial ecosystems into the atmosphere (Guenther et al., 2006; Sakulyanontvittaya, et al., 2008) driven by land cover, weather, and atmospheric chemical composition. MEGAN is a global model with a base resolution of approximately 1 km.

4.5 Boundary conditions

Date specific boundary conditions for ozone and other pollutants entering the GMR CAMx domain were obtained from the global model MOZART (Model for Ozone and Related chemical Tracers; Emmons et al., 2010) available from the (US) National Center for Atmospheric Research (NCAR). The ozone boundary conditions generated from MOZART are consistent with the 20-30 ppb concentration range recommended by OEH for regional ozone modelling in Sydney.

5. EXISTING ENVIRONMENT

5.1 Defining areas of ozone attainment and nonattainment

The tiered procedure for ozone assessment requires classification of areas of Sydney as "attainment" or "non-attainment", based on meeting or exceeding an "acceptance limit" expressed as 82% of the NEPM goal (NEPC, 2007). If the maximum 5 year average is below the "acceptance limit" (1-hour average of 82 ppb or 4-hour average of 65.2 ppb) the area is in attainment. If the maximum 5 year average is above the "acceptance limit", the area is in non-attainment. Although the tiered procedure for ozone assessment is not directly applicable to this assessment, it is useful to classify areas of Sydney as attainment or non-attainment, to provide context on the existing ambient environment in terms of ozone pollution.

Ozone is currently measured at 15 Sydney monitoring sites, operated by the NSW Office of Environment and Heritage (OEH) and shown in **Figure 5-1**. Monitoring data are reported by the OEH in pphm and are converted to ppb for this report.

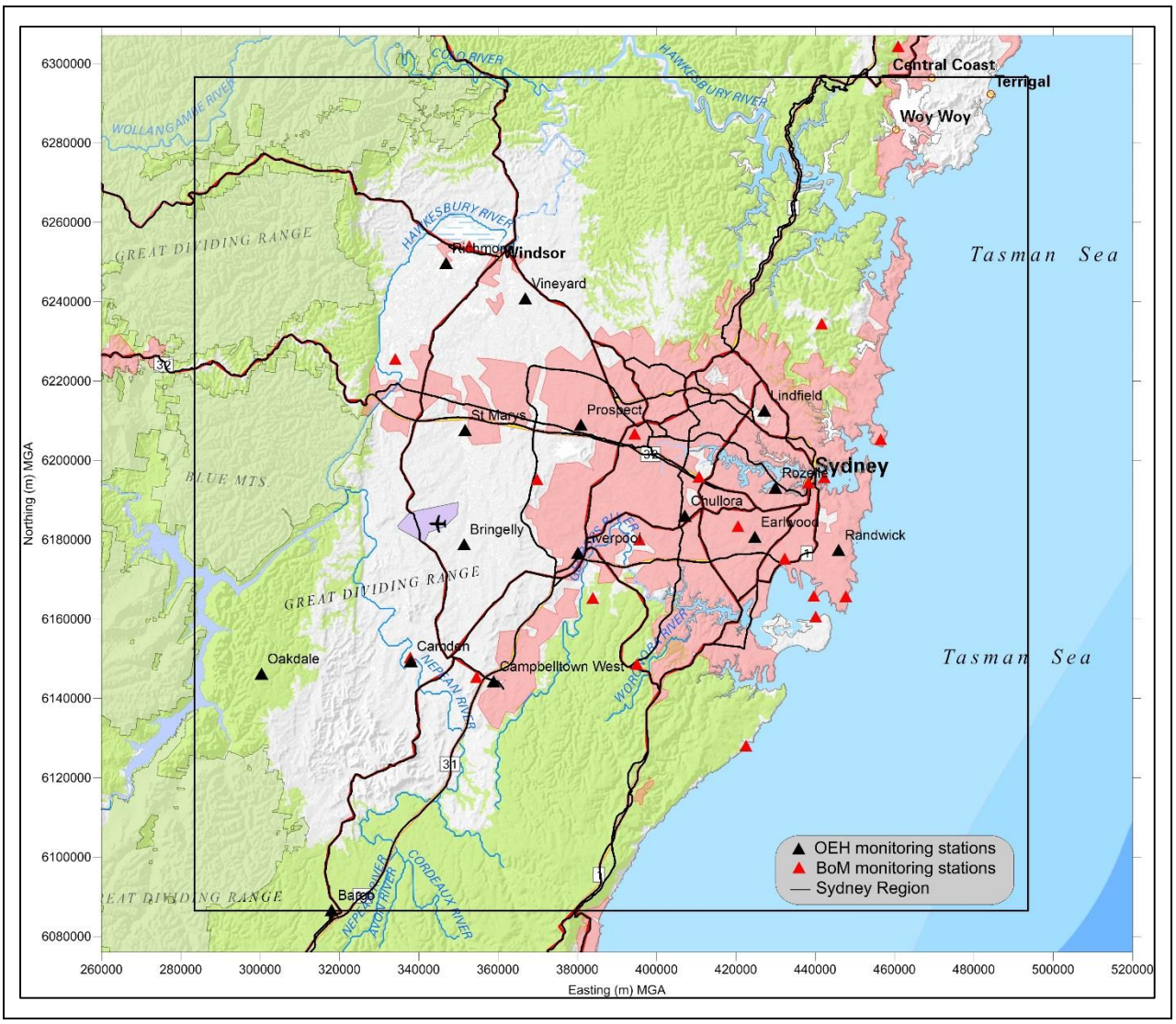


Figure 5-1: OEH monitoring sites in the Sydney Region

The maximum 1 hour and 4 hour average ozone concentrations for the most recent five years of monitoring data at these sites are presented in **Table 5-1** and **Table 5-2**. The average across the 5 years is taken and the maximum 5 year average is compared against the acceptance limits of 82 ppb (1-hour) and 65.2 ppb (4-hour). It is clear from the analysis that all areas of the Sydney region are current classified as non-attainment.

Table 5-1: Classification of ozone nonattainment based on 1-hour average ozone concentrations

Station	Maximum ozone concentration (ppb)					Average
	2010	2011	2012	2013	2014	
Randwick	84	73	66	75	66	73
Rozelle	73	93	69	73	67	75
Lindfield	82	86	73	81	85	81
Chullora	83	114	80	105	79	92
Earlwood	85	99	82	101	69	87
Maximum 5 year average - Sydney central-east (nonattainment)						**92**
Richmond	89	116	85	95	90	95
St Marys	95	136	85	110	100	105
Vineyard	90	94	80	105	112	96
Propect	104	126	80	111	103	105
Maximum 5 year average - Sydney north-west (nonattainment)						**105**
Liverpool	91	103	79	117	103	99
Bringelly	104	125	88	108	124	110
Bargo	110	126	91	95	105	105
Macarthur	119	131				
Oakdale	99	126	89	95	110	104
Campbelltown west				94	124	
Camden				110	123	
Maximum 5 year average - Sydney south-west (nonattainment)						**110**

Table 5-2: Classification of ozone nonattainment based on 4-hour average ozone concentrations

Station	Maximum ozone concentration (ppb)					Average
	2010	2011	2012	2013	2014	
Randwick	77	69	63	67	61	67
Rozelle	67	80	54	63	60	65
Lindfield	79	84	71	74	75	77
Chullora	72	96	68	94	73	81
Earlwood	74	88	68	82	65	75
Maximum - Sydney central-east (nonattainment)						**81**
Richmond	82	88	70	76	73	78
St Marys	83	121	72	101	85	92
Vineyard	79	75	70	90	75	78
Propect	97	114	73	104	97	97
Maximum - Sydney north-west (nonattainment)						**97**
Liverpool	81	95	71	110	87	89
Bringelly	89	118	72	102	113	99
Bargo	86	98	83	82	93	88
Macarthur	103	122				
Oakdale	88	98	81	81	88	87
Campbelltown west				82	111	
Camden				90	110	
Maximum - Sydney south-west (nonattainment)						**99**

5.2 Annual exceedances of 1-hour and 4-hour ozone standards

A review of the most recent 10 years of monitoring data reveals exceedances of the 1-hour and 4-hour standards occur in most years. The number of annual exceedances of the 1-hour and 4-hour ozone standards is presented in **Table 5-3** and **Table 5-4**. The exceedances are most frequent in areas of west and southwest Sydney. At Bringelly (near the airport site), there have been exceedances of the ozone standards in 8 of the past 10 years.

Table 5-3: Number of annual exceedances of the 1-hour ozone standard

Station	Number of annual exceedances of 1-hour ozone standard									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Randwick	0	0	0	0	0	0	0	0	0	0
Rozelle	0	0	0	0	0	0	0	0	0	0
Lindfield	-		-	0	1	0	0	0	0	0
Chullora	0	3	0	0	3	0	1	0	1	0
Earlwood	0	2	0	0	3	0	0	0	1	0
Richmond	3	2	4	0	1	0	1	0	0	0
St Marys	2	4	4	0	9	0	5	0	1	0
Vineyard	3	1	4	0	0	0	0	0	2	1
Prospect			-	1	4	3	5	0	2	2
Liverpool	3	11	3	0	3	0	1	0	5	1
Bringelly	6	10	5	0	7	2	5	0	3	4
Bargo	3	3	5	0	11	1	2	0	0	3
Macarthur	11	18	5	0	11	3	5	-		
Oakdale	7	1	8	0	10	0	4	0	0	1
Campbelltown west								-	0	3
Camden								-	1	4

Note: Blanks cells mean complete year of data missing. Cells with a dash indicate less than 75% complete for the year.

Table 5-4: Number of annual exceedances of the 4-hour ozone standard

Station	Number of annual exceedances of 1-hour ozone standard									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Randwick	0	0	2	0	0	0	0	0	0	0
Rozelle	0	1	0	0	0	0	0	0	0	0
Lindfield	-		-	0	3	0	1	0	0	0
Chullora	1	10	0	0	6	0	4	0	3	0
Earlwood	0	4	0	0	7	0	2	0	3	0
Richmond	7	8	13	0	7	2	3	0	0	0
St Marys	6	12	14	1	18	2	11	0	6	5
Vineyard	12	6	7	0	11	0	0	0	7	0
Prospect			3	2	18	7	13	0	6	5
Liverpool	6	16	7	1	10	1	5	0	6	3
Bringelly	13	17	14	0	14	7	8	0	6	11
Bargo	15	10	15	0	28	3	3	1	2	9
Macarthur	23	28	15	0	23	4	9	-		
Oakdale	16	3	20	0	24	5	10	1	1	4
Campbelltown west								-	1	10
Camden								-	15	9

Note: Blanks cells mean complete year of data missing. Cells with a dash indicate less than 75% complete for the year.

5.3 Temporal patterns in ozone concentration

Temporal variation in ozone concentrations are driven by a number of factors, including availability of sunlight, ambient temperature, atmospheric stability, wind direction and availability of precursor emissions.

As described in **Section 2.1**, peak ozone concentrations in Sydney tend to occur in the mid-afternoon and during summer months. This is clearly demonstrated in the polar plots shown in **Figure 5-2** which presents maximum hourly ozone concentrations at Bringelly, plotted by wind direction.

On the left panel, peak concentrations are plotted by hour of the day and on the right panel by month of the year. The colour gradient shows how the ozone concentrations vary temporally and by wind direction (the darker the shade the higher the ozone concentration).

On the left panel, peak ozone concentrations are represented by the dark band which clearly occurs when wind is blowing from the east through north, associated with the transport of precursor emissions from Sydney. This peak concentration band is also distributed between the hours of midday and 4 pm, as shown by the hour of day scale at each compass point.

On the right panel, similar peak ozone concentrations occur when winds are from the east through north, associated with the transport of precursor emissions from Sydney. In this case the scale at each compass point shows month of the year and there are two very clear peak concentration bands, representing the months of January/February and November/December.

5.4 Long term trends in ozone concentration

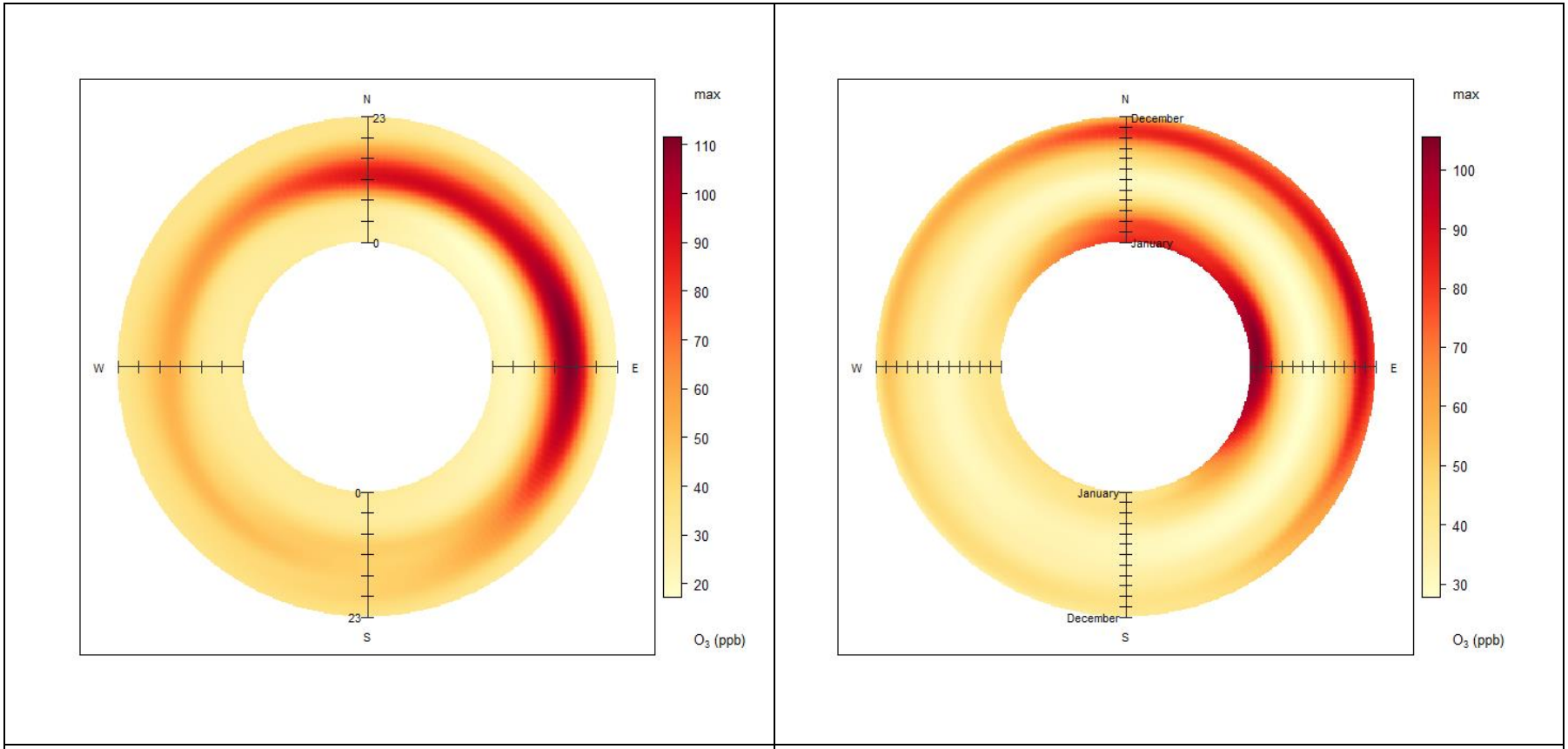
The most recently published "*State of the Air in Australia*" report (DSEWPC, 2011) found no obvious trends in 1-hour or 4-hour ozone concentration for NSW, for the 10 year assessment period examined (1999 – 2008). The report also noted that ambient ozone concentrations were unlikely to decrease in the foreseeable future because of growth in motor vehicle use and higher temperatures/drier weather from climate change resulting in more bushfires, higher photochemical activity and emissions of ozone precursors.

Analysis of ozone and NO_x monitoring data are presented in **Figure 5-2** to examine long term trends in the most recent ten years of monitoring data (2004-2014) for Bringelly (near the airport site). Long term trends were determined by accounting for seasonal variation using the procedure of Cleveland et al. (1990) implemented by Carslaw and Ropkins (2012).

The analysis shows a negative trend in the maximum monthly ozone concentration (approximately 1% decrease per annum) and a more pronounced negative trend in the NO_x data (~3% decrease per annum). Therefore, although exceedances of the 1-hour or 4 hour ozone standard have occurred in 8 of the previous 10 years, there is some evidence of decreasing trends in monthly maximum ozone concentrations at Bringelly. Analysis for other sites in southwest, northwest and central Sydney shows similar trends.

The Bureau of Meteorology (BoM) annual climate statement for 2014[3] reports that 2014 was the hottest year on record and seven of Australia's ten warmest years on record have occurred since 2002. As described previously, the most recent *State of the Air in Australia* report postulates that higher temperatures and drier weather might result in increased photochemical activity and emissions of ozone precursors. This hypothesis is not necessarily reflected in the trend analysis for the most recent 10 years of monitoring data at Bringelly.

[3] http://www.bom.gov.au/climate/current/annual/aus/



Maximum ozone concentration by hour of day	Maximum ozone centration by month of the year

Figure 5-2: Polar plot of maximum hourly and monthly ozone concentration (ppb) by wind direction at Bringelly (2004 to 2014)

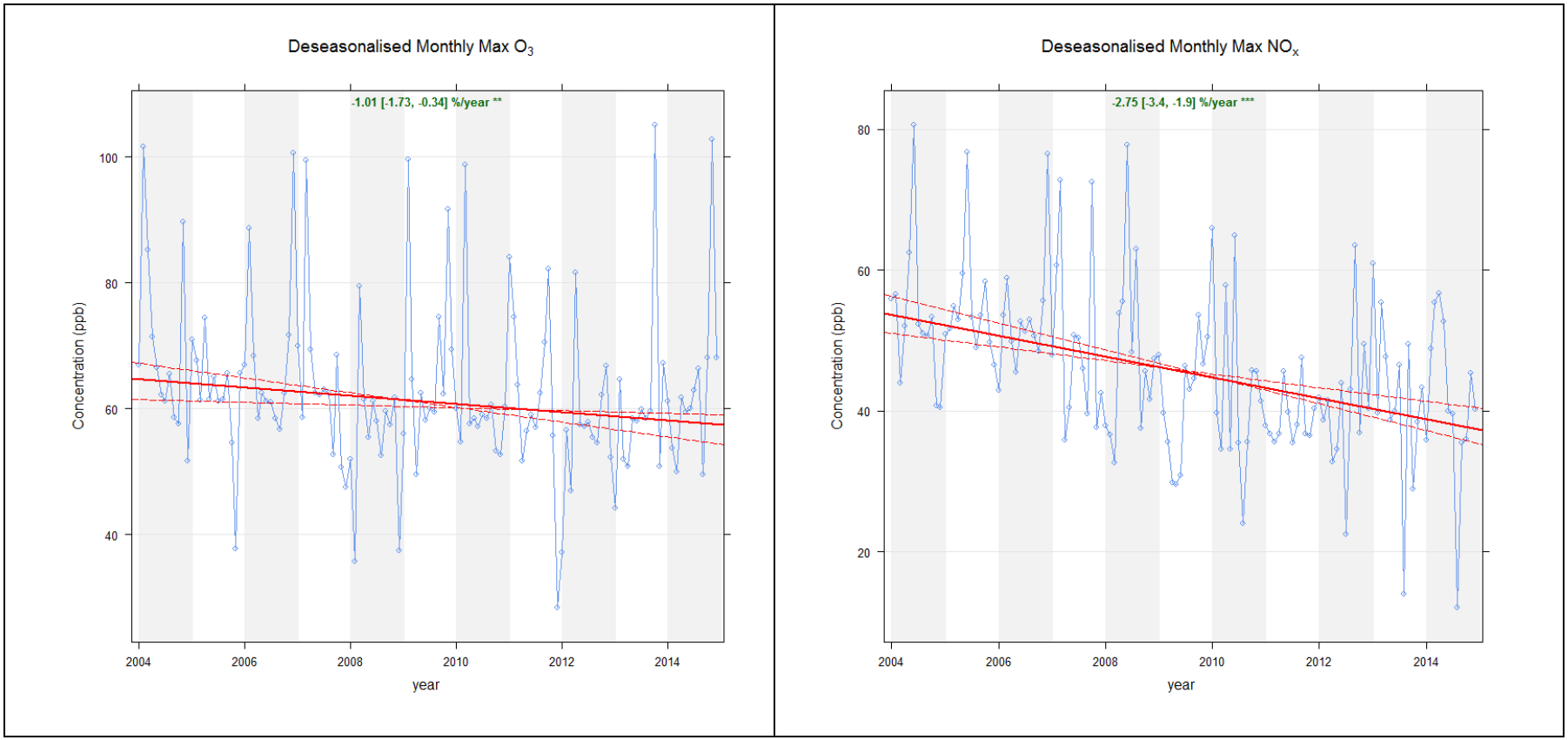


Figure 5-3: Trend in monthly max ozone and NO_x concentrations (ppb) at Bringelly (2004-2014) (% change per year with 95% confidence limits)

6. EVALUATION OF METEOROLOGICAL MODELLING

Meteorological model performance is critical to obtaining accurate photochemical model performance because ozone formation depends upon meteorological conditions (temperature, sunlight, dilution of emissions) and because source-receptor relationships are determined by wind fields.

TAPM has been found to overestimate solar radiation during both clear sky and cloudy conditions (Dehghan et al, 2014) while Hibberd et al (2011) found that TAPM underestimates cloudy days and overestimates net radiation (as reported in Dehghan et al, 2014). This may introduce a systematic bias towards over-predicting ozone production on days that were cloudy, and is discussed further in **Section 7**.

To evaluate TAPM performance for local meteorology, predicted meteorological parameters (wind speed, wind direction and temperature) were extracted from TAPM at four locations and compared with the closest observation sites that are considered to be generally representative of the area of interest. The locations selected for the evaluation are described in **Table 6-1**.

Table 6-1: Locations and observations sites for model evaluation

Area for TAPM extract	TAPM grid coordinate (Easting/Northing MGA)	Observation site for comparison
Area near the airport site, between Bringelly and Badgerys Creek	292500 / 6246000	- Badgerys Creek BoM site - Bringelly OEH site
Southwest Sydney, south of Camden Airport	286500 / 6228000	- Camden Airport BoM site - Campbelltown (Mt Annan) BoM site
Northwest Sydney, between Prospect and Vineyard	304500 / 6261000	- Vineyard OEH site - Prospect OEH site
Western Sydney, between Bankstown and Chullora	3165000 / 6246000	- Chullora OEH site - Bankstown Airport CoM site

An evaluation of the meteorological model performance is presented using visual analysis tools (wind roses, time variation plots and scatter plots) and statistical evaluation, based on the evaluation methods in **Table 6-2**. Indicative performance benchmarks for bias and error are provided, based on Emery et al. (2001). The purpose of these benchmarks was not to give a passing or failing grade to any one particular meteorological model application, but rather to put the model's results into the proper context of other models and meteorological data sets. Since 2001, the benchmarks have been promoted by the EPA-sponsored National Ad Hoc Meteorological Modeling Group and have been consistently relied upon to evaluate Pennsylvania State University / National Center for Atmospheric Research (MM5) and WRF model performance in many regulatory modelling projects throughout Texas and the U.S.

Table 6-2: Statistical evaluation for model performance

Statistical test	Description	
FAC2	$0.5 \leq \frac{M_i}{O_i} \geq 0.5$	Fraction of model predictions (M) within a factor of 2 of the observed values (O)
Mean bias (MB)	$\boldsymbol{MB} = \frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} \boldsymbol{M_i} - \boldsymbol{O_i}$	MB provides an indication of the mean over or under estimate of model predictions and is expressed in the same units as the quantities being considered. Indicative performance benchmark for wind speed is ≤±0.5 m/s and for temperature is ≤± 0.5 K.
Mean Gross Error (MGE)	$\boldsymbol{MGE} = \frac{\mathbf{1}}{\boldsymbol{N}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{N}} \lvert\boldsymbol{M_i} - \boldsymbol{O_i}\rvert$	MGE provides an indication of the mean error regardless of whether it is an over or under estimate and is in the same units as the quantities being considered. Indicative performance benchmark for wind speed is ≤ 2.0 m/s and for temperature is ≤ 2.0 K.
Pearson correlation coefficient (r)	$r = \frac{1}{n-1}\sum_{i=1}^{N}\left(\frac{M_i - \bar{M}}{\sigma_M}\right)\left(\frac{O_I - \bar{O}}{\sigma_O}\right)$	The (Pearson) correlation coefficient is a measure of the strength of the linear relationship between two variables. If there is perfect linear relationship with positive slope between the two variables, r = 1.
Index of Agreement (IOA)	$IOA = 1 - \frac{\sum_{i=1}^{N}\lvert M_i - O_i\rvert}{c\sum_{i=1}^{N}\lvert O_i - \bar{O}\rvert}$	Values approaching +1 representing better model performance. (Willmott et al. 2011).

6.1 Evaluation of model performance near the airport site

A comparison of observed and the TAPM predicted wind roses for the modelling period (November 2008 to February 2009) is presented in **Figure 6-1**. The TAPM predicted winds are extracted from a point between Bringelly OEH and the Badgerys Creek BoM observation sites.

The two observation sites themselves differ slightly, with stronger winds recorded at the Badgerys Creek BoM site. The mean wind speed for Badgerys Creek is 3.7 m/s, compared with 2.1 m/s at Bringelly. The percentage occurrence of calm winds (less than 0.5 m/s) is also higher at Badgerys Creek.

The TAPM average wind speed falls between the observations, while the percentage calms is closer to the Bringelly site. The TAPM wind direction reflects the general wind patterns for both sites with a relatively uniform distribution of winds from the southwest through northeast.

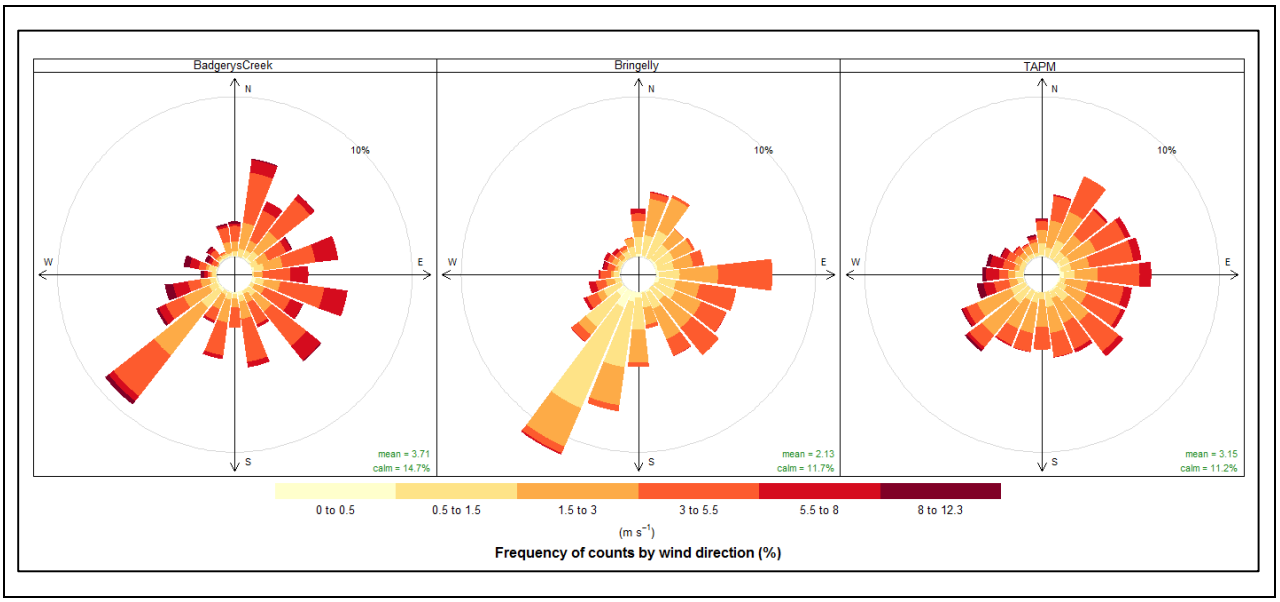


Figure 6-1: Wind rose comparison for proposed airport

Hourly variation in the observed and predicted wind speed and temperature is presented in **Figure 6-1**. TAPM predicted winds generally lie between the observations and appear closer aligned to the measurements at Badgerys Creek. Predicted hourly temperature tracks well with observations at both Badgerys Creek and Bringelly during the afternoon while the predicted night-time and early morning temperatures tend to be higher than observed. This is unlikely to affect ozone predictions as peak concentrations occur in the afternoon.

Scatter plots of the predicted and observed wind speed and temperature are shown in **Figure 6-3** and **Figure 6-4**. The correlation is high for wind speed and temperature at both sites.

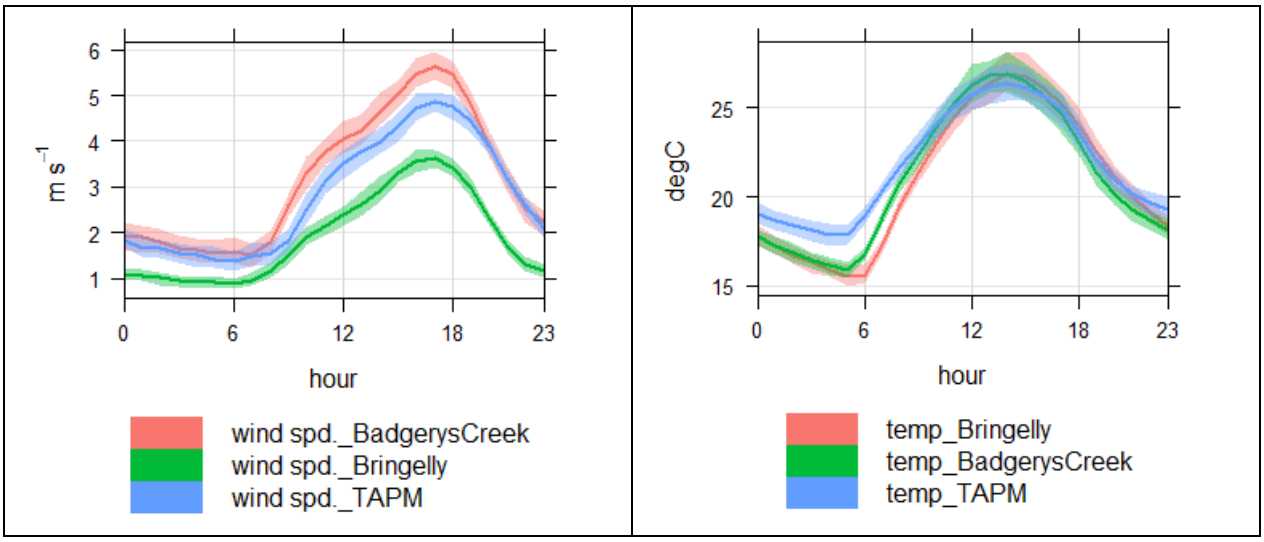


Figure 6-2: Time variation of observed and predicted wind speed and temperature for proposed airport

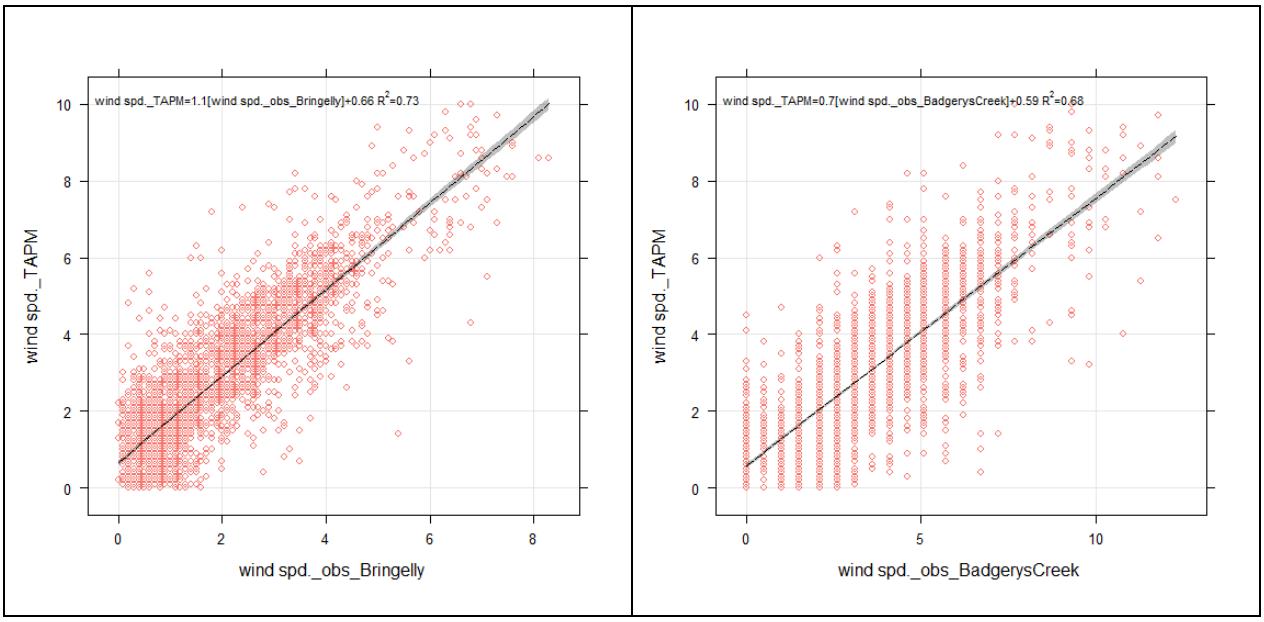


Figure 6-3: Scatter plot of observed and predicted wind speed for proposed airport

Note: Wind speed data recorded at BoM sites (Badgerys Creek) is provided in increments of 0.5, due to conversion from knots to m/s, resulting in a more defined bands seen in the scatter plot on the right.

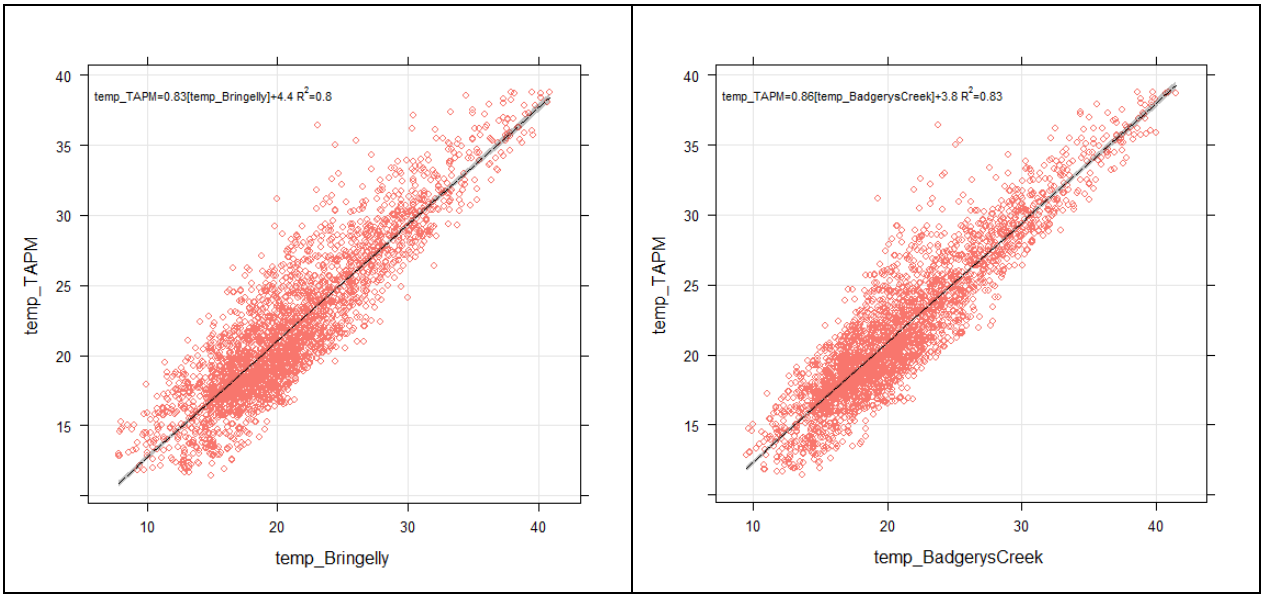


Figure 6-4: Scatter plot of observed and predicted temperature for proposed airport

A summary of the model evaluation statistics for TAPM predicted wind speed and temperature is presented in **Table 6-3**. The statistical evaluation for wind speed which shows more favourable FAC2, correlation and index of agreement and lower bias and error for observations at the Badgerys Creek site. The statistical evaluation for temperature is similar for both sites.

Table 6-3: Evaluation of TAPM wind speed and temperature against observations for Western Sydney Airport

Statistical test	Wind speed		Temperature	
	Badgerys Creek	Bringelly	Badgerys Creek	Bringelly
Fraction of predictions within a factor of 2 (FAC2)	0.82	0.70	1.00	1.00
Mean bias (MB)	-0.37	0.91	0.74	0.87
Mean Gross Error (MGE)	0.69	1.09	1.87	1.97
Pearson correlation coefficient (r)	0.93	0.85	0.91	0.90
Index of Agreement (IOA)	0.80	0.53	0.79	0.78

6.2 Evaluation of model performance in Southwest Sydney

A comparison of observed and the TAPM predicted wind roses for the modelling period (November 2008 to February 2009) is presented in **Figure 6-5**. The TAPM predicted winds are extracted from a point southwest of Camden.

The TAPM predicted mean wind speed and percentage occurrence of calm winds are closer to the observations at the Campbelltown site. As an airport site, it is not surprising that Camden records higher wind speeds. The TAPM wind direction reflects the general wind patterns for both sites with a relatively uniform distribution of winds from the southwest through northeast.

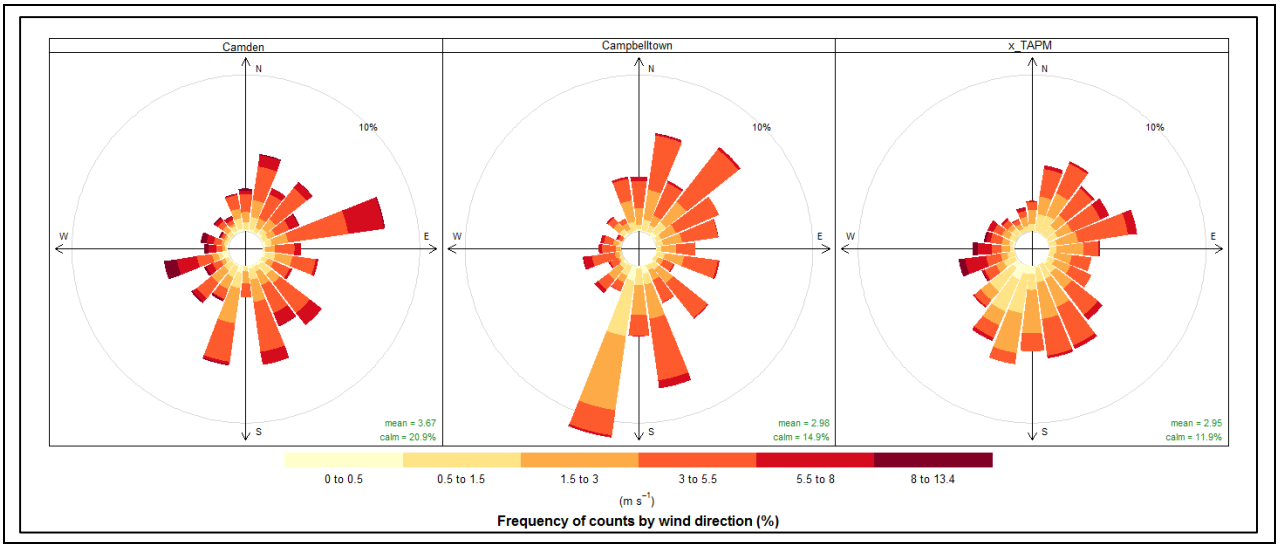


Figure 6-5: Wind rose comparison for Southwest Sydney

The hourly variation in observed and predicted wind speed and temperature is presented in **Figure 6-6**. TAPM predicted winds lie between the observations during the afternoons and track close to observations at other times. Predicted hourly temperature tracks well with observations at both Camden and Campbelltown for afternoon periods (most critical for peak ozone predictions). Predicted temperatures in the early morning tend to be higher than observed.

Scatter plots of the predicted and observed wind speed and temperature are shown in **Figure 6-7** and **Figure 6-8**. The plots show good correlation for wind speed and temperature at both sites.

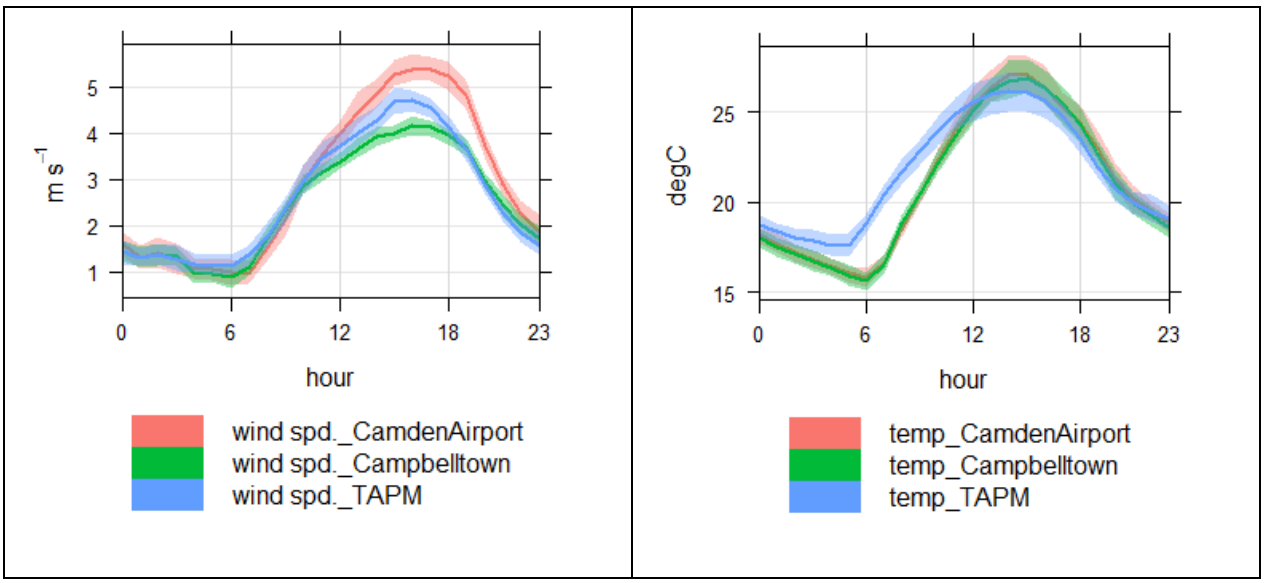


Figure 6-6: Time variation plot of observed and predicted wind speed and temperature for Southwest Sydney

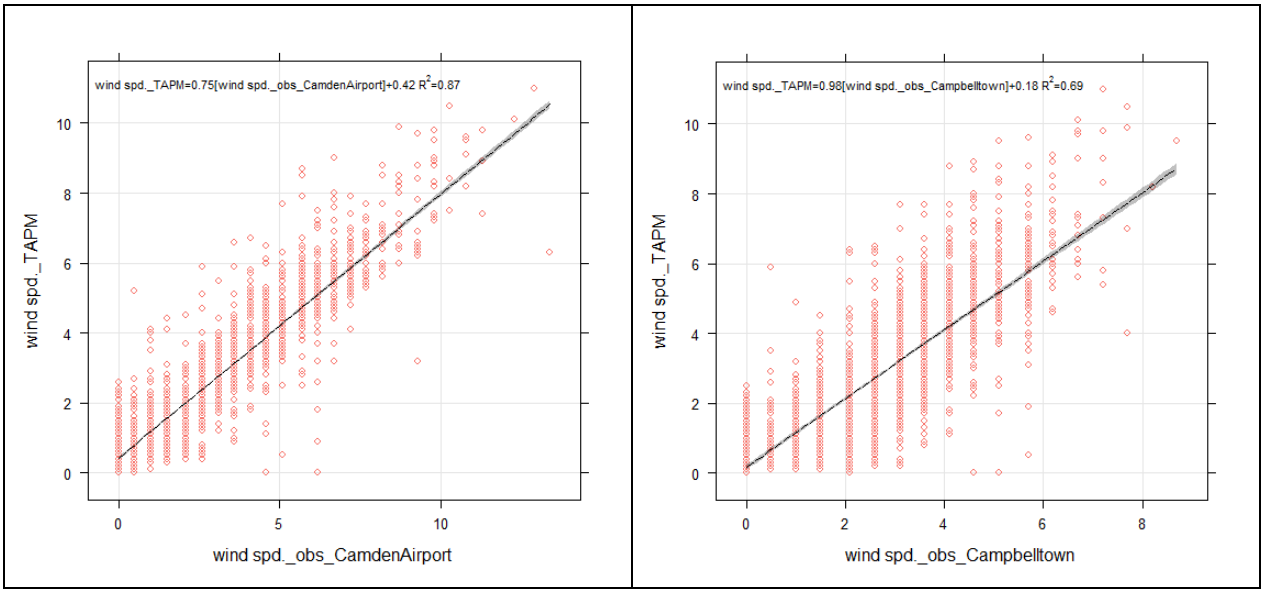


Figure 6-7: Scatter plot of observed and predicted wind speed for Southwest Sydney

Note: Wind speed data recorded at BoM sites is provided in increments of 0.5, due to conversion from knots to m/s, resulting in a more defined bands seen in the scatter plots.

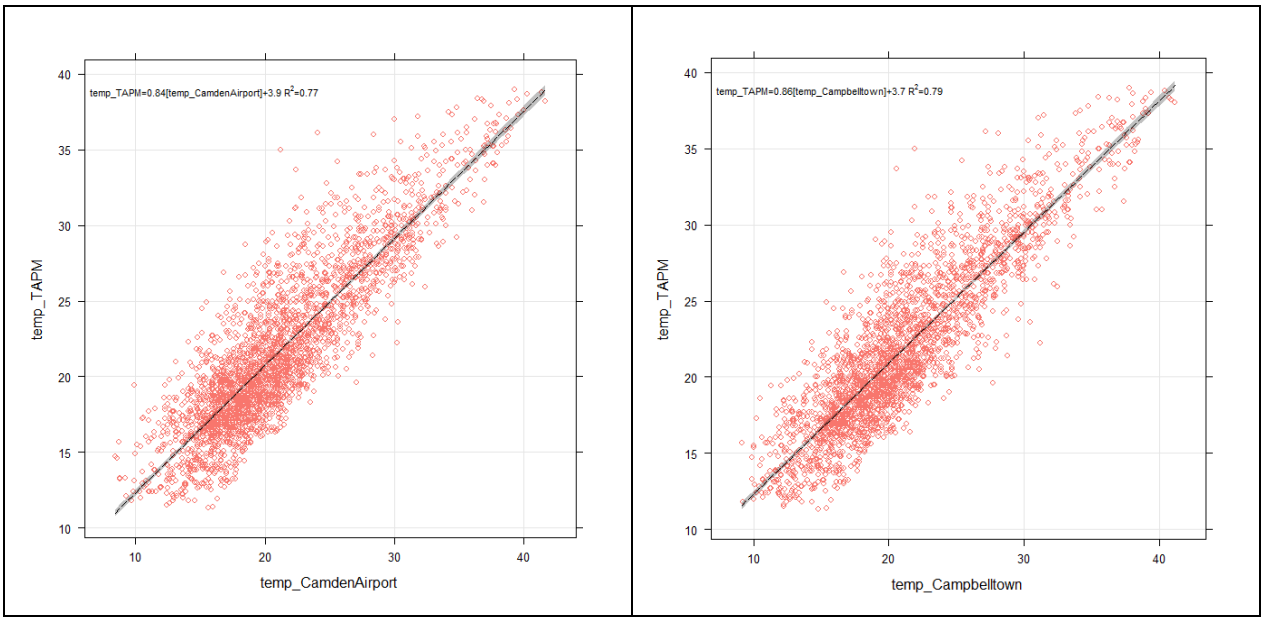


Figure 6-8: Scatter plot of observed and predicted temperature for Southwest Sydney

A summary of the model evaluation statistics for TAPM predicted wind speed and temperature is presented in **Table 6-4**. The statistical evaluation for wind speed shows more favourable FAC2, correlation and index of agreement for observations at the Camden site. Bias and error are similar at both sites. The statistical evaluation for temperature is similar for both sites.

Table 6-4: Evaluation of TAPM wind speeds against observations for Southwest Sydney

Statistical test	Wind speed		Temperature	
	Camden	Campbelltown	Camden	Campbelltown
Fraction of predictions within a factor of 2 (FAC2)	0.75	0.72	1.00	1.00
Mean bias (MB)	-0.29	0.13	0.58	0.78
Mean Gross Error (MGE)	0.71	0.82	2.09	2.06
Pearson correlation coefficient (r)	0.93	0.83	0.88	0.89
Index of Agreement (IOA)	0.81	0.69	0.76	0.76

6.3 Evaluation of model performance in Northwest Sydney

A comparison of observed and the TAPM predicted wind roses for the modelling period (November 2008 to February 2009) is presented in **Figure 6-9**. The TAPM predicted winds are extracted from a point northwest of Prospect.

The TAPM mean wind speeds are slightly higher than observations and the percentage occurrence of calm winds are lower. The TAPM wind direction reflects the general wind patterns for Prospect reasonably well.

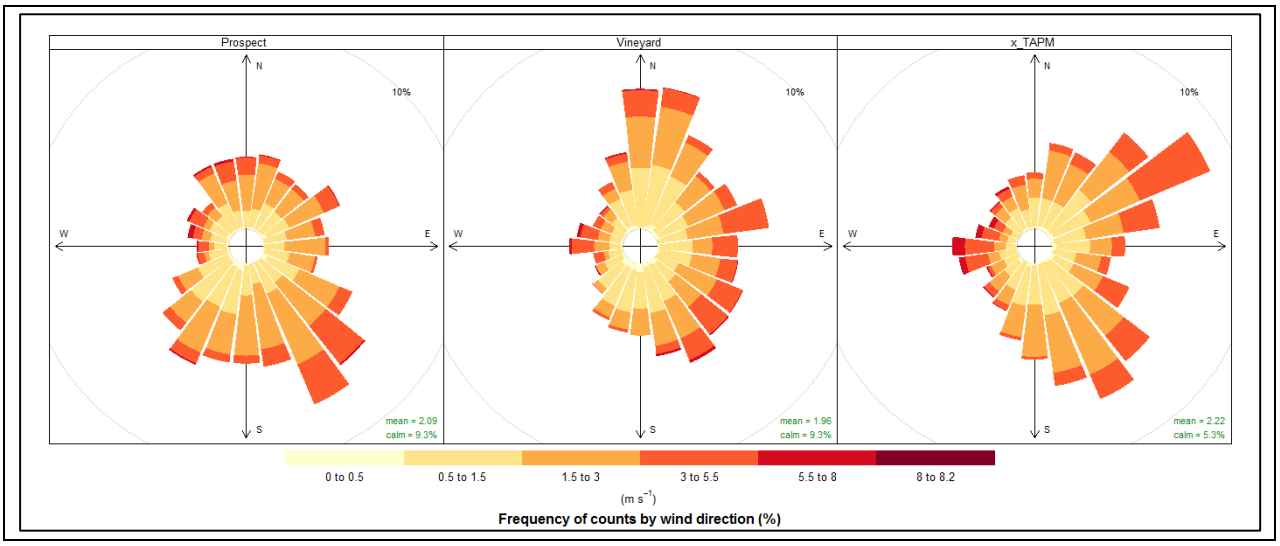


Figure 6-9: Wind rose comparison for Northwest Sydney

The hourly variation in observed and predicted wind speed and temperature is presented in **Figure 6-10**. It is evident that the TAPM predicted winds are higher during the afternoon and track close to observations at other times. Predicted hourly temperature tracks well with observations at both Prospect and Vineyard.

Scatter plots of the predicted and observed wind speed and temperature are shown in **Figure 6-11** and **Figure 6-12**. The correlation is stronger for Prospect, which is expected as the TAPM extraction is closer to and in an area more likely to be representative of the Prospect site.

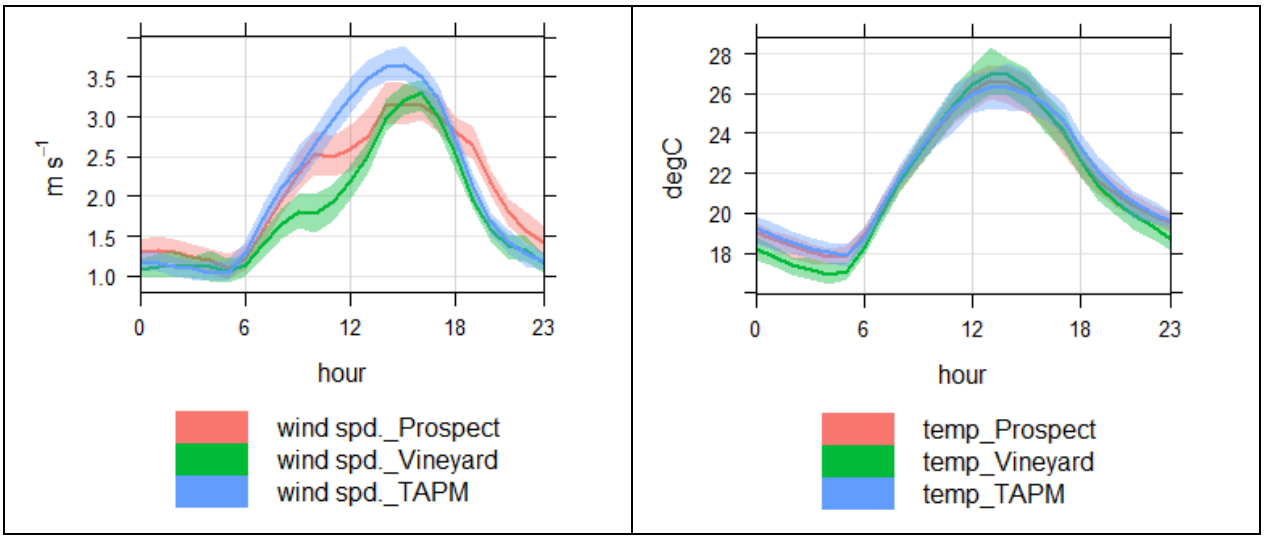


Figure 6-10: Time variation plot of observed and predicted wind speed and temperature for Northwest Sydney

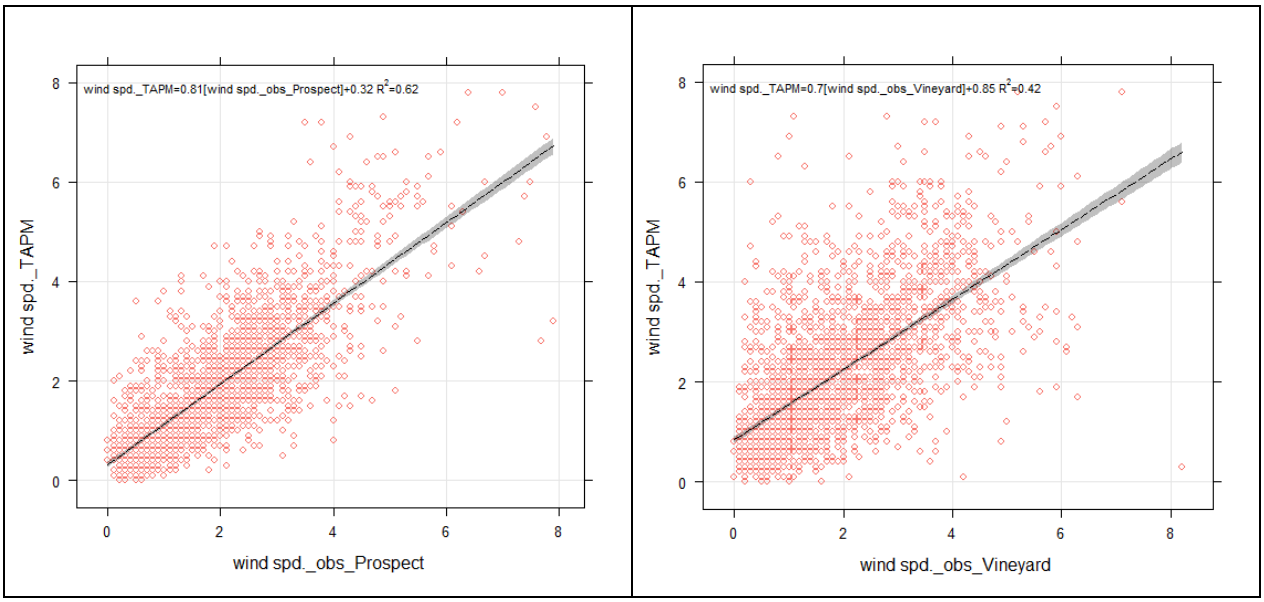


Figure 6-11: Scatter plot of observed and predicted wind speed for Northwest Sydney

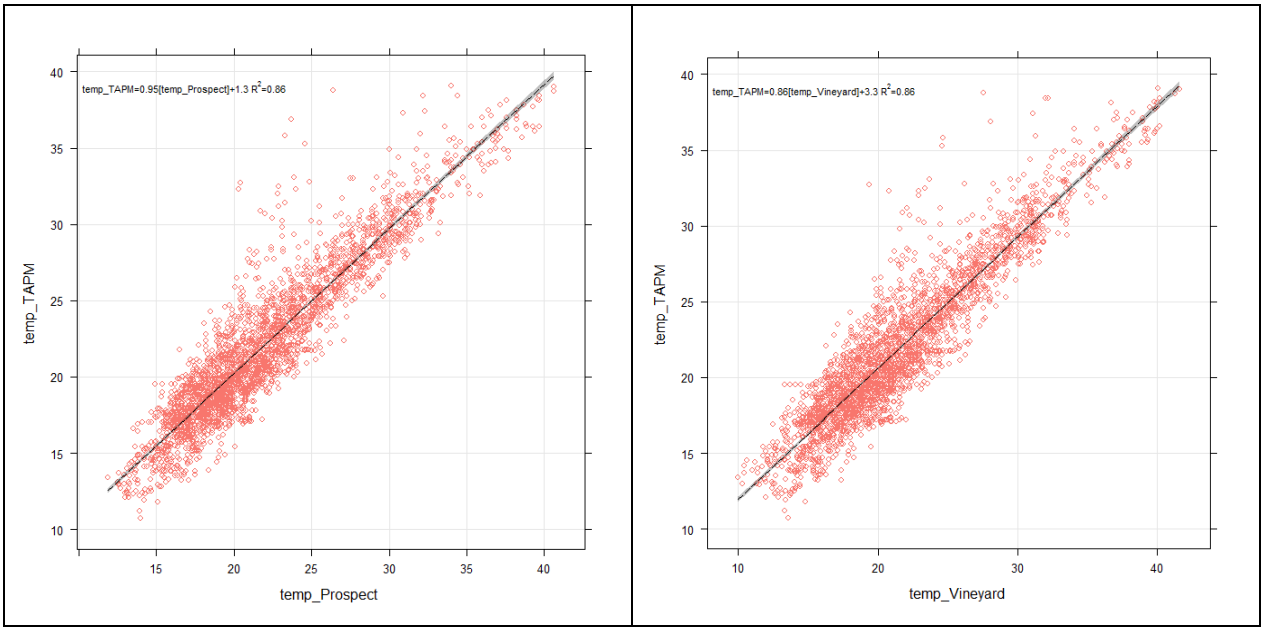


Figure 6-12: Scatter plot of observed and predicted temperature for Northwest Sydney

A summary of the model evaluation statistics for TAPM predicted win speed is presented in **Table 6-5**. The statistical evaluation for wind speed shows more favourable FAC2, correlation and index of agreement and lower bias and error for observations at the Prospect site. This is expected as the TAPM extraction is closer to and in an area more likely to be representative of the Prospect site. The statistical evaluation for temperature is similar for both sites.

Table 6-5: Evaluation of TAPM wind speed and temperature against observations for Northwest Sydney

Statistical test	Wind speed		Temperature	
	Prospect	Vineyard	Prospect	Vineyard
Fraction of predictions within a factor of 2 (FAC2)	0.90	0.75	1.00	1.00
Mean bias (MB)	-0.03	0.31	0.14	0.40
Mean Gross Error (MGE)	0.53	0.82	1.42	1.59
Pearson correlation coefficient (r)	0.83	0.65	0.93	0.93
Index of Agreement (IOA)	0.73	0.60	0.82	0.81

6.4 Evaluation of model performance in Western Sydney

A comparison of observed and the TAPM predicted wind roses for the modelling period (November 2008 to February 2009) is presented in **Figure 6-13**. The TAPM predicted winds are extracted from a point between the observation sites. The TAPM mean wind speeds are similar to observations at Chullora (the observed wind speed at the airport site is expected to be higher) and the percentage occurrence of calm winds lies in between the two observation sites. The TAPM wind direction reflects the general wind patterns for both sites reasonably well.

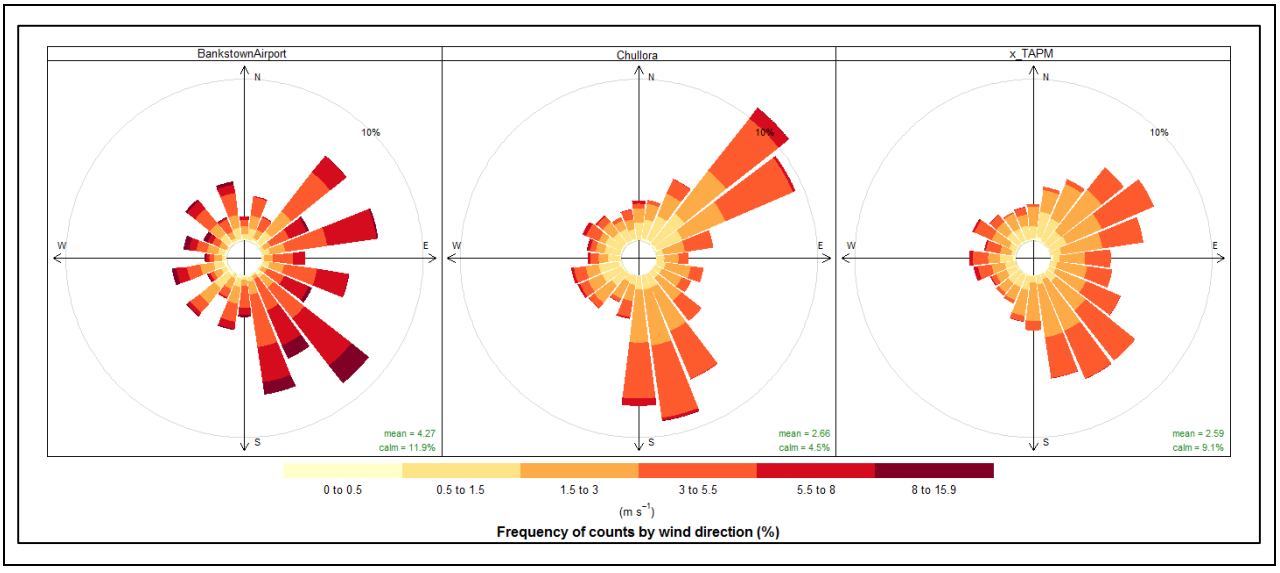


Figure 6-13: Wind rose comparison for Western Sydney

The hourly variation in observed and predicted wind speed and temperature is presented in **Figure 6-14**. It is evident that the TAPM predicted winds track closely to observations at Chullora. Wind speeds are higher at Bankstown Airport, but this is not uncommon for airport monitoring sites.

Predicted hourly temperature tracks well with observations at Bankstown Airport. Observations at Chullora are noticeably lower than observations at Bankstown Airport.

Scatter plots of the predicted and observed wind speed and temperature are shown in **Figure 6-15** and **Figure 6-16**. The plots indicate that correlation is slightly better for Bankstown Airport.

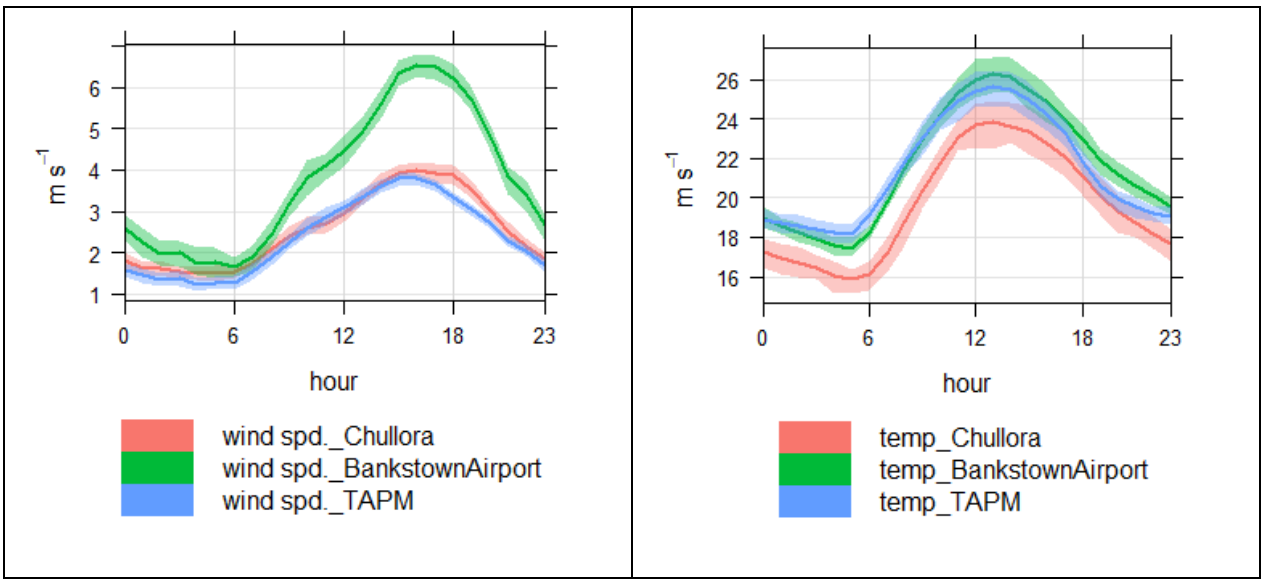


Figure 6-14: Time variation plot of observed and predicted wind speed and temperature for Western Sydney

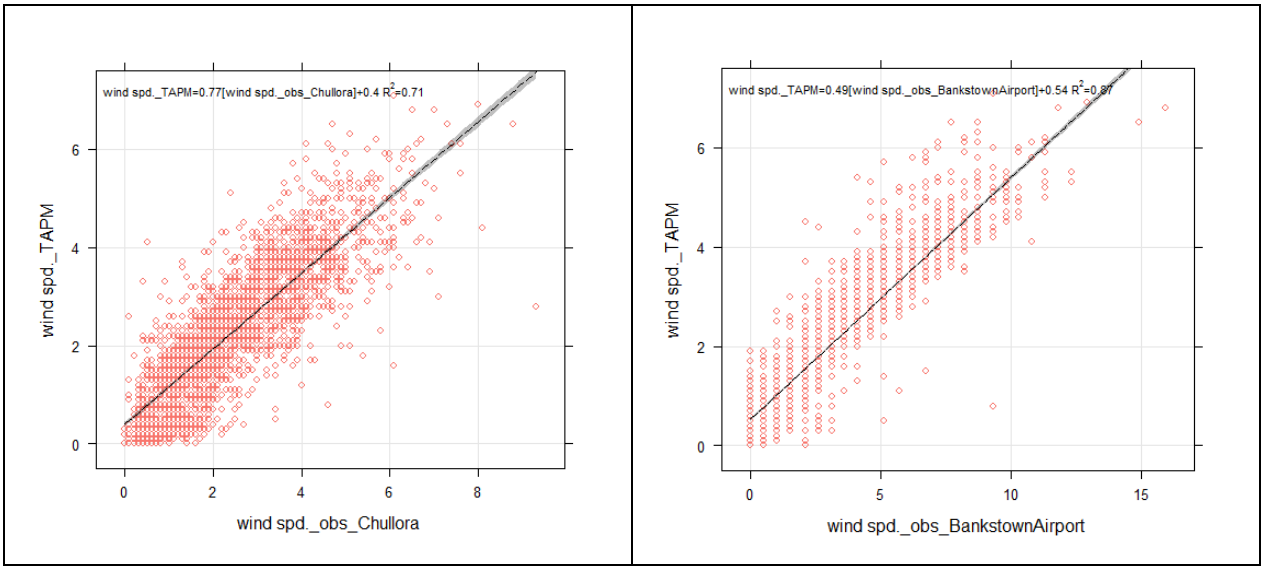


Figure 6-15: Scatter plot of observed and predicted wind speed for Western Sydney

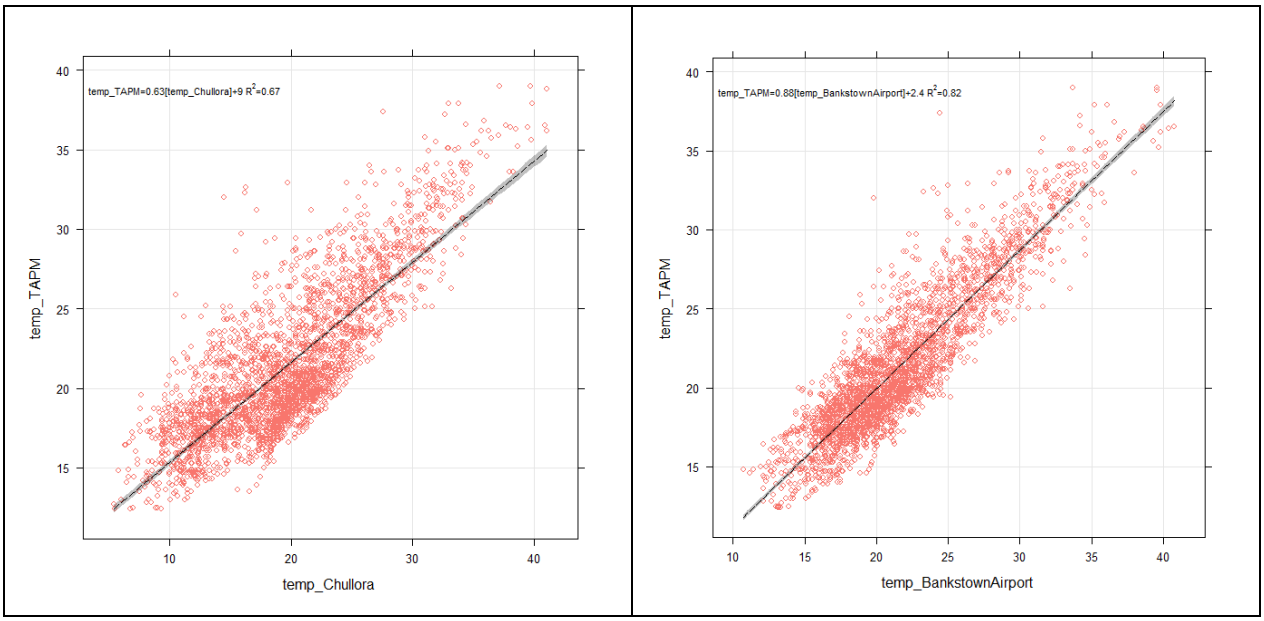


Figure 6-16: Scatter plot of observed and predicted temperature for Western Sydney

A summary of the model evaluation statistics for TAPM predicted wind speed and temperature is presented in **Table 6-6**. The statistical evaluation for wind speed shows mixed performance with a more favourable index of agreement for observations at Chullora but higher correlation for observations at Bankstown Airport. The statistical evaluation for temperature shows more favourable correlation and index of agreement and lower bias and error for observations at Bankstown Airport.

Table 6-6: Evaluation of TAPM wind speeds against observations for Western Sydney

Statistical test	Wind speed		Temperature	
	Chullora	Bankstown Airport	Chullora	Bankstown Airport
Fraction of predictions within a factor of 2 (FAC2)	0.83	0.81	0.99	1.00
Mean bias (MB)	-0.19	-1.39	1.77	-0.25
Mean Gross Error (MGE)	0.70	1.54	3.01	1.97
Pearson correlation coefficient (r)	0.79	0.93	0.82	0.87
Index of Agreement (IOA)	0.71	0.63	0.68	0.73

6.5 Summary

Overall, it is concluded that TAPM simulates the meteorology for the Sydney region with an acceptable degree of accuracy, based on an analysis of four locations considered to be generally representative of the area of interest to this study.

General wind patterns in the observation data were reflected reasonably well in the TAPM predictions and wind speed compared favourably. A statistical evaluation of the modelling predictions generally showed good correlation for wind speed and temperature with reasonably low bias and error.

7. MODEL EVALUATION BASE CASE SCENARIO

7.1 Introduction

The 2008/2009 Base Case is used to assess model performance by comparing predicted ozone concentrations against ambient monitoring data for the same period. The evaluation is presented for the complete modelling period (November 2008 to February 2009) and modelling predictions compared with observations at all monitoring sites. Additional individual comparisons are made at the Bringelly and St Marys monitoring sites because they are the closest monitoring sites to the airport site, and at Oakdale because it can be downwind of the airport site on high ozone days.

A statistical evaluation of model performance is presented based on a visual evaluation of spatially-paired daily maximum ozone and calculated normalised mean bias (NMB) and normalised mean error (NME) for spatially and temporally paired ozone (refer **Table 7-1)**.

The NMB and NME have been calculated for data pairs where the observed ozone is greater than 30 ppb to focus on periods of photochemical ozone production within the Sydney Region. The cut-off value of 30 ppb is representative of background ozone concentrations present in air entering the ozone modelling domain.

Table 7-1: Statistical metrics for model evaluation

Metric	Description
Normalised Mean bias (NMB)	$NMB = \frac{\sum_{i=1}^{N} M_i - O_i}{\sum_{i=1}^{N} O_i}$
Normalised Mean Error (NME)	$NME = \frac{\sum_{i=1}^{N} \lvert M_i - O_i \rvert}{\sum_{i=1}^{N} O_i}$

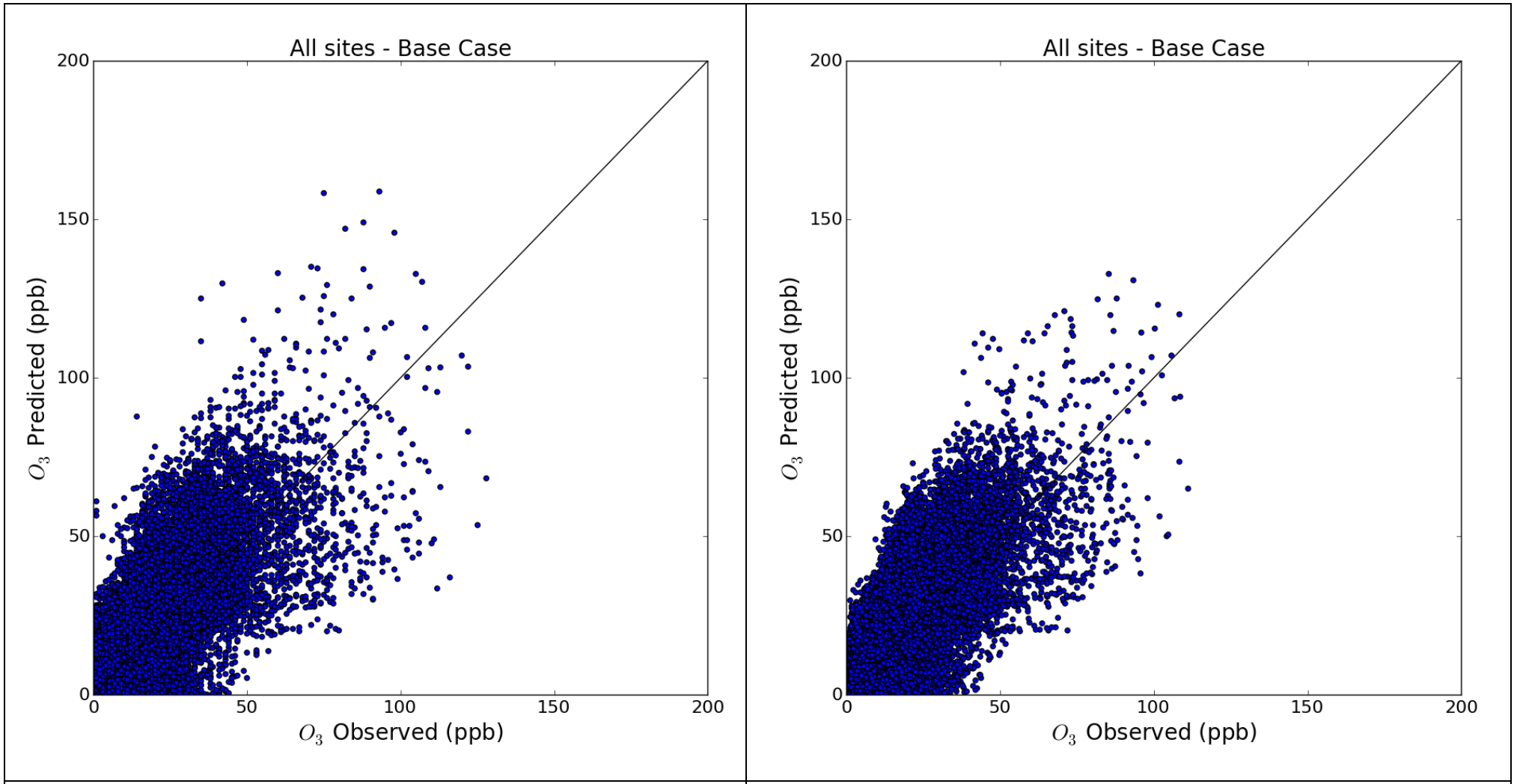
7.2 Graphical evaluation

Scatter plots of predicted and observed 1-hour and 4-hour ozone concentrations for all monitoring sites within the domain are presented in **Figure 7-1**. Similar scatter-plots of predicted and observed ozone concentrations for the Bringelly, St Marys and Oakdale sites are show in **Figure 7-2** (1-hour average) and **Figure 7-3** (4-hour average).

The scatter plots demonstrate that modelled-observed data pairs are clustered around the 1:1 line showing that the model tends to correctly predict variability in ozone. At Bringelly and St Marys, observed ozone can be reduced to near zero due to titration of ozone by fresh NO_x emissions at night (also seen in **Figure 7-4**) whereas observed ozone were seldom reduced to zero at Oakdale, which is more rural and has less NO_x emissions. The model correctly captures the difference in ozone minimums between the Oakdale and Bringelly/St Marys sites.

Time-series of predicted and observed 1-hour ozone concentrations are shown in **Figure 7-4** for the Bringelly, St Marys and Oakdale sites. The model captures correctly periods of both higher and lower ozone showing that the model responds dynamically to changes in meteorology.

For example, a build-up of ozone occurred at the start of February 2009 followed by a period of low ozone (at background values) which the model reproduces. Time-series of 4-hour ozone concentration (**Figure 7-5**) show similar features.



1-hour	4-Hour

Figure 7-1: Scatter plot of modelled and observed ozone concentration for all sites

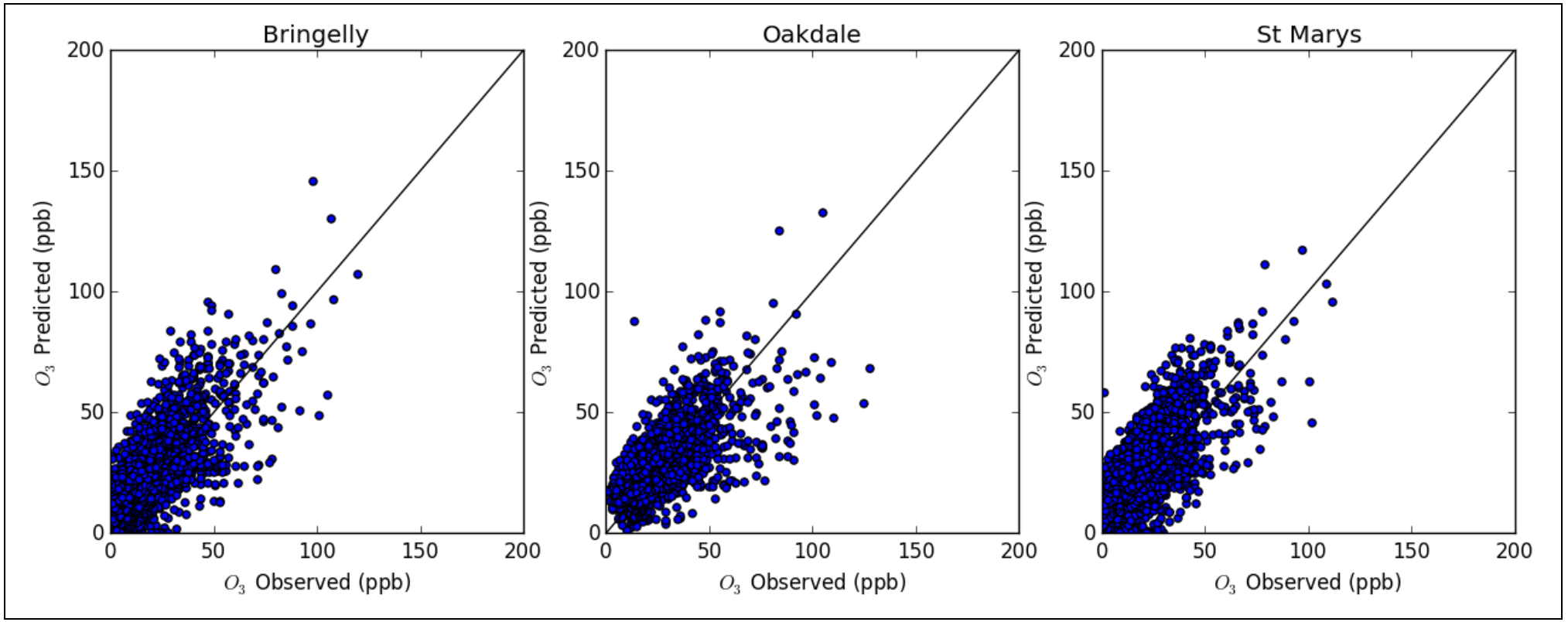


Figure 7-2: Scatter plots of modelled and observed 1-hour ozone concentration at Bringelly, Oakdale and St Marys

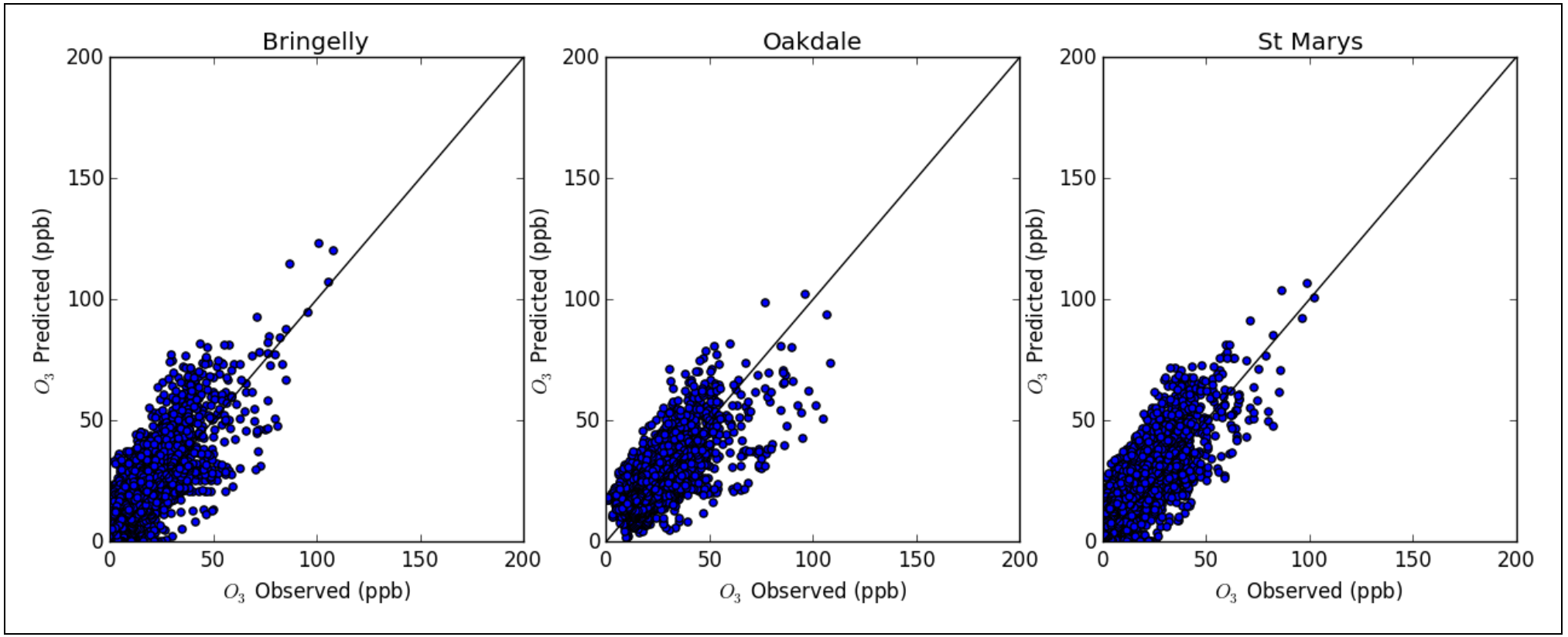


Figure 7-3: Scatter plots of modelled and observed 4-hour ozone concentration at Bringelly, Oakdale and St Marys



Figure 7-4: Timeseries of modelled and observed 1-hour ozone concentration at Bringelly, Oakdale and St Marys

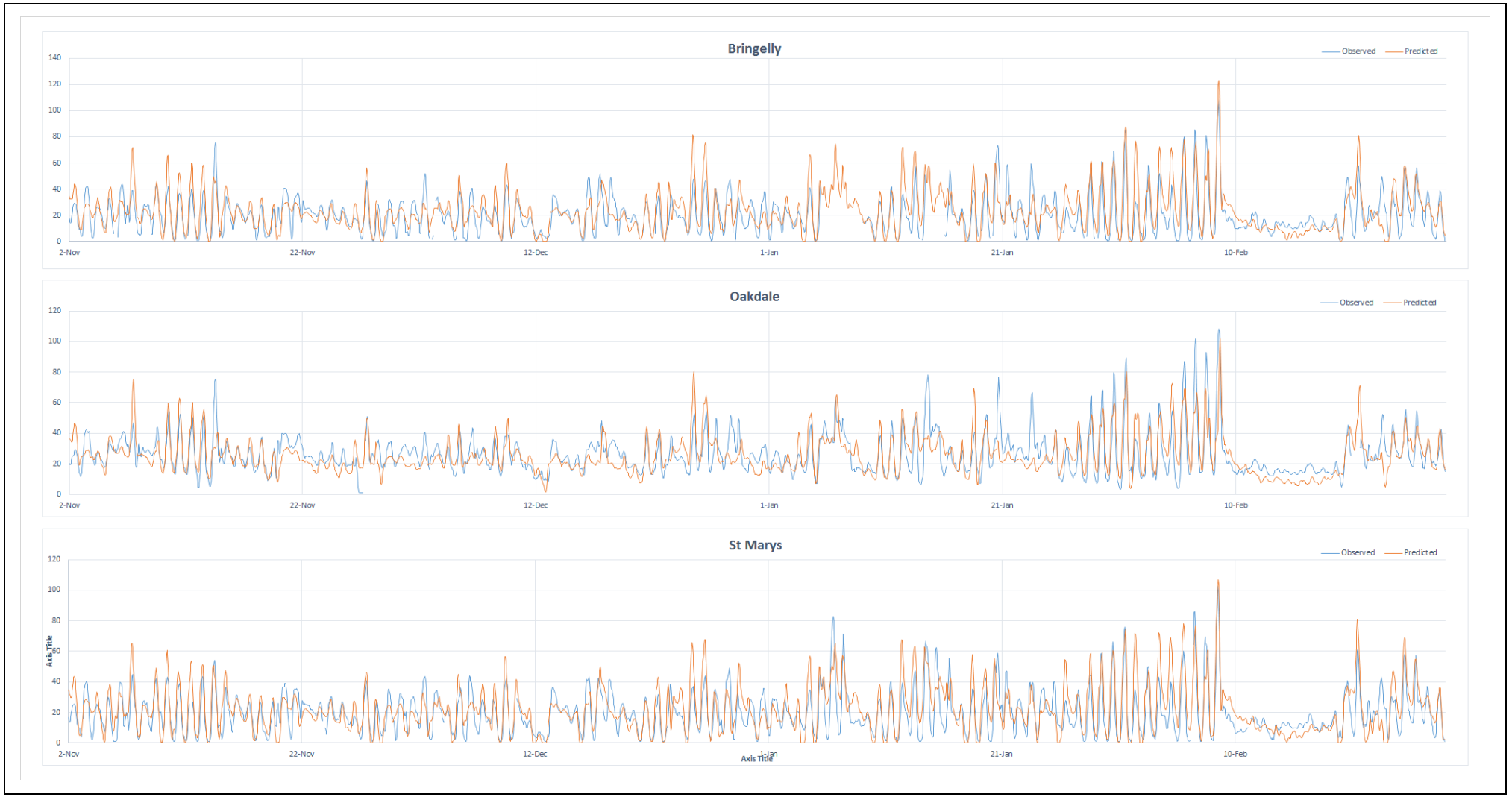


Figure 7-5: Timeseries of modelled and observed 4-hour ozone concentration at Bringelly, Oakdale and St Marys

7.3 Statistical evaluation

A statistical evaluation of ozone model performance was performed for the Bringelly, St Marys and Oakdale sites by computing metrics for bias (NMB) and error (NME). US EPA guidance for ozone model performance evaluation has aimed for bias within ±15% and error smaller than 35%, although the guidance also emphasizes that statistical metrics should not be used as pass/fail tests (US EPA, 2007; US EPA, 2014b).

The model exhibits little bias at Bringelly and St Marys with NMB for 1-hour ozone less than 2% and for 4-hour ozone less than 7%. The model has a tendency to under predict ozone at Oakdale by 11% for 1-hour ozone and 14% for 4-hour ozone. The model errors are larger, from 27% to 33% for 1-hour ozone and from 25% to 30% for 4-hour ozone, but still lower than the EPA suggested benchmark of 35%.

Table 7-2: Performance statistics for predicted 1-hour ozone concentration

Site	Peak observed (ppb)	Peak predicted (ppb)	NMB (%)	NME (%)
Bringelly	120	146	-1.1	32.5
St Marys	112	117	-1.8	30.4
Oakdale	128	133	-11.2	27.2

Note: NMB and NME were computed for all data pairs with observed ozone above 30 ppb

Table 7-3: Performance statistics for predicted 4-hour ozone concentration

Site	Peak observed (ppb)	Peak predicted (ppb)	NMB (%)	NME (%)
Bringelly	108	123	-5.8	29.5
St Marys	103	107	-6.6	27.0
Oakdale	108	102	-14.3	25.3

Note: NMB and NME were computed for all data pairs with observed ozone above 30 ppb

8. EVALUATION OF OZONE IMPACTS

8.1 Selecting days for detailed analysis

The NSW tiered procedure for ozone assessment described in **Section 3.4** outlines criteria for selecting dates for Level 2 assessment based on photochemical modelling.

The criteria are:

- The maximum modelled ozone concentrations should be close to the NEPM standards to ensure that the conditions are relevant to non-attainment of the standards.
- The model should have acceptable performance, meaning low bias and error statistics, to gain confidence that the simulation provides a realistic representation of conditions on the high ozone day.
- The impacts of the new source should occur primarily over land, rather than over the ocean.
- Several days should be selected, and as a minimum at least three days, to enable comparison of source impacts across multiple high ozone days.

Based on the above criteria, days with high observed ozone (1-hour ozone concentrations greater than 70 ppb and 4-hour ozone concentrations greater than 65 ppb) and good model performance (bias within ±15% in these peak values) were selected for analysis.

A summary of the analysis is presented in **Table 8-1**. The selected dates provide good coverage by day of the week, to account for any weekday vs. weekend differences, and include several periods of ozone build-up that allow for potential build-up of ozone impacts due to the airport.

The selection of historical dates in January and February 2009 may appear counter intuitive for the modelling future emissions in 2030 and 2063. However, these dates simply represent the meteorological conditions that have historically led to peak ozone formation and which the model has effectively captured for peak ozone formation with future emissions added.

Table 8-1: Date selection for detailed analysis

Date		Ozone concentration (ppb)			
	Day of Week	Max 1-hour	Location	Max 4-hour	Location
06/01/2009	Tue	90	Chullora	70	Liverpool
07/01/2009	Wed	80	Chullora	-	-
14/01/2009	Wed	83	Liverpool	77	Liverpool
29/01/2009	Thu	88	Bargo	76	Bargo
30/01/2009	Fri	77	Macarthur	76	Bargo
31/01/2009	Sat	113	Bargo	92	Bargo
04/02/2009	Wed	70	Oakdale	-	-
05/02/2009	Thu	88	Bringelly	85	Bargo
06/02/2009	Fri	89	St Marys	92	Bargo
07/02/2009	Sat	102	Chullora	79	Oakdale
08/02/2009	Sun	120	Bringelly	109	Bringelly
20/02/2009	Fri	86	Prospect	-	-

8.2 Approach to Evaluating Ozone Impacts

The approach to evaluating ozone impacts attributable to the airport development is based on daily maximum 1-hour and 4-hour ozone concentrations, for which NEPM standards exist. Consequently, changes in ozone are computed as differences in daily maximum concentration. The highest daily maximum concentration on a day is referred to as the peak ozone. The assessment is restricted to days with good model performance, as discussed, to reduce the influence of model uncertainties on outcomes.

Changes in modelled ozone are evaluated throughout the modelling domain and are not restricted to ozone monitoring locations. This is because the spatial relationship between emissions and ozone formation varies from day-to-day, due to meteorology.

It is not recommended to use a single model result for ozone impacts (e.g., the largest ozone change) because reliance on a single model result could accentuate the influence of uncertainties in model input data or model formulation. For example, as discussed previously, TAPM can under estimate cloud cover which may introduce a systematic bias towards over-predicting ozone production.

It is recommended that discussion of ozone impacts focuses on a high percentile of modelled impacts, such as the 99th percentile, which represents the 4th highest of the daily maximum values for a full year. Although we have only modelled a few months of the year, the modelled period captures peak ozone days, so this approach is possible. The average of the 2nd to 4th highest ozone change is therefore used to assess the potential ozone impacts.

8.3 Stage 1 airport development

The daily maximum predicted 1-hour ozone concentrations are presented in **Table 8-2**. Results are presented as peak concentrations for the 2030 Future Base Case (no airport), the 2030 Airport Case (airport emissions plus 2030 Future Base Case) and the largest difference in daily maximums (the 2030 Airport Case – 2030 Future Base Case). The largest difference represents the maximum change in daily maximum ozone concentration, as a result of the additional emissions from the airport.

For each day of analysis, the peak predicted 1-hour ozone concentrations were unchanged between the 2030 Base Case and the 2030 Airport Case. This is because predicted ozone concentration changes from the airport occur in a different location to the predicted peak ozone concentrations (shown in the spatial plots presented in **Section 8.3.1**). Both the 2030 Base Case and the 2030 Airport Case were above the NEPM criterion of 100 ppb for all but one day of analysis.

To provide context, the predicted peak ozone concentrations presented in **Table 8-2** can be compared with measured peak 1-hour ozone concentrations at Bringelly. During 2014, there were two days when the maximum daily 1-hour ozone concentration was above the NEPM standard, with a peak concentration of 124 ppb measured in November 2014. It is noted that the modelled peak values are expected to be higher than observed peak values because monitoring networks never achieve full coverage of an airshed. In other words, modelling can predict higher peak ozone for areas not covered by monitoring networks.

The largest difference in daily maximum 1-hour ozone concentration, from the addition of 2030 airport emissions, was 5.5 ppb, however the second highest was significantly lower at 1.3 ppb. This highlights that reliance on a single model result (e.g. the largest ozone change) could accentuate the influence of uncertainties in model input data or model formulation. Therefore the average of the 2nd and 4th highest ozone change in daily maximum 1-hour ozone is used to describe ozone impacts, which in this case is 1.1 ppb. As described in **Section 3.4**, the NSW tiered procedure for ozone assessment sets a maximum allowable increment level of 1 ppb. Comparing this to the average of the 2nd to 4th highest change in daily maximum 1-hour ozone, indicates that a marginal impact is predicted from the 2030 Airport Case.

Table 8-2: Maximum daily predicted 1-hour ozone concentration (ppb) - 2030

Date	2030 Base Case Peak Value	2030 Airport Case Peak Value	2030 Airport Case – 2030 Base Case Largest Difference
06/01/2009	149.1	149.1	0.4
07/01/2009	129.8	129.8	5.5
14/01/2009	106.6	106.6	1.3
29/01/2009	124.1	124.1	0.3
30/01/2009	107.4	107.4	0.6
31/01/2009	109.4	109.4	0.6
04/02/2009	103.8	103.8	1.1
05/02/2009	119.6	119.6	0.3
06/02/2009	112.5	112.5	0.8
07/02/2009	133.7	133.7	0.3
08/02/2009	148.6	148.6	0.6
20/02/2009	98.3	98.3	1.0

The daily maximum predicted 4-hour ozone concentrations are presented in **Table 8-3**. The peak predicted 4-hour ozone concentration was unchanged on ten days and increased on two days, by a maximum of 0.1 ppb.

The highest change in daily maximum 4-hour ozone concentration, from the addition of airport emissions, was 2.4 ppb, while the second highest was 1.2 ppb. The average of the 2nd to 4th highest change in daily maximum 4-hour ozone was 0.9 ppb, which is below the maximum allowable increment of 1 ppb.

Table 8-3: Maximum daily predicted 4-hour ozone concentration (ppb) - 2030

Date	2030 Base Case Peak Value	2030 Airport Case Peak Value	2030 Airport Case – 2030 Base Case Largest Difference
06/01/2009	126.2	126.3	0.3
07/01/2009	115.3	115.4	2.4
14/01/2009	98.7	98.8	0.7
29/01/2009	95.9	95.9	0.5
30/01/2009	78.2	78.2	0.6
31/01/2009	99.9	99.9	0.5
04/02/2009	97.3	97.3	0.7
05/02/2009	108.7	108.7	0.4
06/02/2009	92.4	92.4	0.4
07/02/2009	121.0	121.0	0.6
08/02/2009	129.9	129.9	0.6
20/02/2009	83.9	84.0	1.2

8.3.1 Spatial variation in peak ozone concentrations

Locations of ozone differences due to 2030 airport emissions are shown in the spatial plots of the daily maximum predicted 1-hour and 4-hour ozone concentration, presented in **Figure 8-1** to **Figure 8-12**.

Decreases in daily maximum ozone occur only in the vicinity of the airport and are attributable to ozone suppression by NOx emissions. Increases in ozone occur downwind of the airport which, on most days, is to the south. Ozone increases on opposing sides of the airport within a single day indicate that changes in wind direction, such as a land/sea breeze reversal, carried airport emissions and/or ozone formed from airport emissions in different directions. The largest ozone differences are confined close to the airport. On this day, both the modelled and measured wind speeds were light during the morning until a change in the afternoon brought higher wind speeds and a change in wind direction.

Spatial plots of the maximum predicted 1-hour and 4-hour ozone concentration over all days of analysis is presented in **Figure 8-13**.

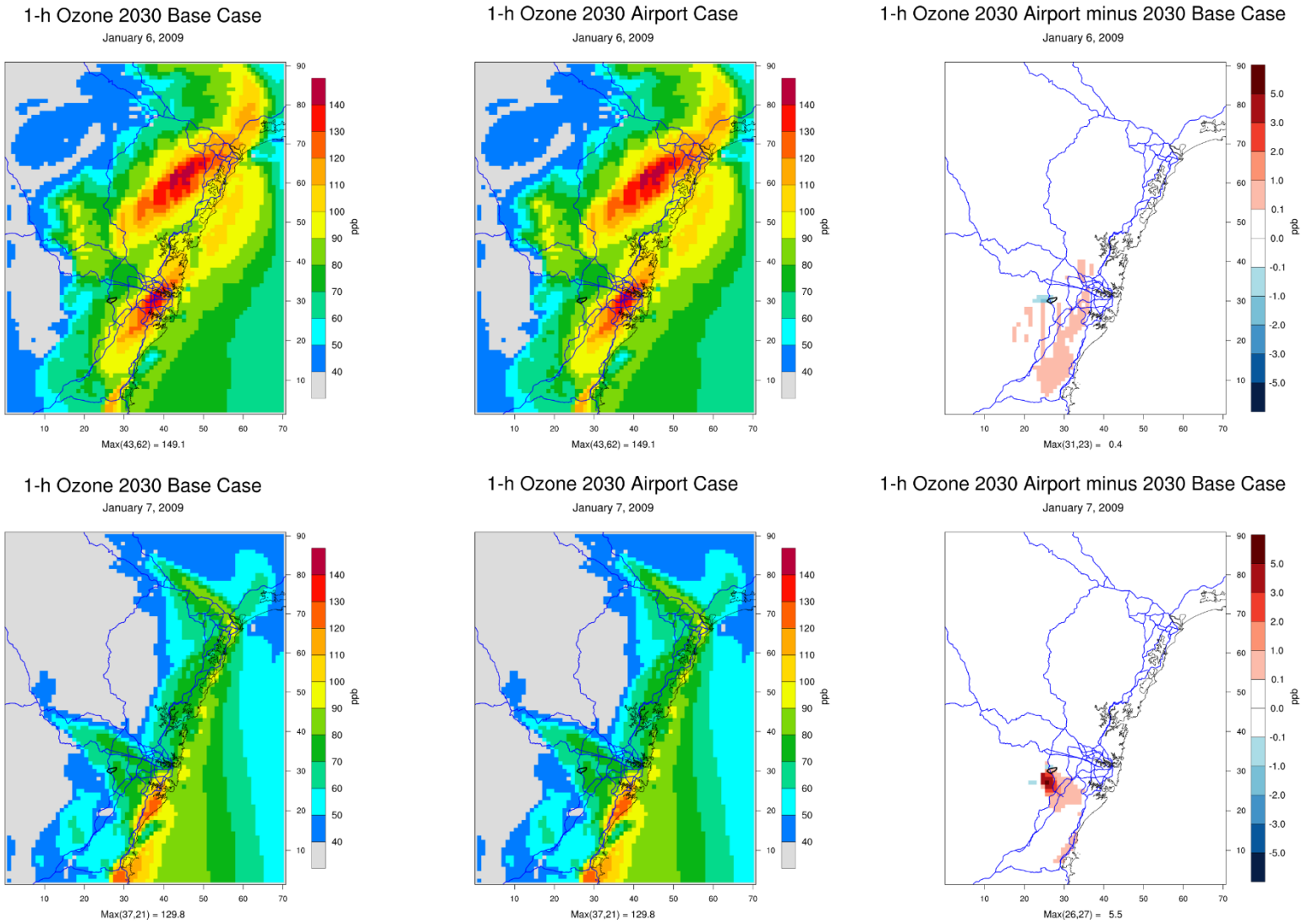


Figure 8-1: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 January

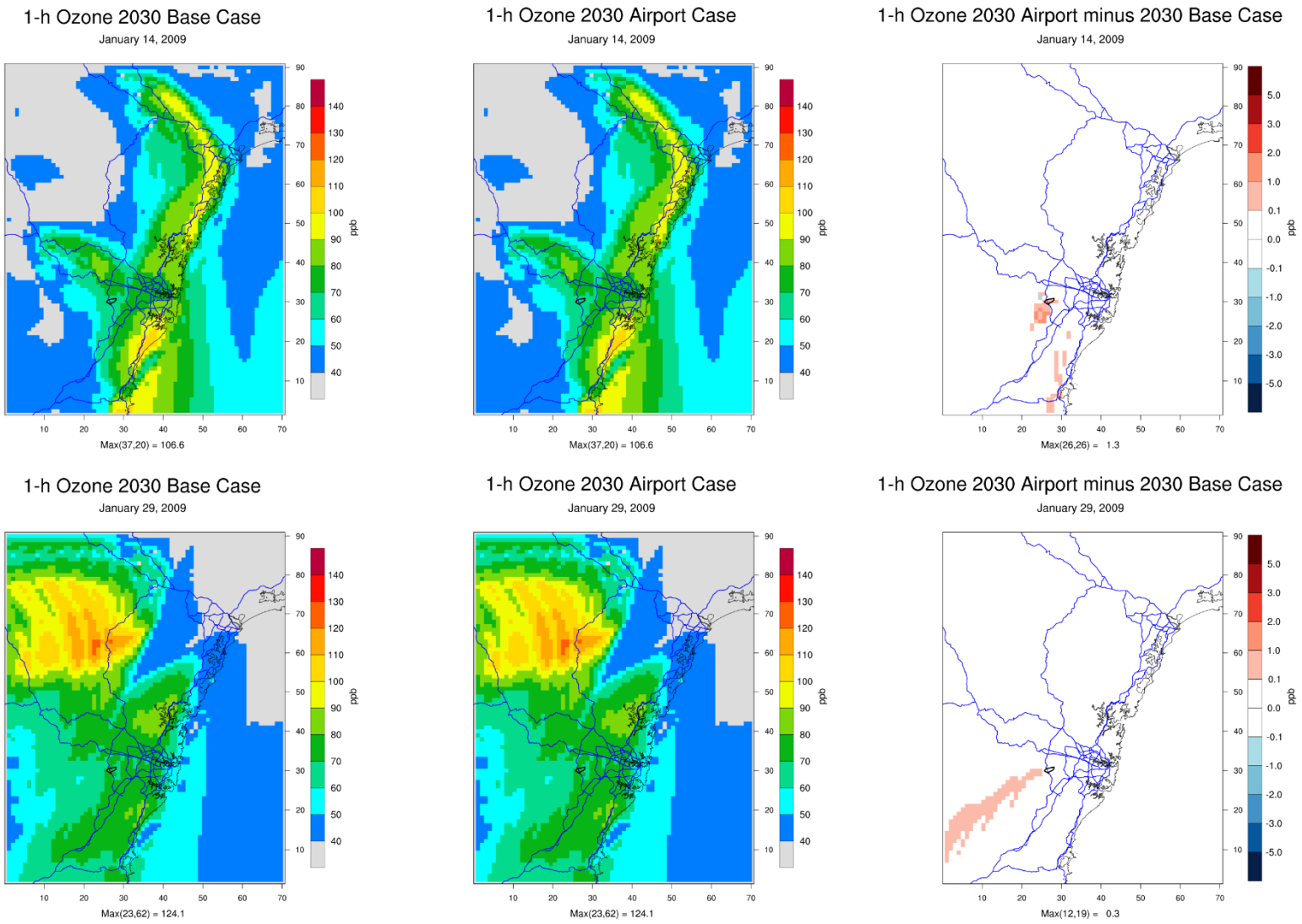


Figure 8-2: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 14 and 29 January

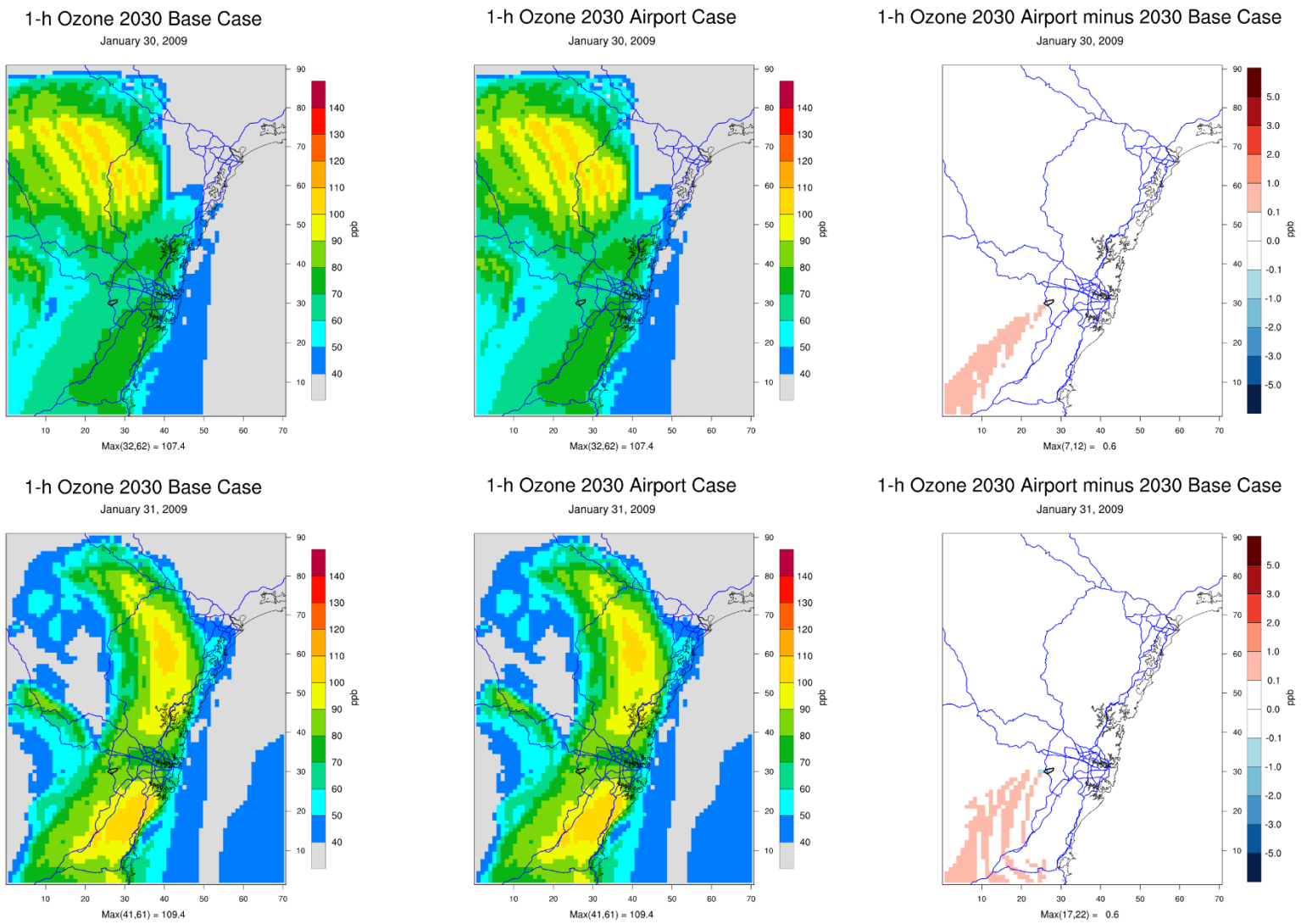


Figure 8-3: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 30 and 31 January

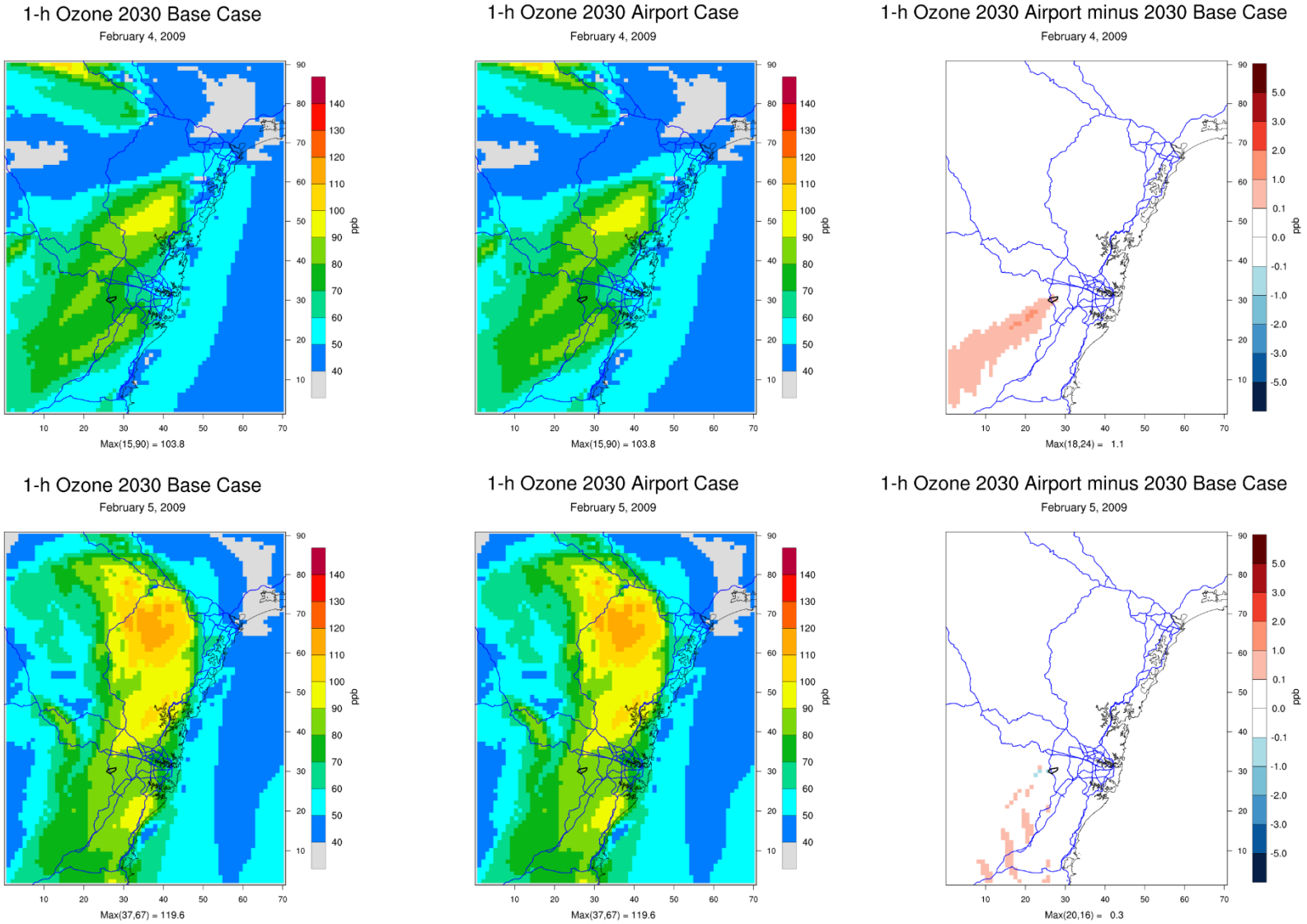


Figure 8-4: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 4 and 5 February

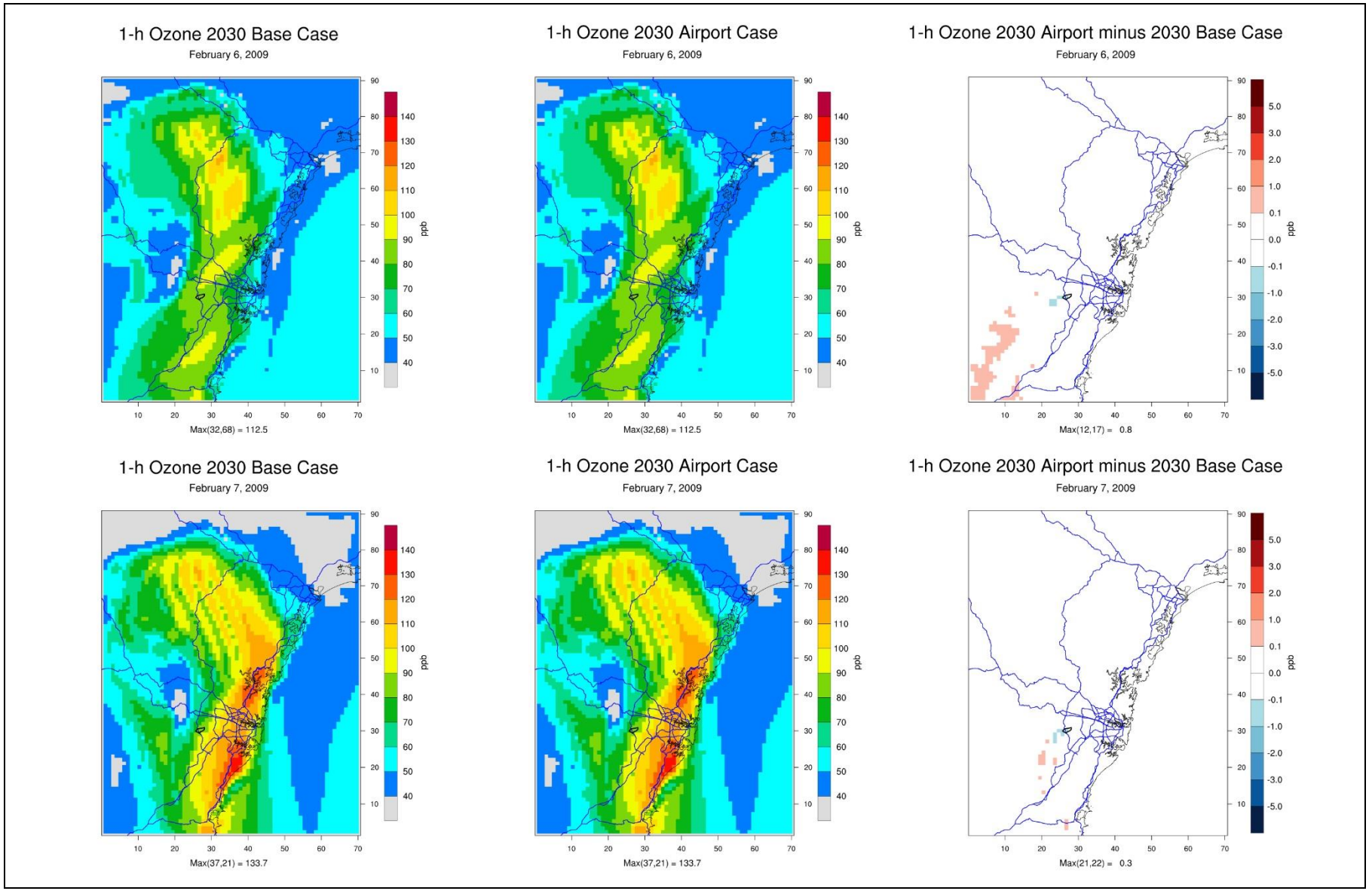


Figure 8-5: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 February

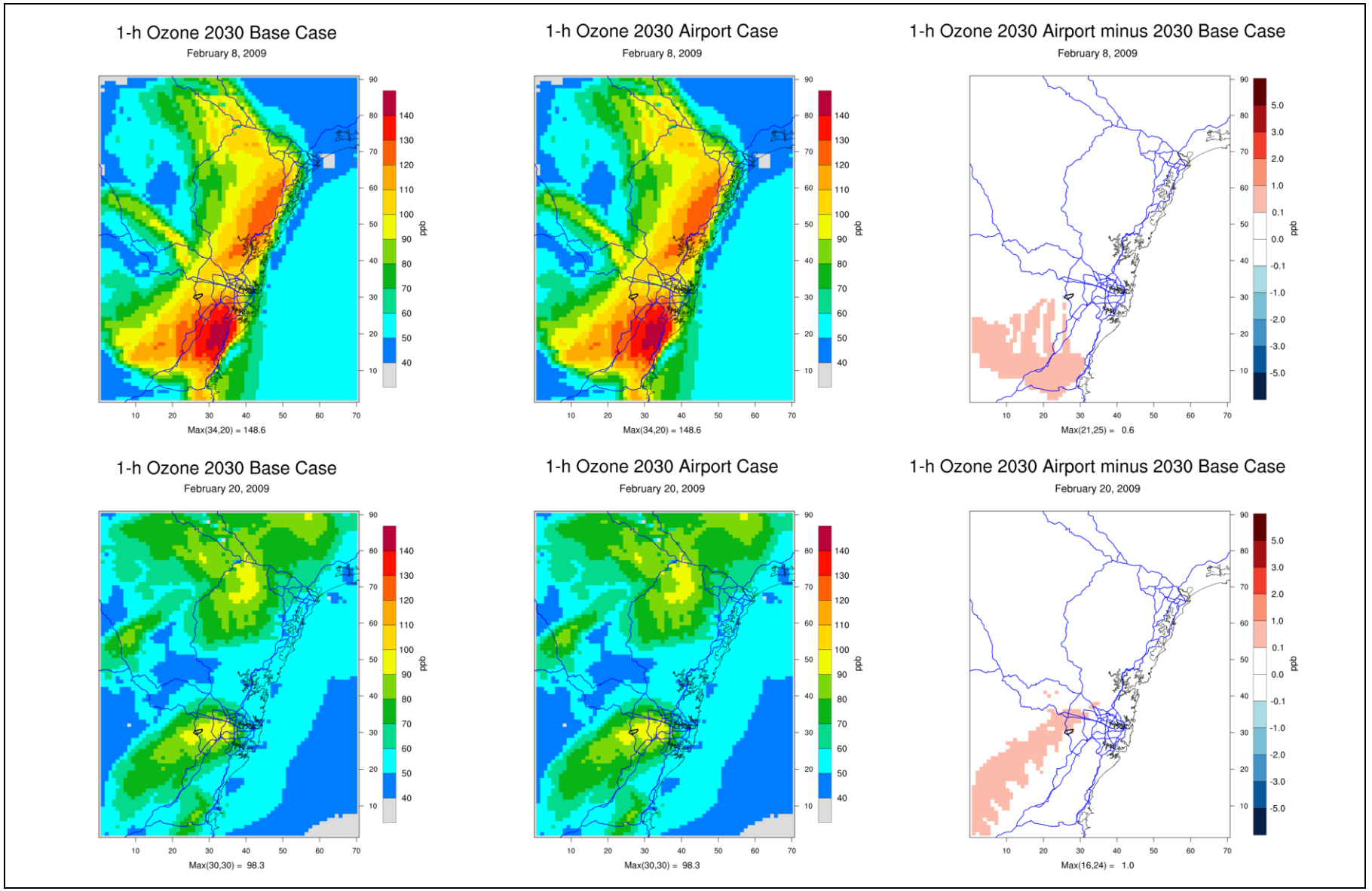


Figure 8-6: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 8 and 20 February

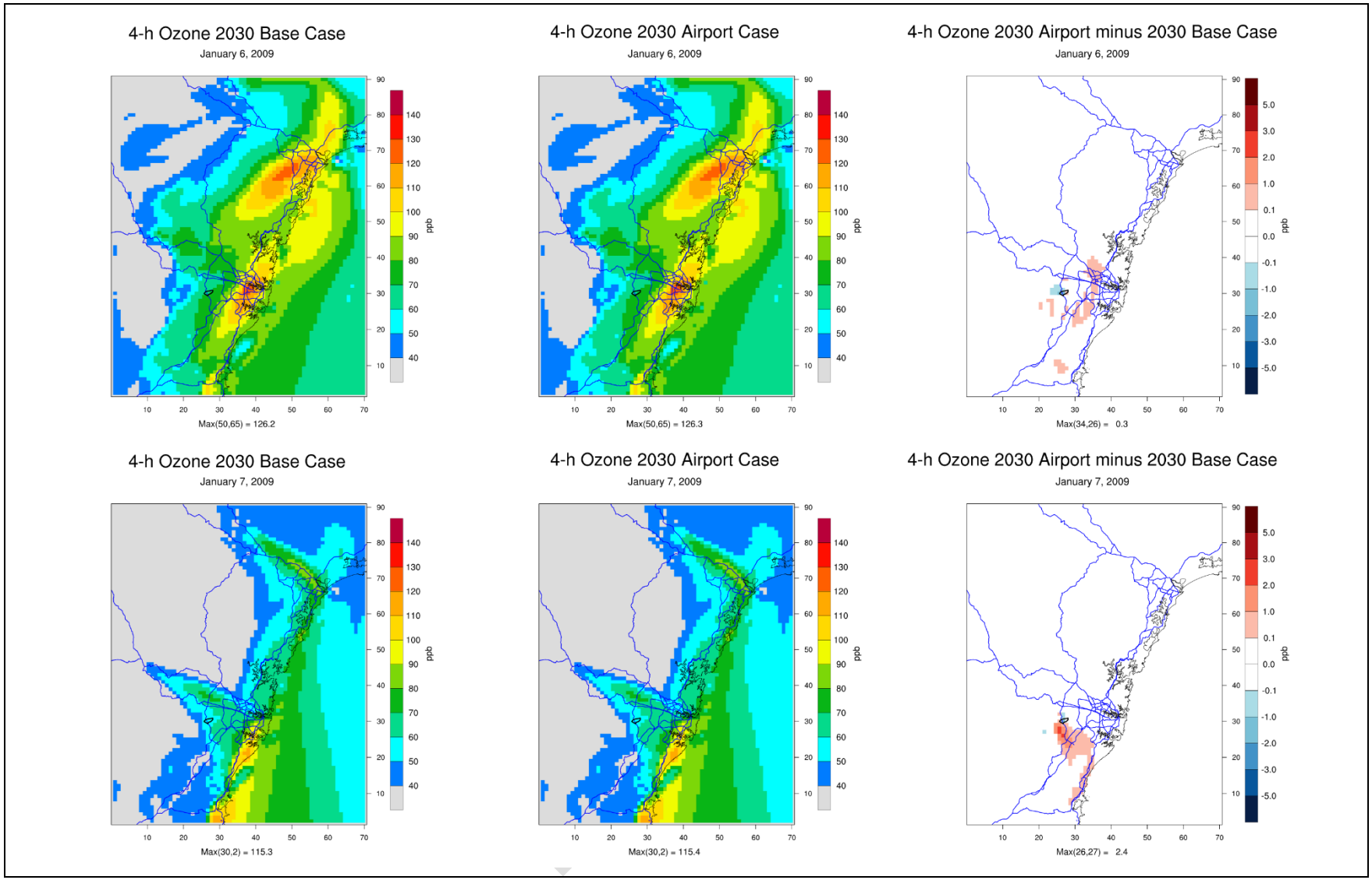


Figure 8-7: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 January

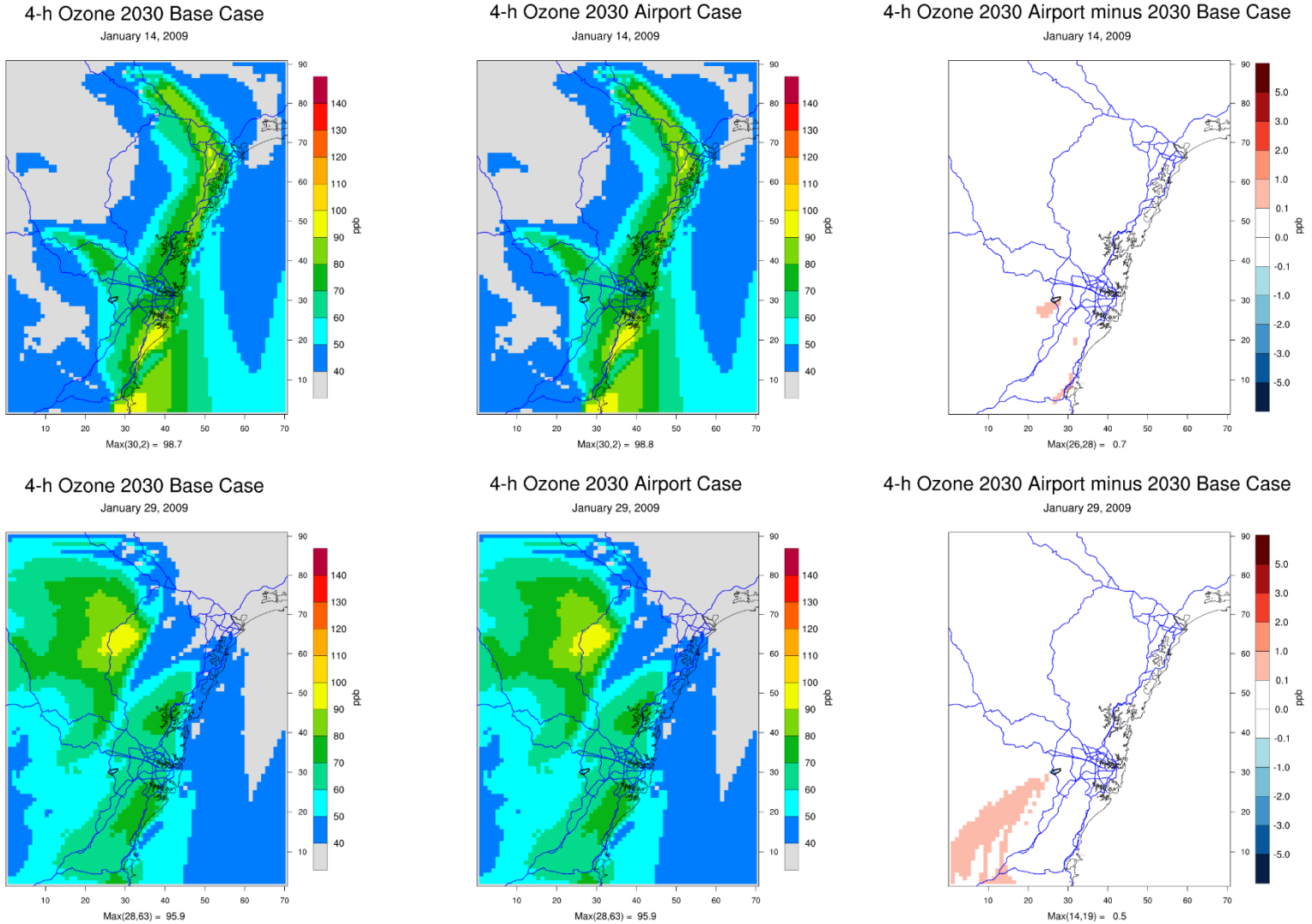


Figure 8-8: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 14 and 29 January

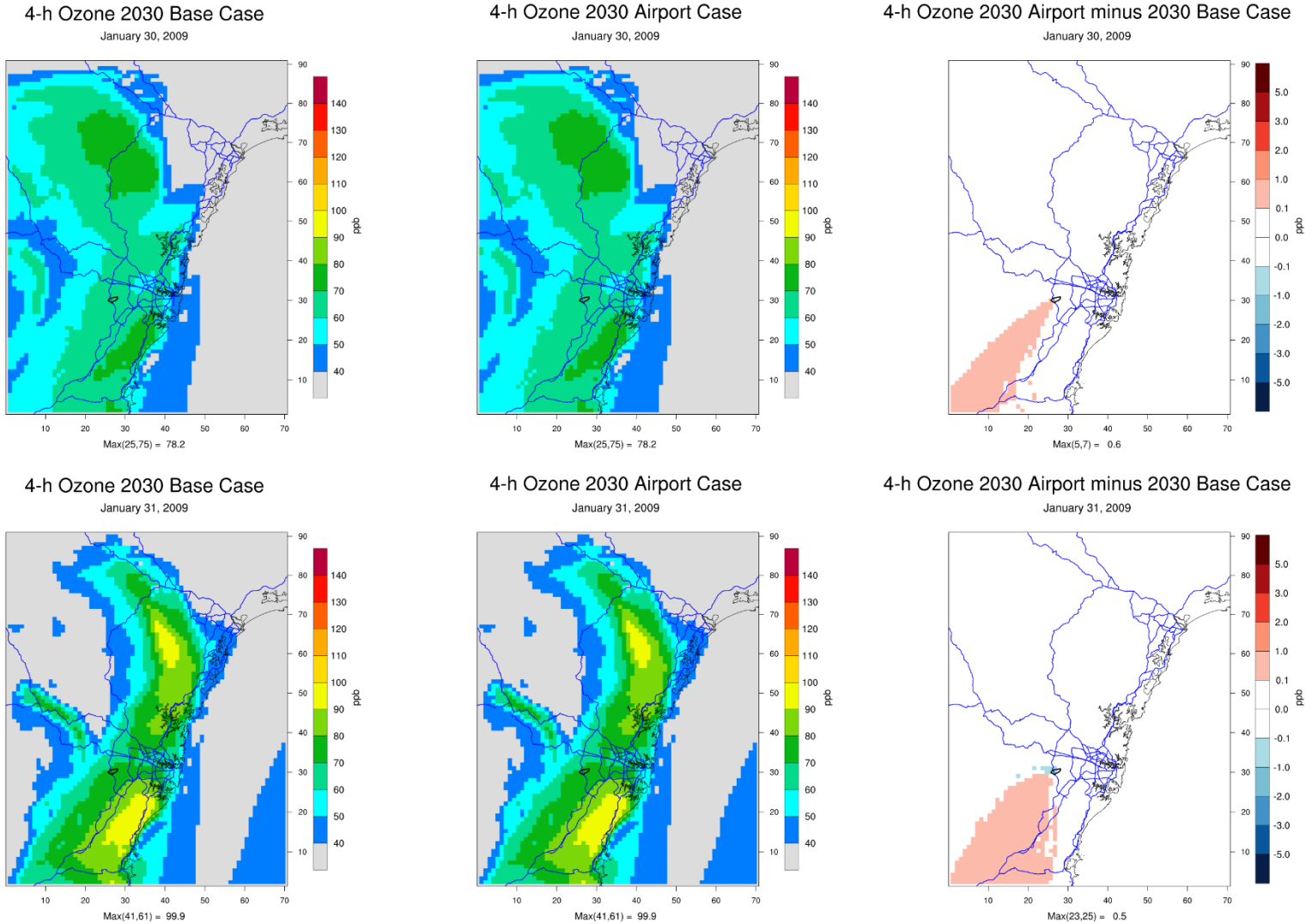


Figure 8-9: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 30 and 31 January

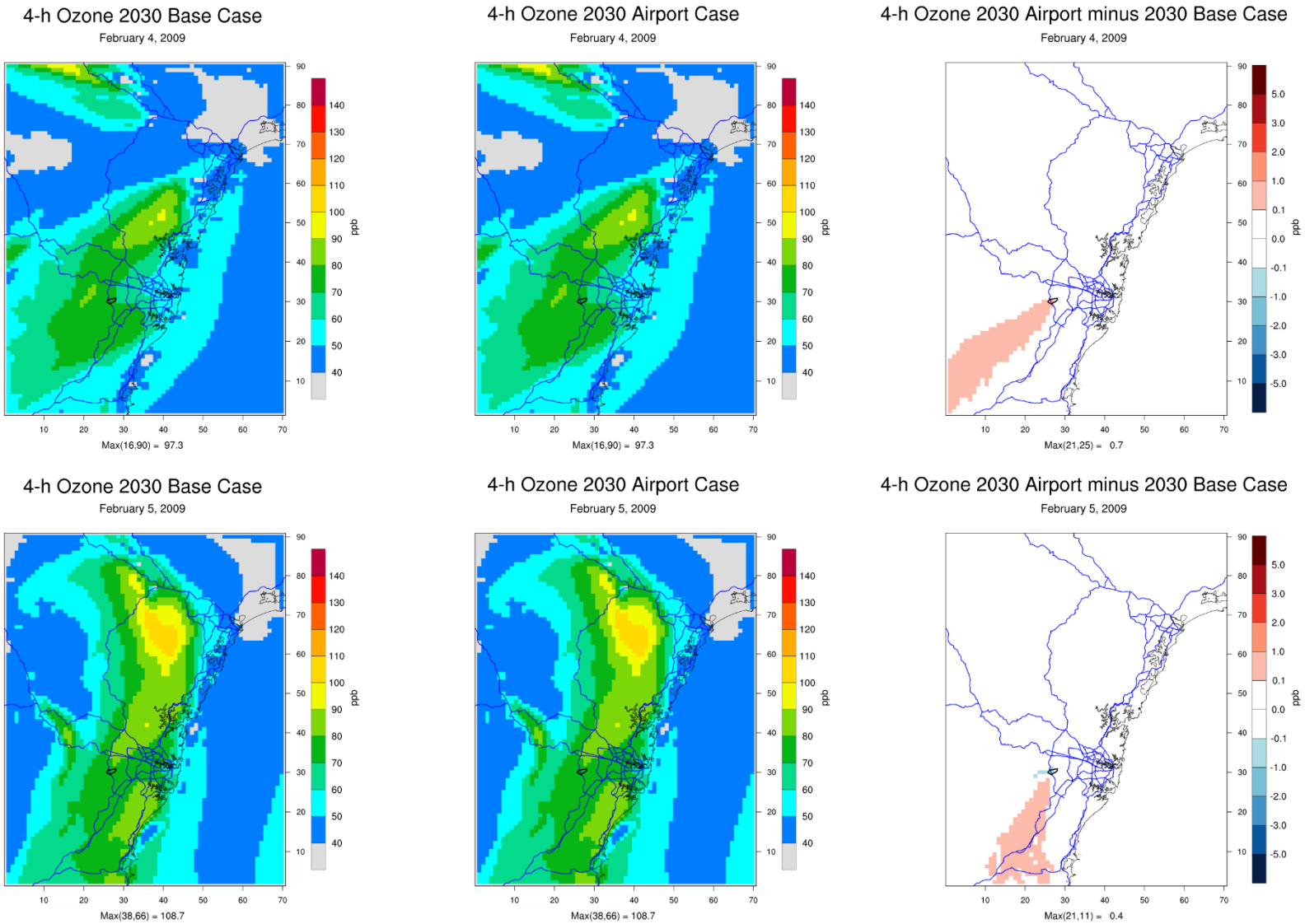


Figure 8-10: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 4 and 5 February

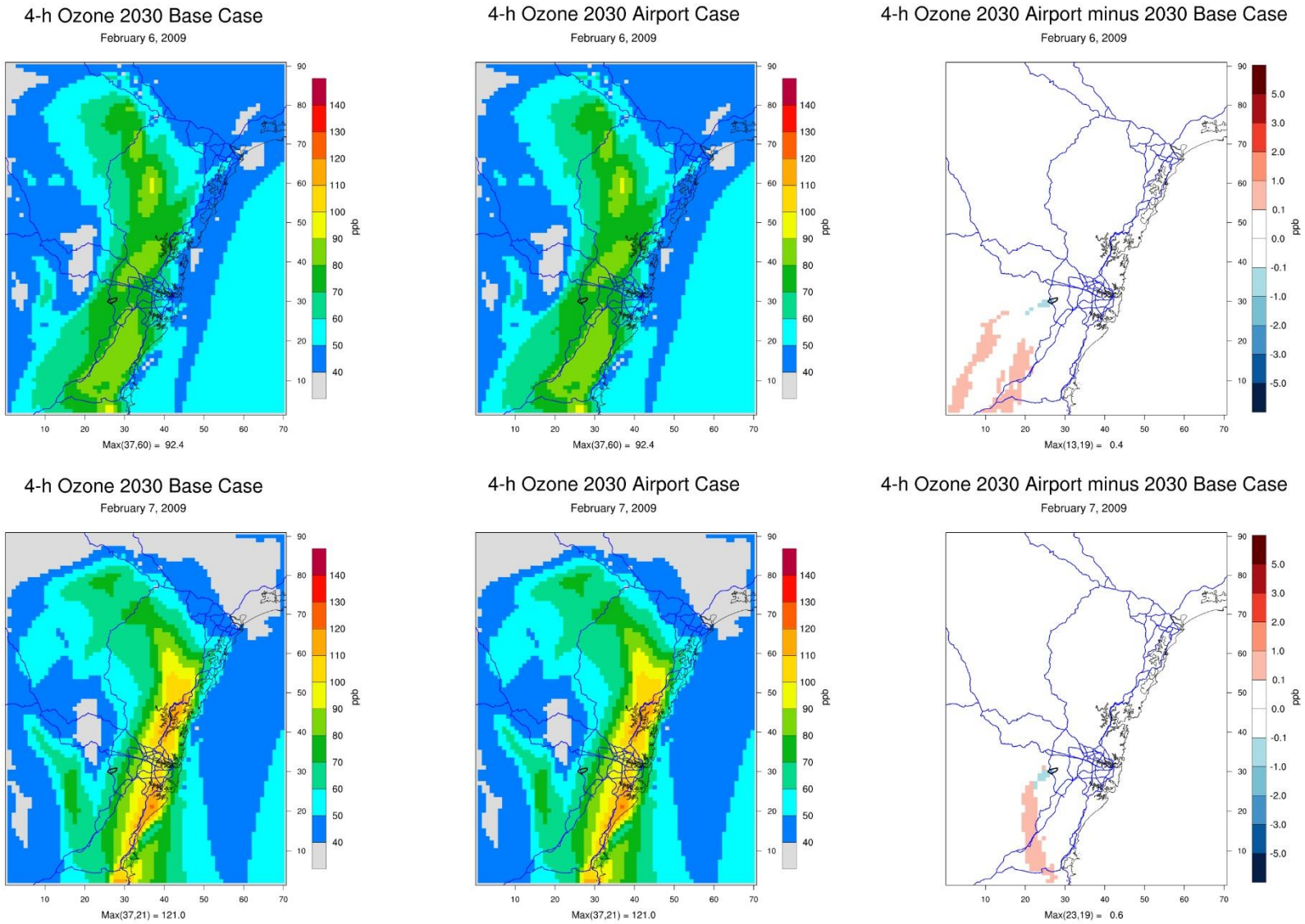


Figure 8-11: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 6 and 7 February

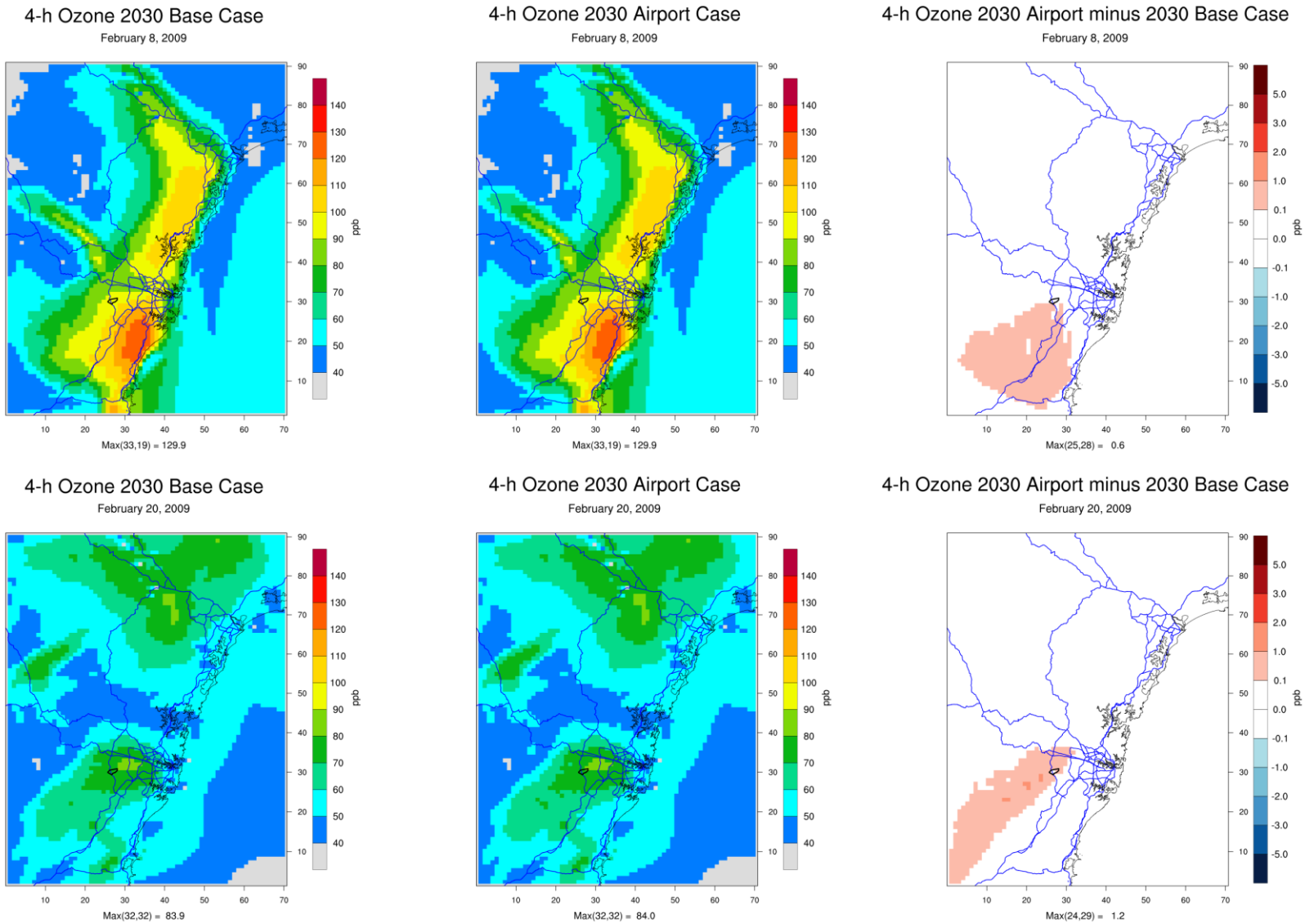


Figure 8-12: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for 8 and 20 February

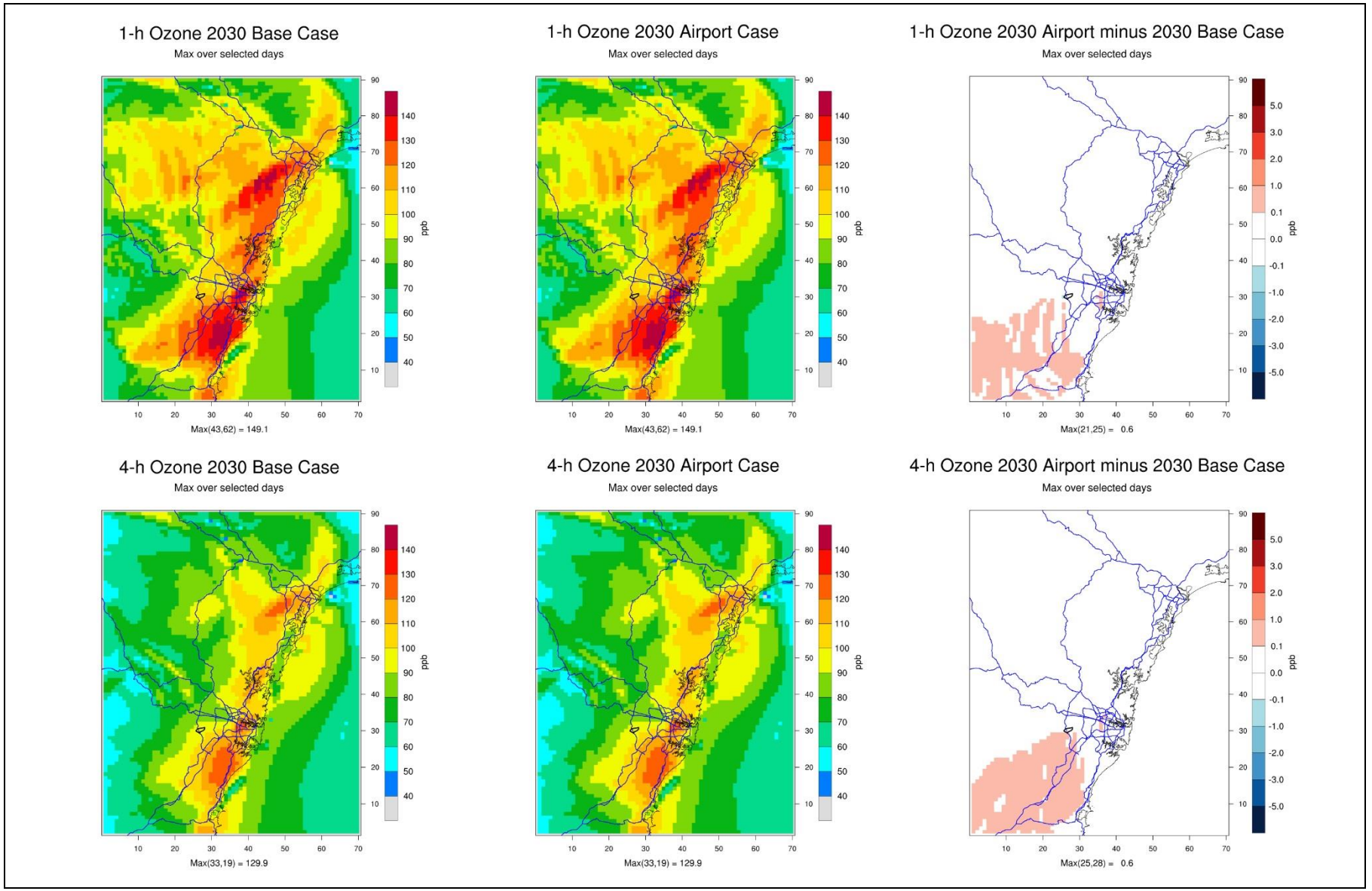


Figure 8-13: Maximum predicted 1-hour and 4-hour ozone concentration (ppb) and the difference (2030 Airport minus 2030 Base Case) for all days

8.4 Longer term airport development

Future projected emissions for sources other than the airport (commercial, industrial, on-road mobile, etc.) are not available for the 2063 scenario, therefore the longer term development scenario becomes a hypothetical scenario of longer term airport development occurring within the context of 2030 Base Case emissions.

The daily maximum predicted 1-hour ozone concentrations are presented in **Table 8-4**. The maximum predicted 1-hour ozone concentration was unchanged between the 2030 Base Case and the 2063 Airport Case for eight of the analysis days. On four days, the peak predicted 1-hour ozone concentration increased, by a maximum of 0.2 ppb. Both the 2030 Base Case and the 2063 Airport Case were above the NEPM criterion of 100 ppb for all but one day of analysis.

The highest change in daily maximum 1-hour ozone concentration, from the addition of 2063 airport emissions, was 12.3 ppb, while the second highest was 5.6 ppb. The largest ozone differences are also confined close to the airport. Larger ozone increases are modelled for the 2063 Airport Case than the 2030 Airport Case. The average of the 2nd to 4th highest increases in daily maximum 1-hour ozone rose from 1.1 ppb for 2030 to 4.5 ppb for 2063. This is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

Table 8-4: Maximum daily predicted 1-hour ozone concentration (ppb) - 2063

Date	2030 Base Case Peak Value	2063 Airport Case Peak Value	2063 Airport Case – 2030 Base Case Largest Difference
06/01/2009	149.1	149.2	2.0
07/01/2009	129.8	130.0	12.3
14/01/2009	106.6	106.6	5.6
29/01/2009	124.1	124.1	1.6
30/01/2009	107.4	107.4	2.3
31/01/2009	109.4	109.4	2.2
04/02/2009	103.8	103.8	3.3
05/02/2009	119.6	119.6	1.6
06/02/2009	112.5	112.5	3.3
07/02/2009	133.7	133.7	1.7
08/02/2009	148.6	148.7	2.5
20/02/2009	98.3	98.4	4.5

The daily maximum predicted 4-hour ozone concentrations are presented in **Table 8-5**. The peak predicted 4-hour ozone concentration was unchanged on seven days and increased on five days, by a maximum of 0.2 ppb.

The highest change in daily maximum 4-hour ozone concentration, from the addition of 2063 airport emissions, was 6.3 ppb, while the second highest was 5.8 ppb. The average of the 2nd to 4th highest increases in daily maximum 4-hour ozone is 3.7 ppb, which is significantly greater than the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

Table 8-5: Maximum daily predicted 4-hour ozone concentration (ppb) - 2063

Date	2030 Base Case Peak Value	2063 Airport Case Peak Value	2063 Airport Case – 2030 Base Case Largest Difference
06/01/2009	126.2	126.5	1.9
07/01/2009	115.3	115.6	5.8
14/01/2009	98.7	98.9	1.6
29/01/2009	95.9	95.9	2.2
30/01/2009	78.2	78.2	2.4
31/01/2009	99.9	99.9	2.3
04/02/2009	97.3	97.3	3.0
05/02/2009	108.7	108.7	1.6
06/02/2009	92.4	92.4	1.7
07/02/2009	121.0	121.0	2.4
08/02/2009	129.9	130.0	2.3
20/02/2009	83.9	84.2	6.3

8.4.1 Spatial variation in peak ozone concentrations

Locations of ozone differences due to 2063 airport emissions are shown in the spatial plots of the daily maximum predicted 1-hour and 4-hour ozone concentration, presented **Figure 8-14** to **Figure 8-25**.

Decreases in daily maximum ozone, due to ozone suppression by NOx emissions, occur in the vicinity of the airport and on some days extend to the aircraft flight corridor and areas downwind of the airport. Areas of ozone decrease are more extensive for the 2063 Airport Case than for the 2030 Airport Case because NO_x emissions from the airport are 5.2 times larger in 2063. Increases in ozone occur downwind of the airport and also are larger for the 2063 Airport Case than for the 2030 Airport Case.

Spatial plots of the maximum predicted 1-hour and 4-hour ozone concentration over all days of analysis is presented in **Figure 8-26**.

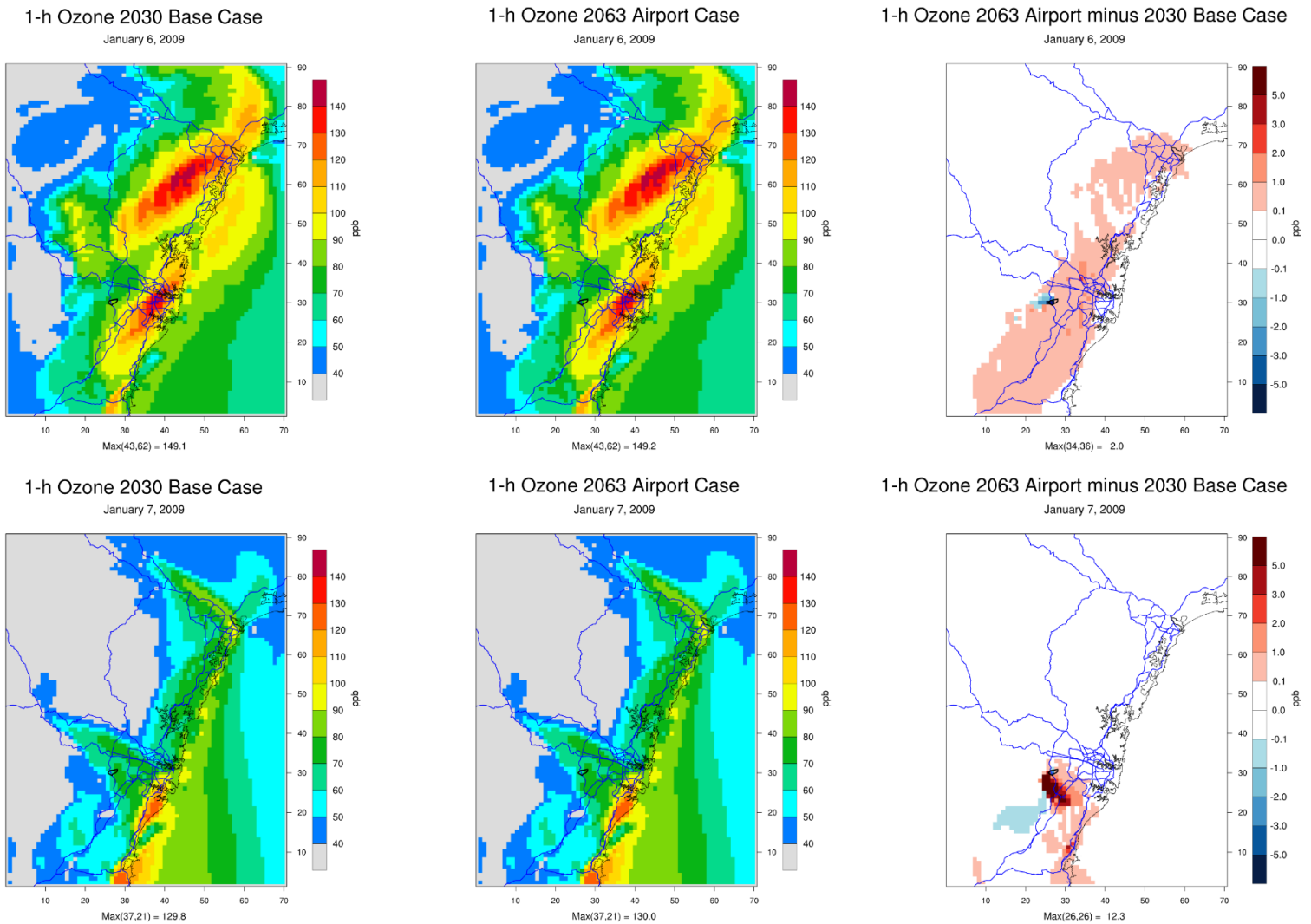


Figure 8-14: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 January

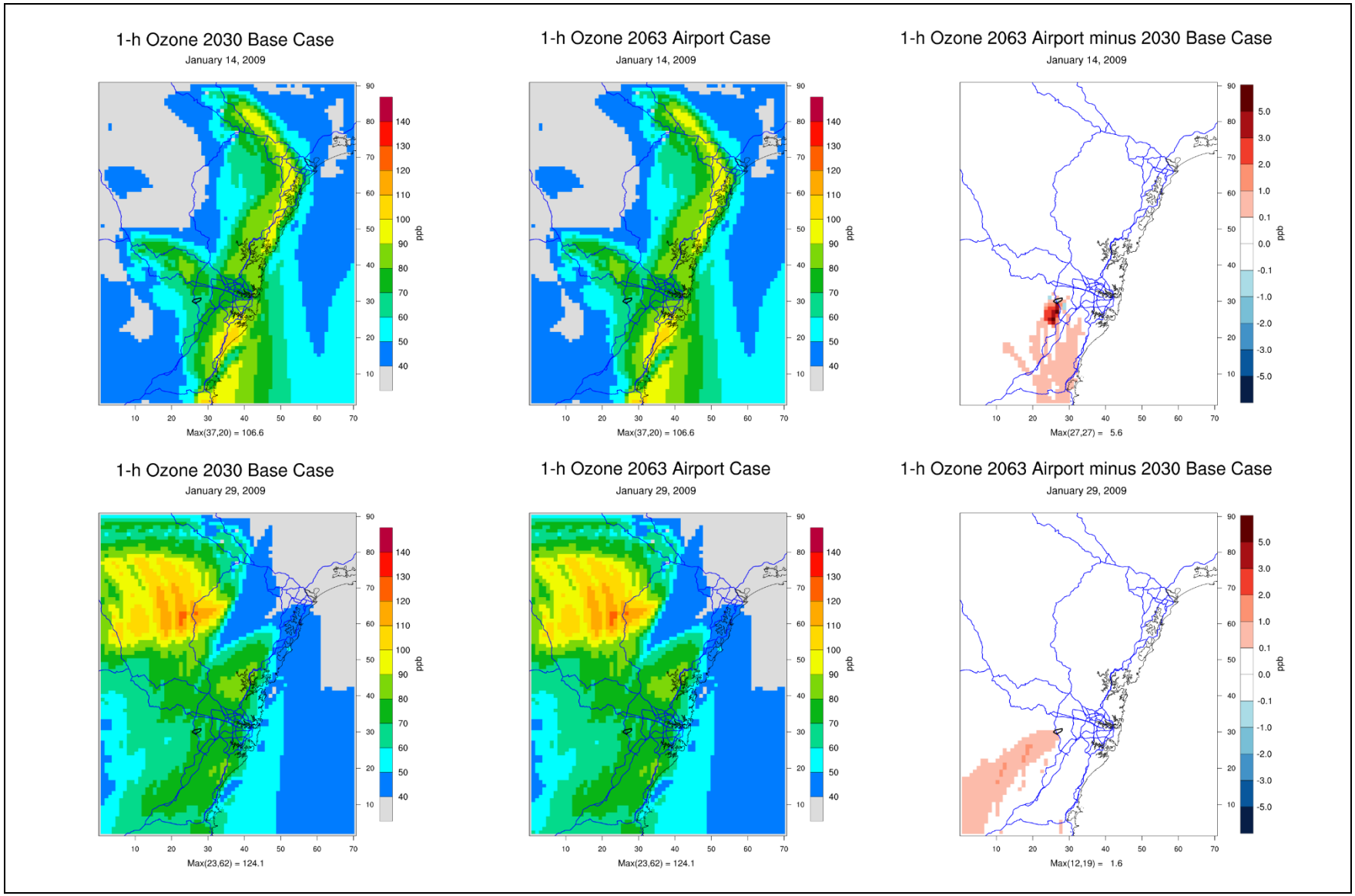


Figure 8-15: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 14 and 29 January

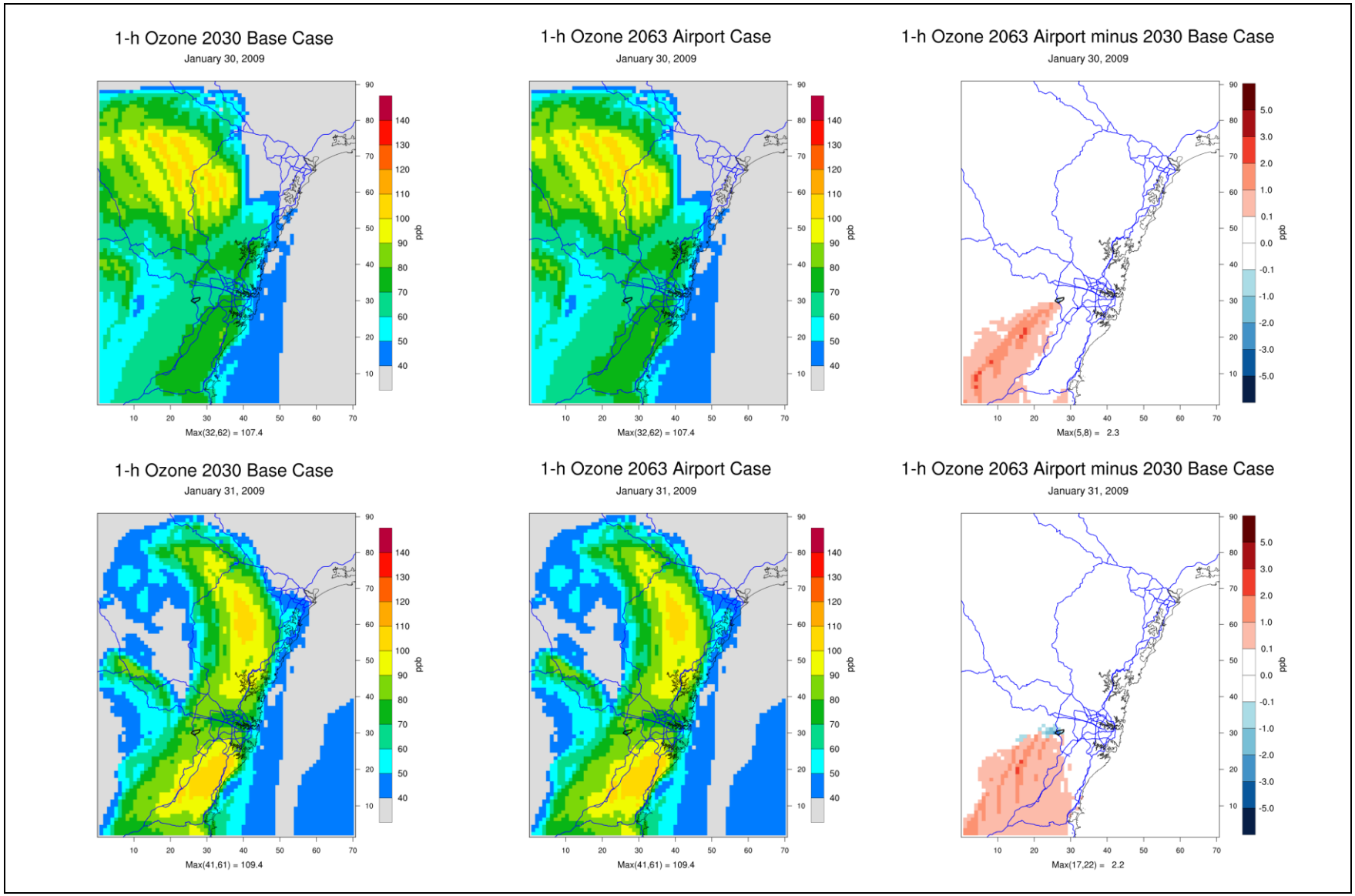


Figure 8-16: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 30 and 31 January

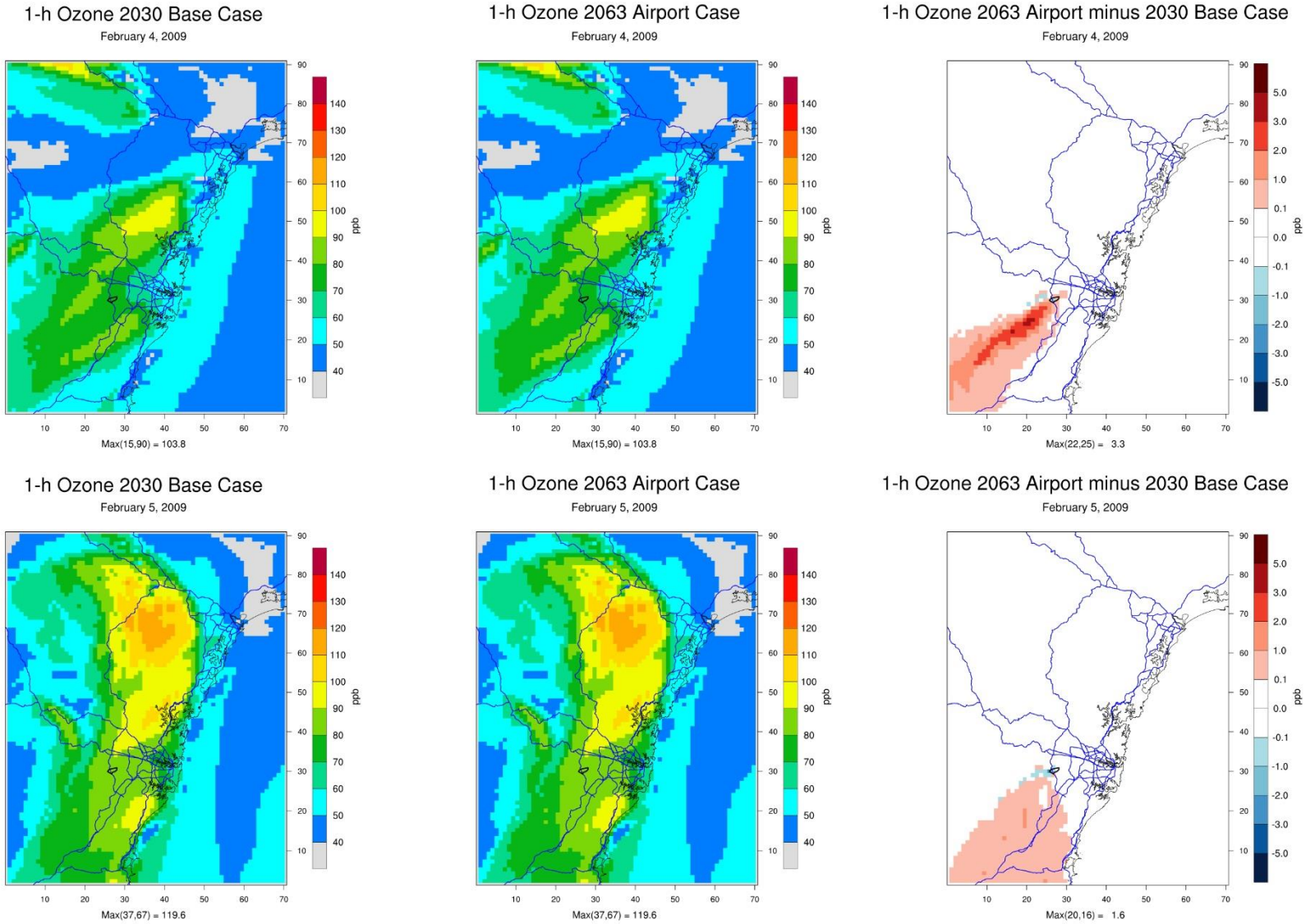


Figure 8-17: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 4 and 5 February

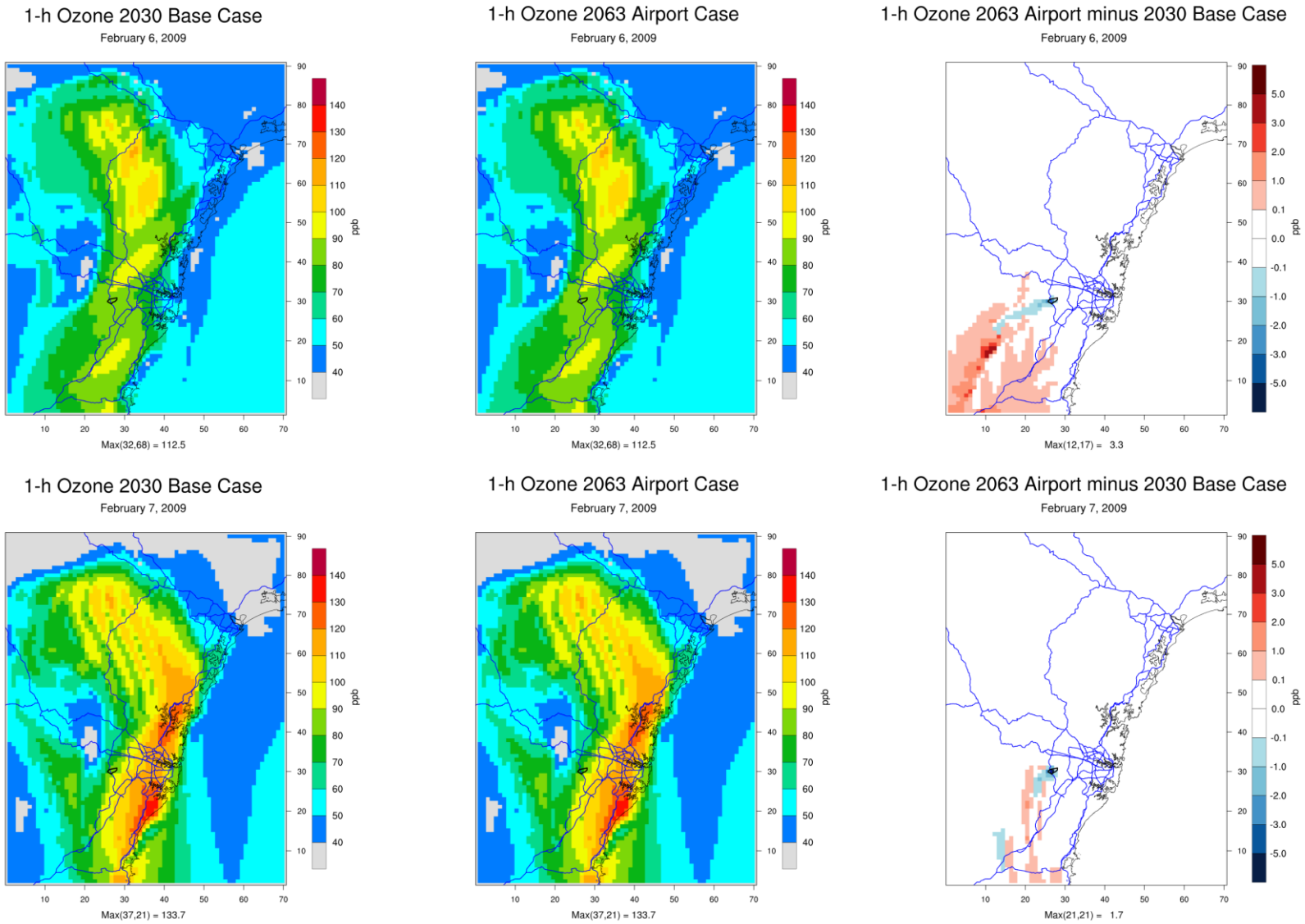


Figure 8-18: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 February

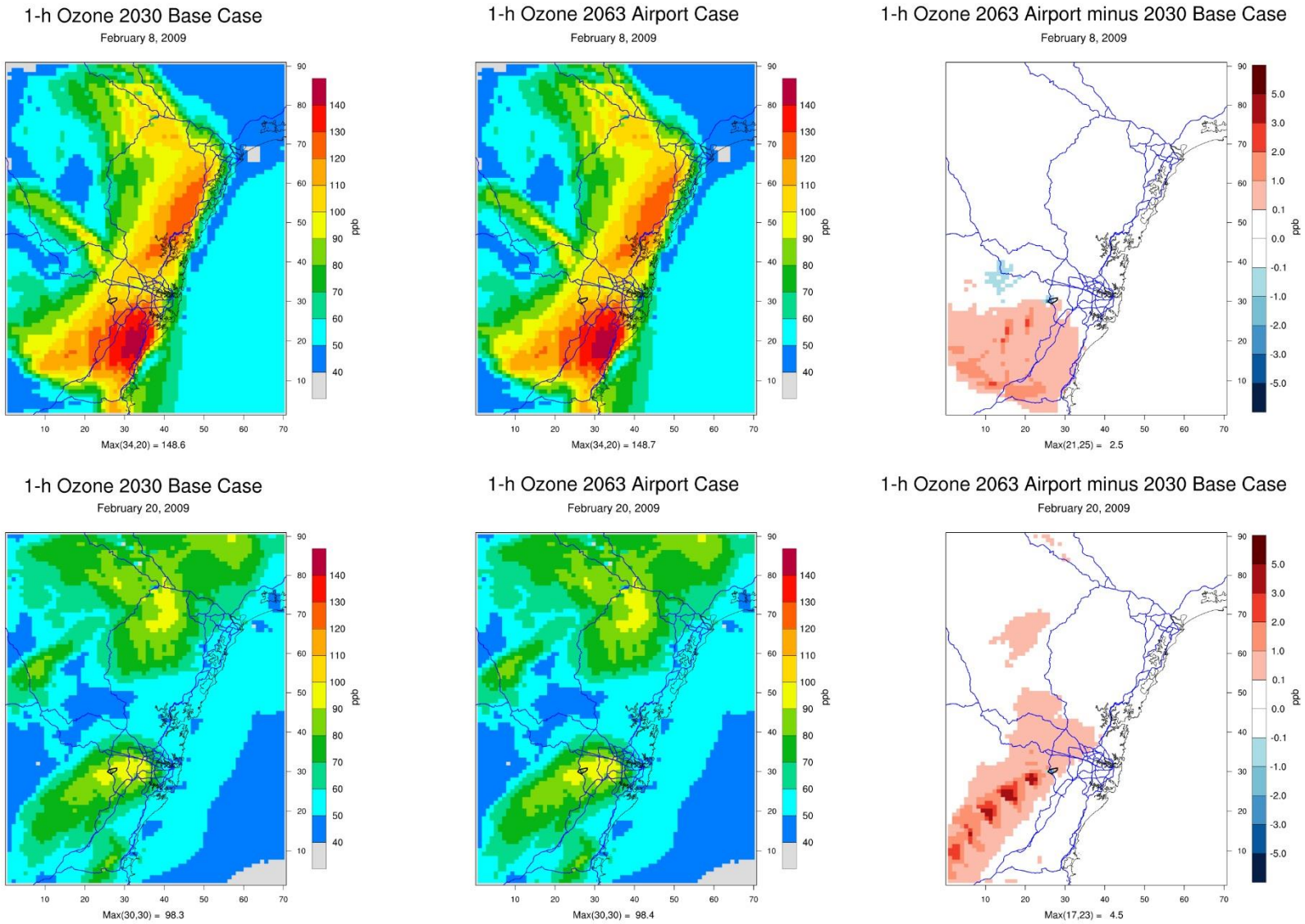


Figure 8-19: Maximum predicted 1-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 8 and 20 February

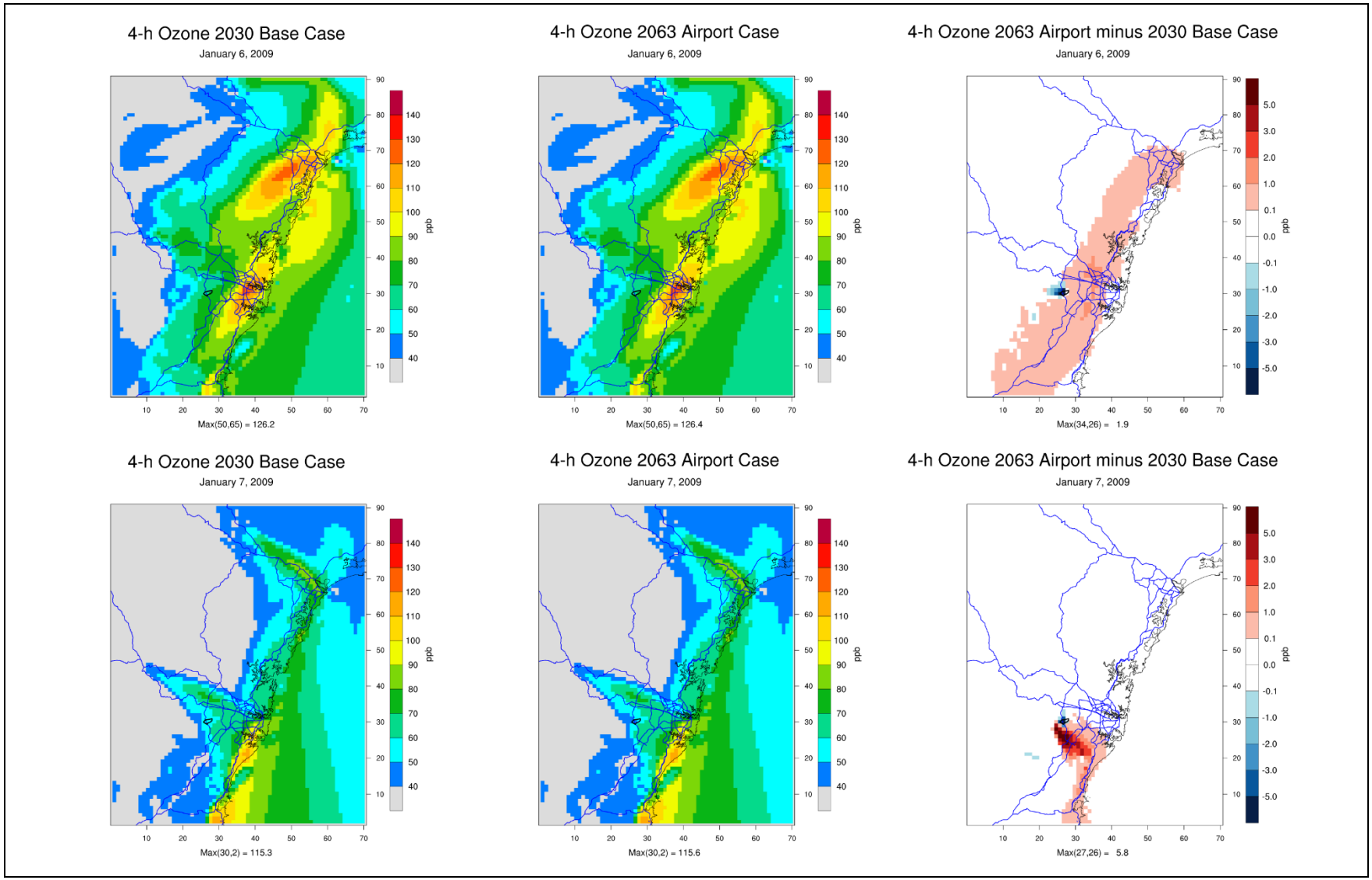


Figure 8-20: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 January

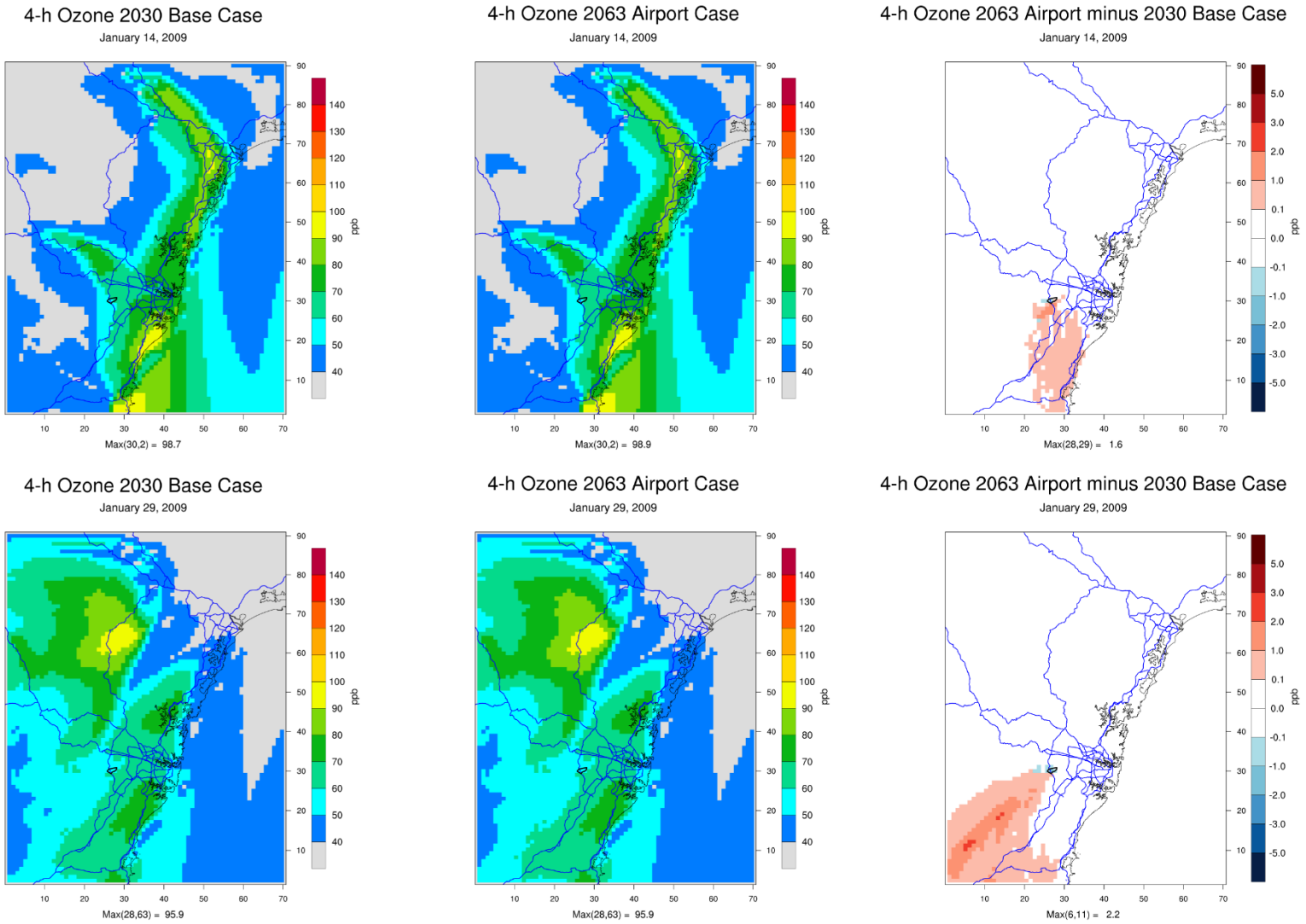


Figure 8-21: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 14 and 29 January

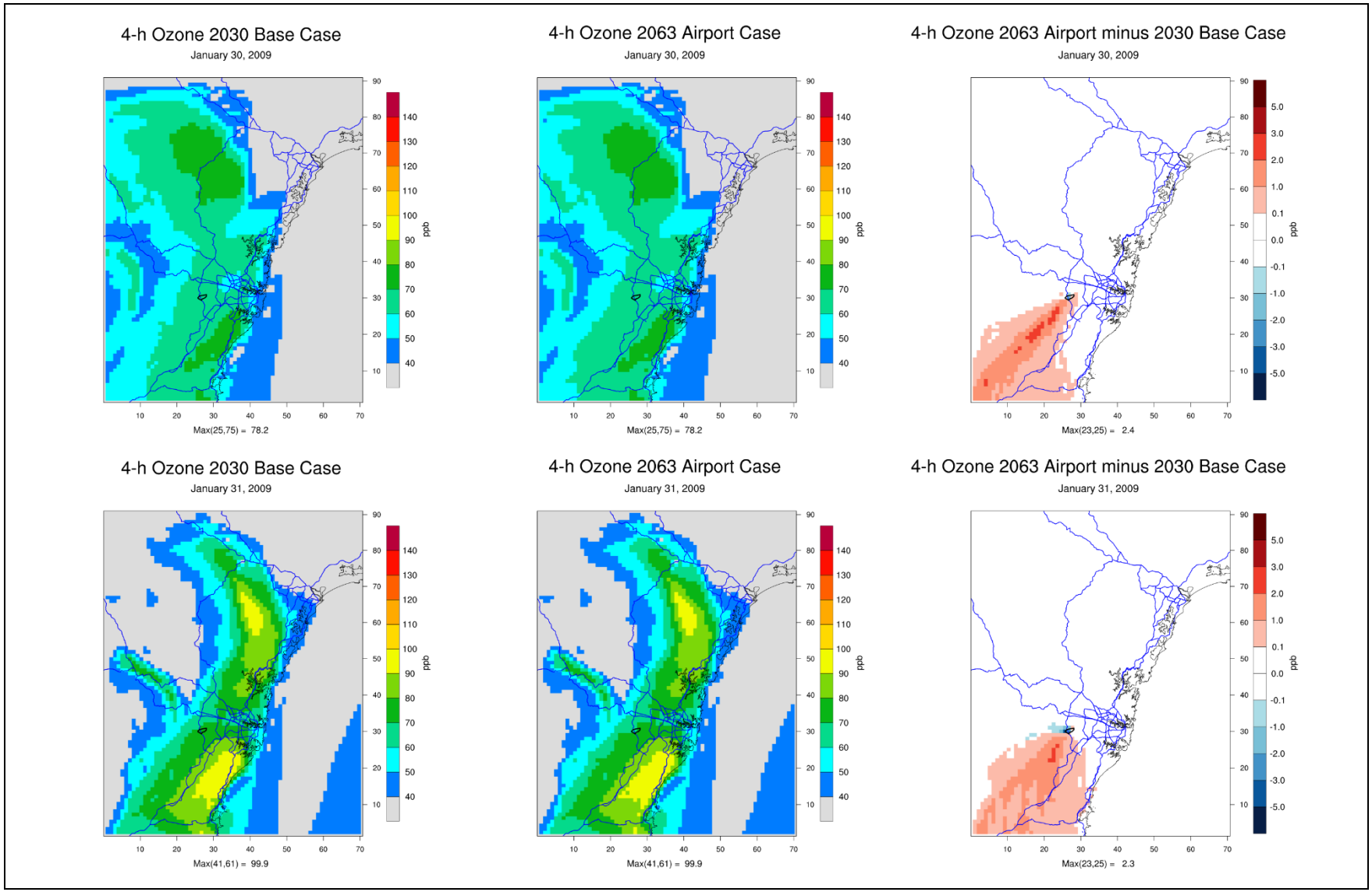


Figure 8-22: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 30 and 31 January

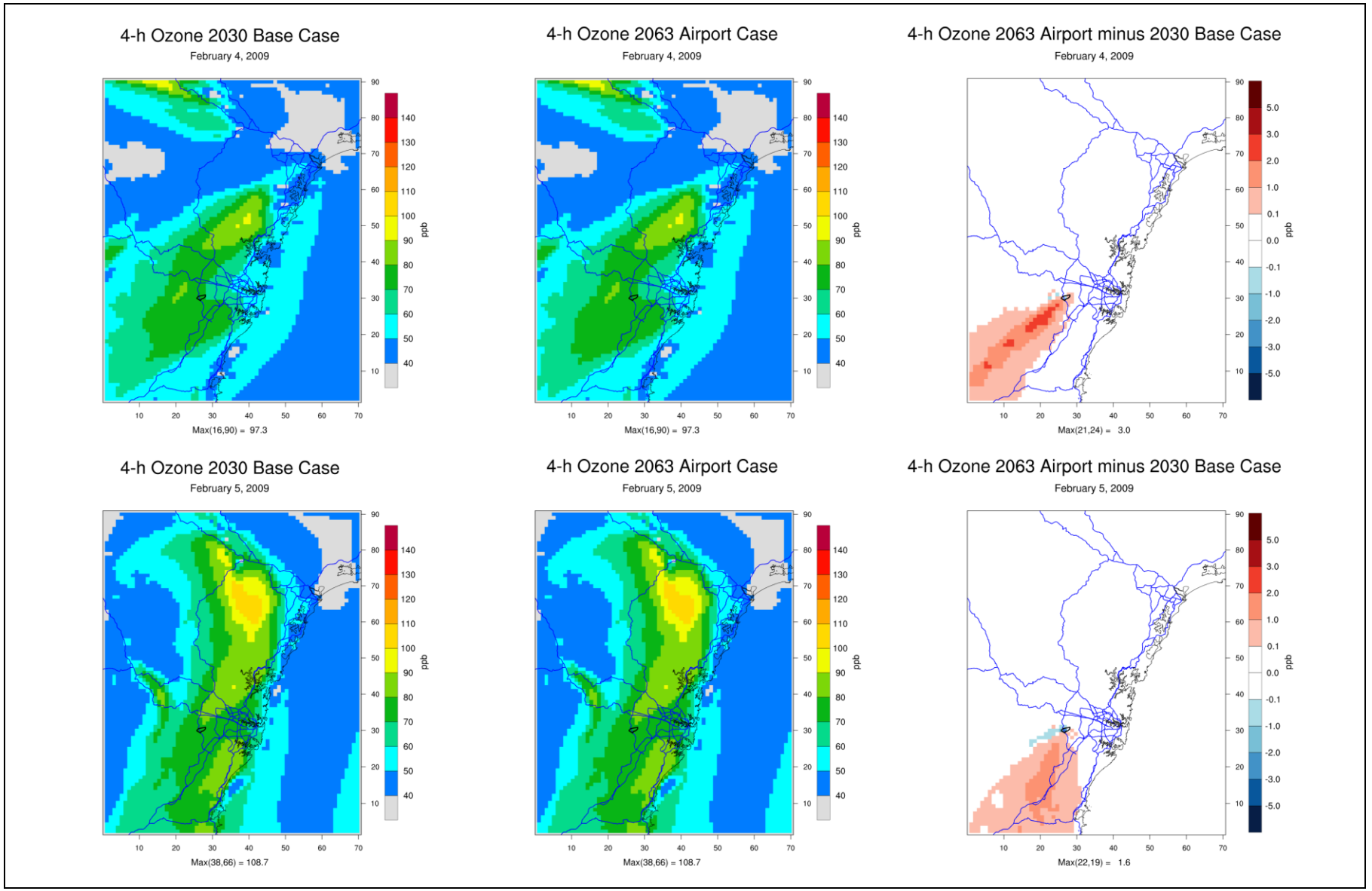


Figure 8-23: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 4 and 5 February

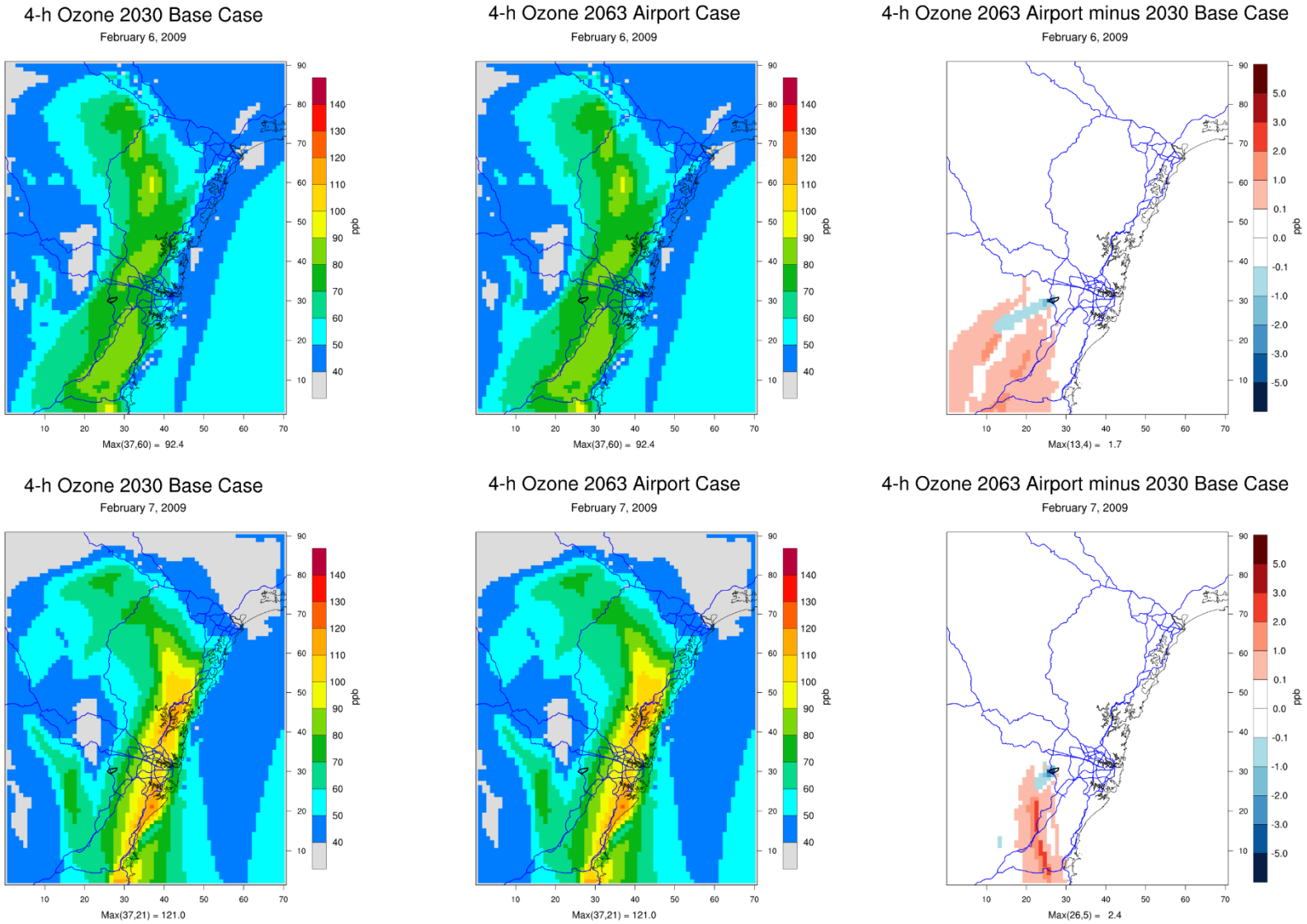


Figure 8-24: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 6 and 7 February

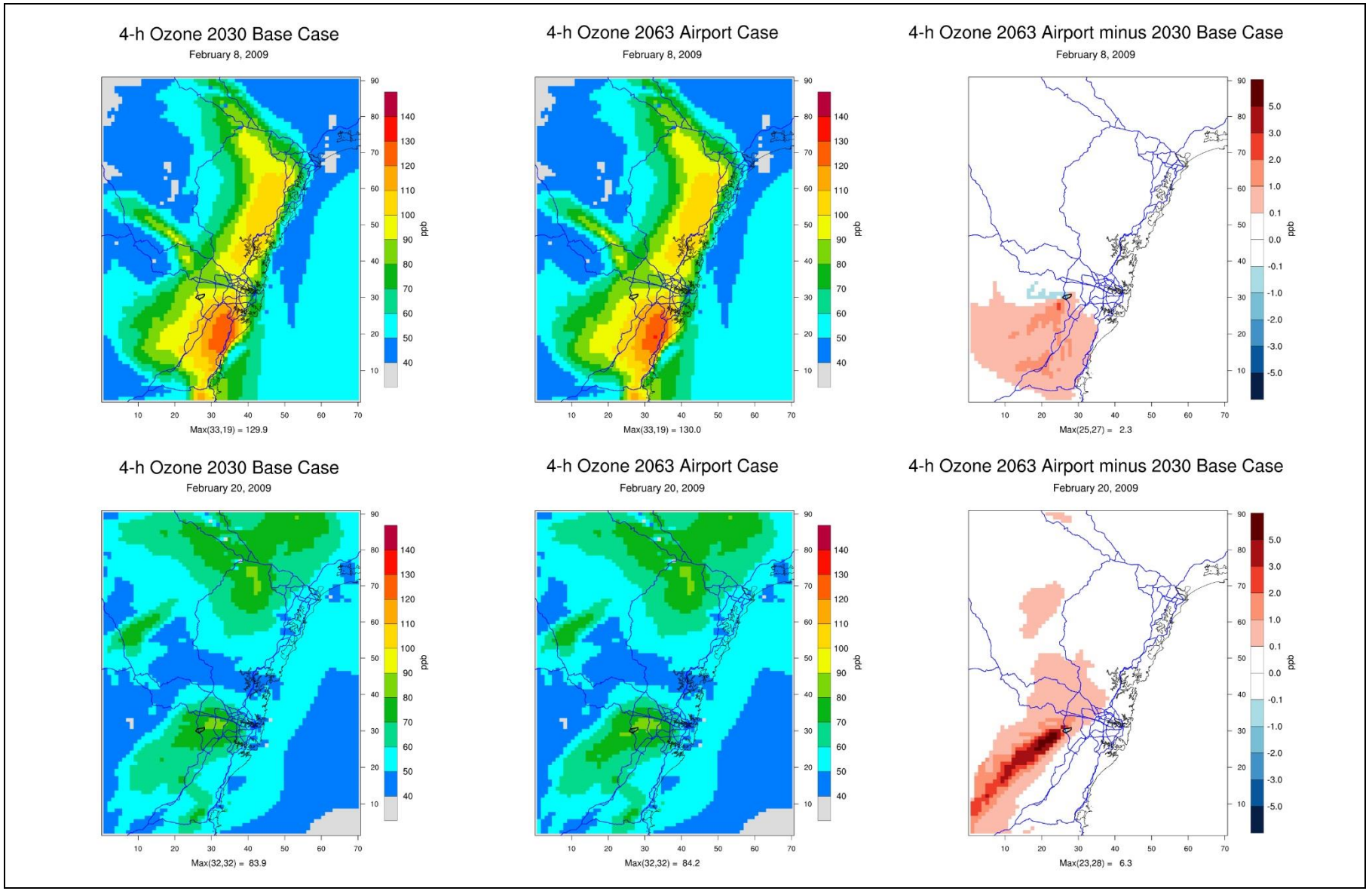


Figure 8-25: Maximum predicted 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for 8 and 20 February

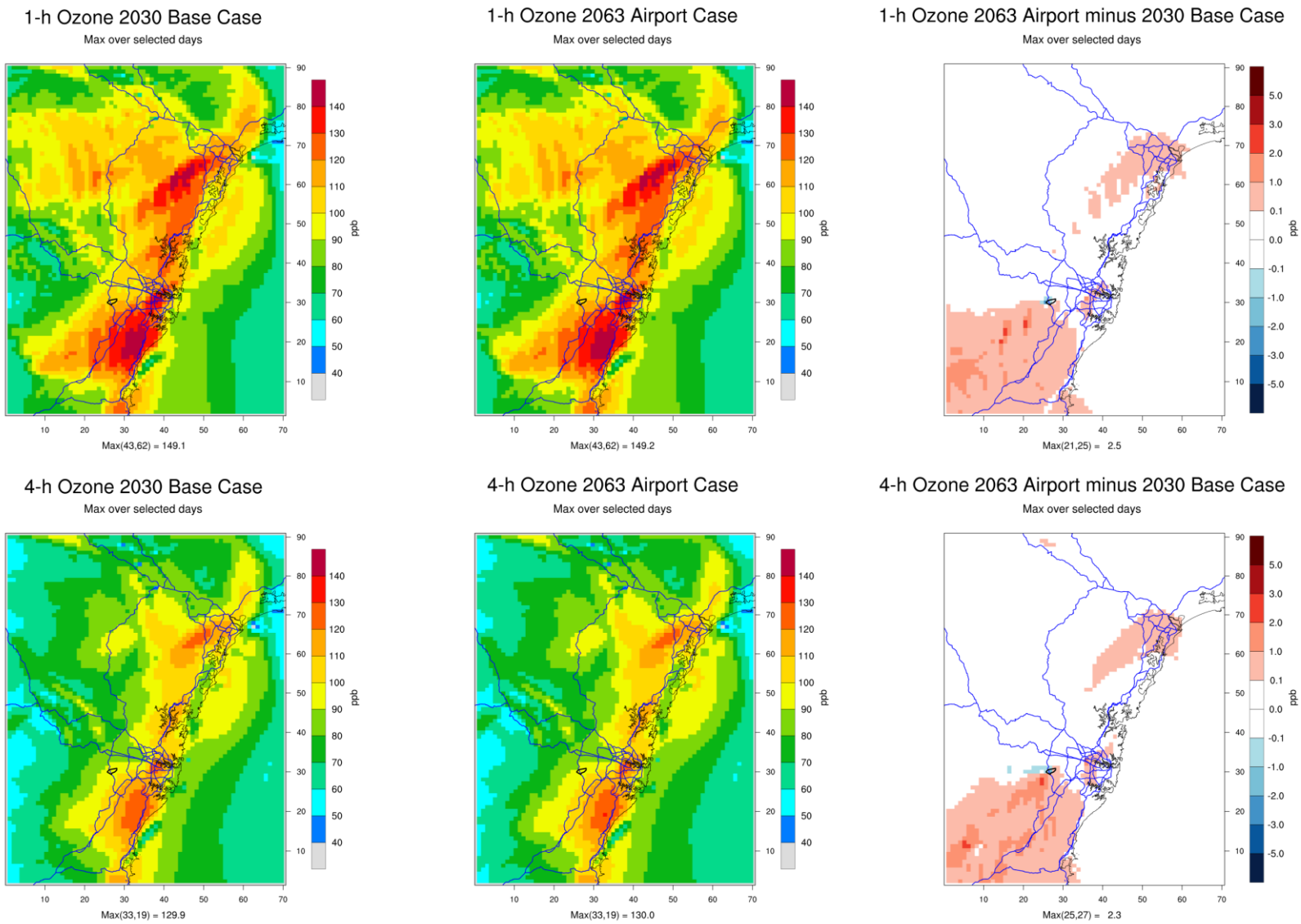


Figure 8-26: Maximum predicted 1-hour and 4-hour ozone concentration (ppb) and the difference (2063 Airport minus 2030 Base Case) for all days

9. MITIGATION MEASURES

The ozone modelling for the Stage 1 airport development predicts a marginal exceedance of the maximum allowable increment level of 1 ppb, based on the average of the 2nd to 4th highest change in daily maximum 1-hour ozone. For the longer term airport development, the change in daily maximum 1-hour ozone is significantly above the maximum allowable increment.

Mitigation for ozone impacts should therefore be considered for both the proposed Stage 1 and longer term development and should focus primarily on measures which result in reductions in NO_x emissions, and to a lesser extent VOC emissions.

The NSW tiered procedure for ozone assessment requires new or modified facilities located within ozone non-attainment areas to consider best available techniques (BAT) and/or emission offsets when undertaking best management practice (BMP) determinations. The effectiveness of any proposed management measures could be quantified in tonnes of emissions reduced, however it is more relevant to consider the resultant reduction in ozone concentrations. The sensitivity of ozone concentrations to reductions in NO_x and VOCs (i.e., ppb ozone per tonne of emissions) should be evaluated for future years, in particular for the longer term airport development, when total regional NO_x emissions may be lower than they are today. Therefore a BMP determination should consider both effectiveness in reducing ozone and cost-effectiveness.

The largest source of NO_x emissions for the Stage 1 airport development are the external roadways. The future operator of the airport would have no operational control over emissions from external roadways and emission reductions from this source would be driven by progressive improvements in emissions standards for on-road vehicles. NO_x emissions from on-road transportation are already projected to decline for future years, as discussed in **Section 4.3.2**. Emissions from roads have a much wider spatial distribution than sources at the airport which could influence their relative effectiveness in forming ozone. The second largest source of NO_x emissions for the Stage 1 airport development is aircraft engines, the majority of which would occur during landing and take-off. Similar to roadways, the future operator of the airport would have no operational control over emissions from jet engines and emissions reductions would be driven by technological advances, emission standards and aviation jet fuel standards.

The next largest source of NO_x emissions are ground support equipment and auxiliary power units while the aircraft is at the gate. EDMS emission estimates presented in this report include APUs powered by jet fuel and diesel and gasoline powered GSE equipment. These emissions would be reduced were the airport operator to implement best available technology such as mains powered APUs at airport gates. Other emission reduction options for the airport operator to consider, which would have associated benefits in NO_x and VOC emissions reduction include:

- Replacing conventionally fuelled GSE with electric or hydrogen powered belt loaders, pushback tractors, bag tugs, cargo loaders.
- Providing remote ground power for remote aircraft parking positions.
- Installing co-generation or tri-generation in-lieu of traditional gas fired boilers or solar hot water systems to replace gas fired boilers.
- Avoiding certain activities, such as training fires, maintenance (spray painting) during the ozone season.
- Using underground fuel hydrant systems and / or vapour recovery systems for refuelling and fuel storage.
- Promoting the use of public transport to the airport.

NO_x control measures are also outlined in the local air quality assessment, as well as recommendations for the installation of an air quality monitoring station. Ozone is already measured in the vicinity of the airport site (at Bringelly), however if an air quality monitoring station is installed at the airport site, an ozone monitoring sensor could be included in the station.

10. CONCLUSION

Regional air quality considers the formation of secondary pollutants (such as ozone) through photochemical reactions from primary emissions of precursor gases. The primary emissions of precursor gases considered in this assessment include nitrogen oxides (NOx), volatile organic compounds (VOCs) and carbon monoxide (CO), and the assessment focuses on the regional impacts from ozone formation. Ozone air quality impacts from the proposed Western Sydney Airport were evaluated using the Comprehensive Air quality Model with extensions (CAMx).

TAPM was used to simulate meteorology within the study area. Surface observation data from meteorological stations located in the modelling domain were included in the modelling. The performance of TAPM in simulating meteorology for the Sydney region was evaluated. General wind patterns in the observation data were reflected reasonably well in the TAPM predictions and wind speed compared favourably. A statistical evaluation shows good correlation for wind speed and temperature with reasonably low bias and error.

The ozone modelling assessment considered emissions data for the following scenarios:

- 2008/2009 Base Case - for model evaluation.
- 2030 Future Base Case - for comparison with future airport operations.
- 2030 Airport Case – for the Stage 1 airport emissions.
- 2063 Airport Case – for the longer term airport emissions.

The 2008/2009 Base Case scenario was used to assess model performance, by comparing predicted ozone concentrations against ambient monitoring data for the same period. Scatter plots presented for the evaluation demonstrate that modelled-observed data pairs are clustered around the 1:1 line, showing that the model tends to correctly predict variability in ozone. The model exhibits little bias at Bringelly and St Marys with normalised mean bias less than 2% for 1-hour ozone and for 4-hour ozone less than 7%.

To assess the impact of airport operations for a future scenario, it was necessary to apply projections to the 2008/2009 emissions. The NSW EPA provided future year emissions projections for 2031, which were used to scale baseline emissions for the 2030 Future Base Case, to allow direct comparison with the Stage 1 airport development year (2030). A number of days were selected for detailed analysis. Twelve days with high observed ozone (1-hour ozone concentrations greater than 70 ppb and 4-hour ozone concentrations greater than 65 ppb) and good model performance (bias within ±15% in peak values) were selected for analysis. The selection of historical dates in January and February 2009 may appear counter intuitive for the modelling future emissions in 2030 and 2063. However, these dates simply represent the meteorological conditions that have historically led to peak ozone formation and which the model has effectively captured for peak ozone formation with future emissions added. They represent days when worst case ozone impacts may be expected.

10.1 Results for Stage 1 airport development

For each day of analysis, the peak predicted 1-hour ozone concentrations were unchanged between the 2030 Base Case and the 2030 Airport Case. This is because the predicted ozone concentrations from the airport occur in different locations to where ozone peaks occur. Both the 2030 Base Case and the 2030 Airport Case were above the NEPM criterion of 100 ppb for all but one day of analysis.

The largest difference in daily maximum 1-hour ozone concentration, from the addition of airport emissions, was 5.5 ppb. However, reliance on a single model result (e.g., the largest ozone change) could accentuate the influence of uncertainties in model input data or model formulation, therefore the average of the 2nd to 4th highest ozone change (1.1 ppb) is used to describe ozone impacts. This approach is similar to the use of a 99th percentile to describe maximum ozone impacts. When compared to the maximum allowable increment level of 1 ppb, prescribed by the

NSW tiered procedure for ozone assessment, a marginal impact is predicted from the 2030 Airport Case.

The peak predicted 4-hour ozone concentration were unchanged between the 2030 Airport Case and the 2030 Base Case on eight days and increased on four days, by a maximum of 0.1 ppb. The highest change in daily maximum 4-hour ozone concentration, from the addition of airport emissions, was 2.4 ppb, while the second highest change was 1.2 ppb. The average of the 2nd to 4th highest change in daily maximum 4-hour ozone was 0.9 ppb, which is below the maximum allowable increment of 1 ppb.

Locations of ozone differences due to 2030 airport emissions are shown in the spatial plots of the daily maximum predicted 1-hour and 4-hour ozone concentration. Decreases in daily maximum ozone would only occur in the vicinity of the airport site for the 2030 Airport Case and are attributable to ozone suppression by NOx emissions. Increases in ozone would occur downwind of the airport which, on most days, is to the south. The largest ozone differences are confined close to the airport site.

10.2 Results for longer term airport development

Future projected emissions for sources other than the airport (commercial, industrial, on-road mobile, etc.) are not available for the 2063 scenario. Therefore the longer term development scenario becomes a hypothetical scenario of longer term airport development occurring within the context of 2030 Base Case emissions.

The maximum predicted 1-hour ozone concentration was unchanged between the 2030 Base Case and the 2063 Airport Case for eight of the analysis days. On four days, the peak predicted 1-hour ozone concentration increased by a maximum of 0.2 ppb. Both the 2030 Base Case and the 2063 Airport Case were above the NEPM criterion of 100 ppb for all but one day of analysis.

Larger ozone increases are modelled for the 2063 Airport Case than the 2030 Airport Case. The average of the 2nd to 4th highest increases in daily maximum 1-hour ozone rose from 1.1 ppb for 2030 to 4.5 ppb for 2063. This is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

The peak predicted 4-hour ozone concentration was unchanged on seven days and increased on five days, by a maximum of 0.2 ppb. The highest change in daily maximum 4-hour ozone concentration, from the addition of 2063 airport emissions, was 6.3 ppb, while the second highest change was 5.8 ppb. The average of the 2nd to 4th highest increases in daily maximum 4-hour ozone is 3.7 ppb, which is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

Decreases in daily maximum ozone, due to ozone suppression by NOx emissions, would occur in the vicinity of the airport site and on some days extend to the aircraft flight corridor and areas downwind of the airport for the 2063 Airport Case. Areas of ozone decrease are more expansive for the 2063 Airport Case than for the 2030 Airport Case because NO_x emissions from the airport site are higher in 2063. Increases in ozone occur downwind of the airport and also are larger for the 2063 Airport Case than for the 2030 Airport Case.

It is noted that emission data provided for airport operations assumes worst case operations, for example by including emissions from APUs rather than the use of mains powered APUs at the airport gates. Furthermore, for the longer term airport development we have not accounted for changes in emissions from all other sources (commercial, industrial, on-road mobile, etc.), some of which may increase and some of which may decrease. The modelling predictions for the longer term development should therefore be viewed in this context.

10.3 Mitigation

Mitigation for ozone impacts should be considered for both the Stage 1 and longer term development and should focus primarily on measures which result in reductions in NO_x emissions. The NSW tiered procedure for ozone assessment requires that a best management practice

(BMP) determination, for facilities located within ozone non-attainment areas, should consider best available techniques (BAT) and/or emission offsets. As recommended in the local air quality assessment, emissions would be reduced were the proposed airport operator to implement BAT where it can, for example through the use of mains powered APUs at airport gates. It is recommended that any assessment of the effectiveness of any proposed management measures include an evaluation of the sensitivity of ozone concentrations to reductions in NO_x and VOCs (i.e., ppb ozone per tonne of emissions) for future years.

11. GLOSSARY OF TERMS AND ACONYMNS

µg/m³	micrograms per cubic metre
µm	micron
APU	auxiliary power units
BoM	Bureau of Meteorology
CAMx	Comprehensive Air quality Model with extensions
CB05	Carbon Bond chemical mechanism 2005
CB4	Carbon Bond chemical mechanism version 4
CFR	United States Code of Federal Regulations
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
DoE	Department of Environment
DSEWPC	Department of Sustainability, Environment, Water, Population and Communities
EDMS	Emissions and Dispersion Modeling System
EIS	Environmental Impact Statement
EPP (Air)	Environment Protection Policy (Air)
EPS3	Emissions Processing System version 3
FAC2	Fraction of model predictions within a factor of 2
g/m^3	grams per metre cubed
GMR	Greater Metropolitan Region in New South Wales
GSE	ground support equipment
HRA	Health Risk Assessment
IOA	Index of Agreement
ISA	Integrated Science Assessment
K	Kelvin
km	kilometre
LTO	Landing/Take-Off
m	metre
m/s	meters per second
m^2/s	metre squared per second
mb	millbar
MB	Mean bias
MEGAN	Model of Emissions of Gases and Aerosols from Nature
MGE	Mean Gross Error
Monotonic	Continuously increasing (or continuously decreasing)
MOZART	Model for Ozone and Related chemical Tracers
NAAQS	National Ambient Air Quality Standards
NCAR	National Center for Atmospheric Research
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NO	nitrogen oxide

NO_x	nitrogen oxides
NSW EPA	New South Wales Environment Protection Authority
NW	northwest
O_3	ozone
OEH	NSW Office of Environment and Heritage
PEL	Pacific Environment Limited
PM	particulate matter
PM_{10}	Particulate matter with an aerodynamic diameter of less than 10 µm
$PM_{2.5}$	Particulate matter with an aerodynamic diameter of less than 2.5 µm
POEO	Protection of the Environment Operations Act
ppb	parts per billion
pphm	parts per hundred million
ppm	parts per million
ROI	Radius of Influence
SIL	screening impact level
SO_2	sulphur dioxide
SW	southwest
TAPM	The Air Pollution Model
US EPA	United States Environment Protection Agency
VKT	vehicle kilometres travelled
VOCs	volatile organic compounds

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APPENDIX 1
NSW EPA TIERED PROCEDURE FOR OZONE ASSESSMENT

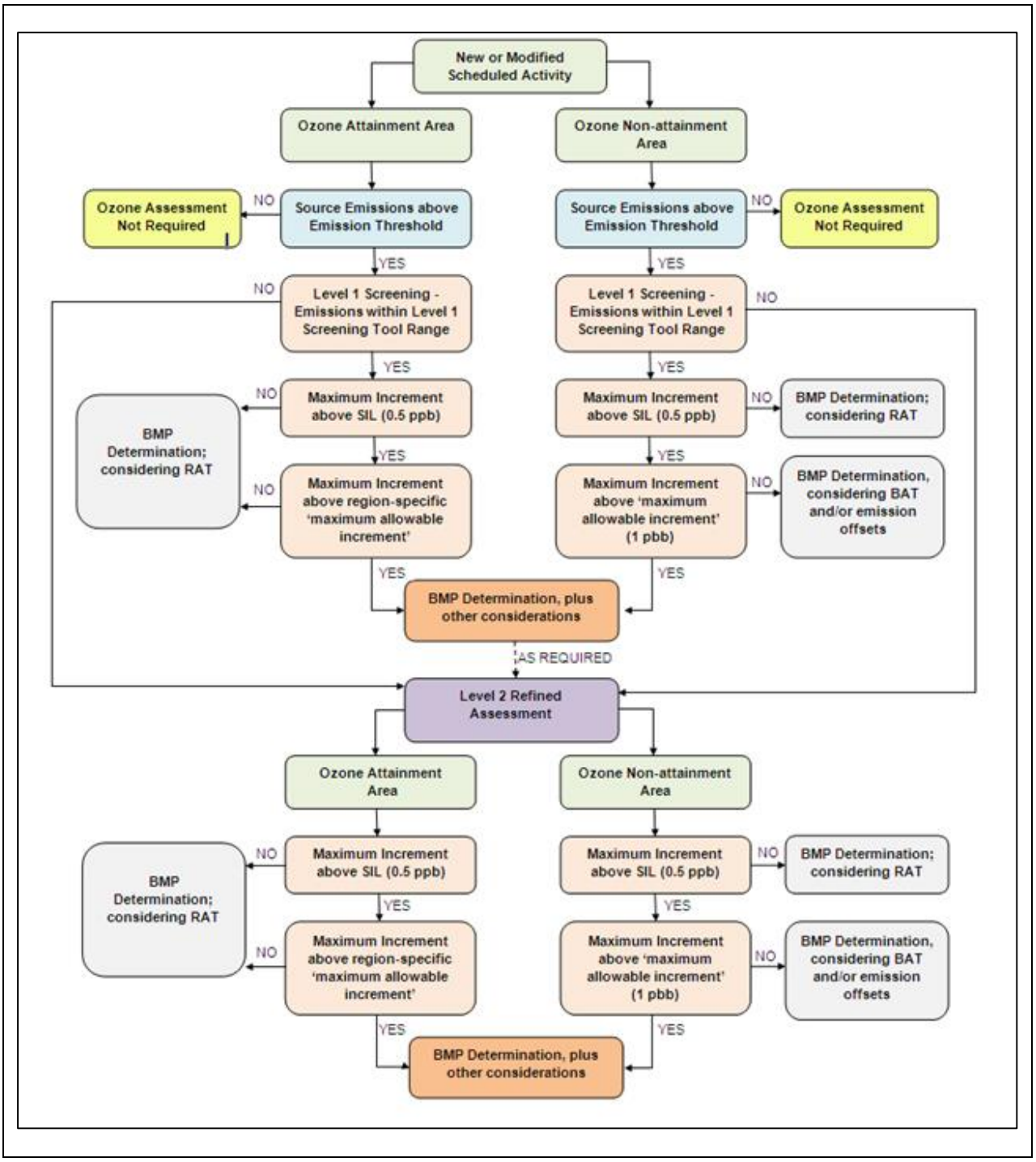


Figure 12-1: Tiered procedure for ozone assessment in NSW

APPENDIX 2
SPECIATION PROFILES FOR VOC EMISSIONS

VOC speciation source-profile cross references

Source ID	Source Description	Profile	Profile Description
AIRBORNE_L	Airborne Landing	5565	Aircraft Landing/Takeoff (LTO) - Commercial
AIRBORNE_T	Airborne Takeoff	5565	Aircraft Landing/Takeoff (LTO) - Commercial
FIRE	Training Fire	0122	Bar Screen Waste Incinerator
GATEAPU	APUs at the Gate	5565	Aircraft Landing/Takeoff (LTO) - Commercial
GATEGSE	GSE at the Gate	EXHDS[a]	Diesel Vehicle Exhaust
PARKINGE00	Parking Facilities - Ethanol free (E0) Petrol	EVE00[a]	Petrol Vehicle - Evaporative emission - E0 ethanol petrol
PARKINGE10	Parking Facilities - E10 Ethanol Petrol	EVE10[a]	Petrol Vehicle - Evaporative emission - E10 ethanol petrol
ROADDSL	Roadway Sources - Diesel	EXHDS[a]	Diesel Vehicle Exhaust
ROADE00EV	Roadway Sources - Ethanol free (E0) Petrol Evap	EVE00[a]	Petrol Vehicle - Evaporative emission - E0 ethanol petrol
ROADE00EX	Roadway Sources - Ethanol free (E0) Petrol Exhaust	EXE00[a]	Petrol Vehicle Exhaust - E0 ethanol petrol
ROADE10EV	Roadway Sources - E10 Ethanol Petrol Evap	EVE10[a]	Petrol Vehicle - Evaporative emission - E10 ethanol petrol
ROADE10EX	Roadway Sources - E10 Ethanol Petrol Exhaust	EXE10[a]	Petrol Vehicle Exhaust - E10 ethanol petrol
RUNWAY_LAN	Runway Landing	5565	Aircraft Landing/Takeoff (LTO) - Commercial
RUNWAY_TAK	Runway Takeoff	5565	Aircraft Landing/Takeoff (LTO) - Commercial
TAXIPATH	Taxipath	5565	Aircraft Landing/Takeoff (LTO) - Commercial
STAT_001	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_002	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_003	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_004	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_005	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_006	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_007	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_008	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_009	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_010	Boiler	0003	External Combustion Boiler - Natural Gas

STAT_011	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_012	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_013	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_014	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_015	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_016	Boiler	0003	External Combustion Boiler - Natural Gas
STAT_017	Engine testing	5565	Aircraft Landing/Takeoff (LTO) - Commercial
STAT_018	Fuel_D_Ac_Main	0297	Fixed Roof Tank - Crude Oil Refinery
STAT_019	Fuel_D_ARRF	0297	Fixed Roof Tank - Crude Oil Refinery
STAT_020	Fuel_D_Fuel_Farm	0297	Fixed Roof Tank - Crude Oil Refinery
STAT_021	Fuel_D_Refueler	0297	Fixed Roof Tank - Crude Oil Refinery
STAT_022	Fuel_JF_ARRF	0100	Fixed Roof Tank - Commercial Jet Fuel (Jet A)
STAT_023	Fuel_JF_Fuel_Farm	0100	Fixed Roof Tank - Commercial Jet Fuel (Jet A)
STAT_024	Fuel_P_Ac_Main	1190	Gasoline Marketed - Summer Blend - 1984
STAT_025	Fuel_P_Fuel_Farm	1190	Gasoline Marketed - Summer Blend - 1984
STAT_026	Fuel_P_Refueler	1190	Gasoline Marketed - Summer Blend - 1984
STAT_027	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_028	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_029	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_030	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_031	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_032	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_033	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_034	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_035	Generator	0009	Emergency Generator: Distillate Oil (Diesel)
STAT_036	Paint and solvent	1003	Surface Coating/Painting: Solvent Base

a) On-road mobile profiles are derived from the technical report "Air Emissions Inventory for the Greater Metropolitan Region in New South Wales, 2008 Calendar Year, On-Road Mobile Emissions: Results" http://www.epa.nsw.gov.au/resources/air/120256AEITR7OnRoadMobile.pdf

VOC speciation profiles for CB4 chemical mechanism (in moles CB4 species per gram TOG)

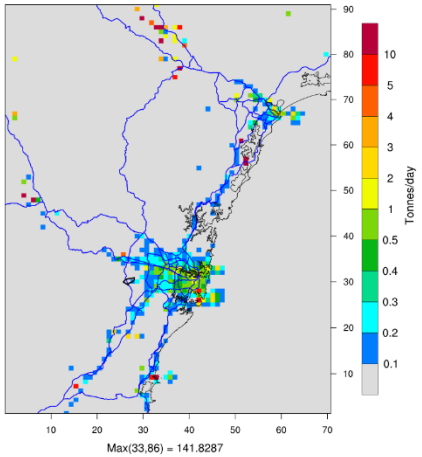
Profiles	ALD2	ETH	ETOH	FORM	ISOP	MEOH	NVOL	OLE	PAR	TOL	UNK	UNR	XYL
0003	-	-	-	0.0027	-	-	-	-	0.0202	0.0002	-	0.0385	-
0009	-	0.0102	-	-	-	-	-	0.0091	0.0147	-	-	0.0180	-
0100	-	-	-	-	-	-	-	-	0.0704	-	-	-	-
0122	-	0.0031	-	-	-	-	-	0.0001	0.0020	-	-	0.0560	-
0297	-	-	-	-	-	-	-	-	0.0535	0.0002	-	0.0141	-
1003	0.0000	-	-	-	-	-	-	0.0000	0.0313	0.0042	-	0.0017	0.0007
1190	0.0009	0.0000	0.0000	0.0001	0.0000	0.0000	-	0.0003	0.0255	0.0025	-	0.0024	0.0032
5565	0.0035	0.0055	-	0.0047	-	0.0006	-	0.0030	0.0262	0.0002	-	0.0035	0.0003
EVE00	0.0036	-	-	0.0005	0.0000	-	-	0.0005	0.0567	0.0003	-	0.0009	0.0002
EVE10	0.0037	-	0.0007	0.0005	0.0000	-	-	0.0005	0.0555	0.0002	-	0.0008	0.0001
EXE00	0.0009	0.0037	-	0.0007	0.0000	0.0000	0.0000	0.0018	0.0256	0.0012	-	0.0128	0.0012
EXE10	0.0010	0.0037	0.0005	0.0008	0.0000	0.0001	0.0000	0.0018	0.0238	0.0012	-	0.0126	0.0012
EXHDS	0.0017	0.0025	-	0.0035	0.0000	0.0004	0.0003	0.0010	0.0285	0.0003	0.0000	0.0125	0.0007

APPENDIX 3
SPATIAL ALLOCATION OF EMISSIONS

2030

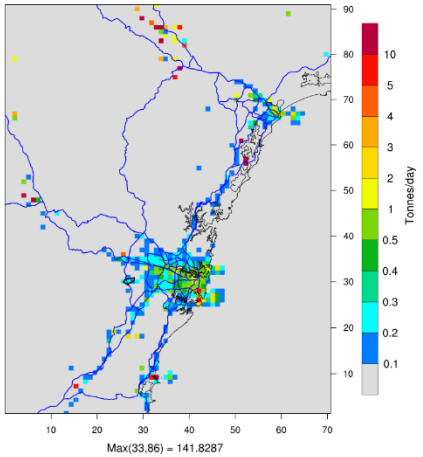
2030 Base Case

Average Day NOx Emissions (tonnes/day)



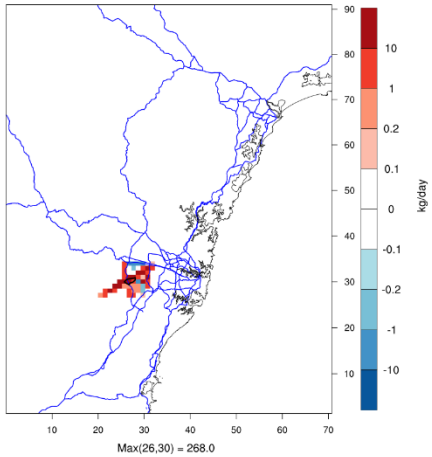
2030 Airport Case

Average Day NOx Emissions (tonnes/day)



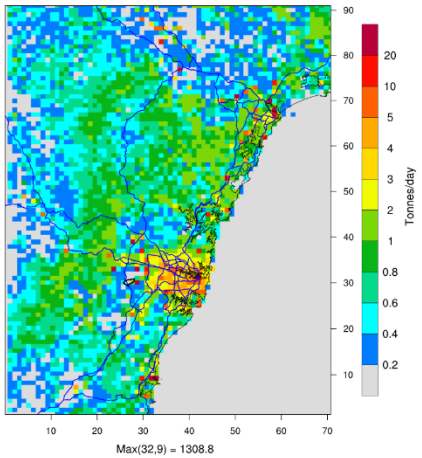
2030 Airport minus 2030 Base Case

Average NOX Emissions (Kg/day)



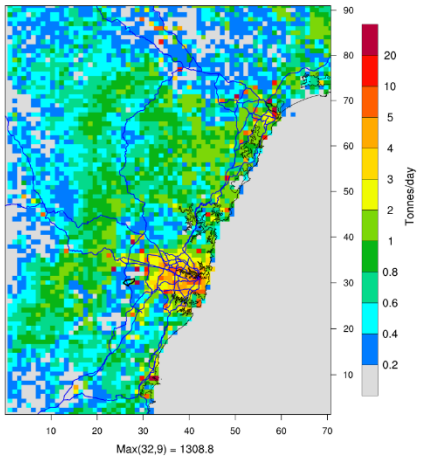
2030 Base Case

Average Day VOC Emissions (tonnes/day)



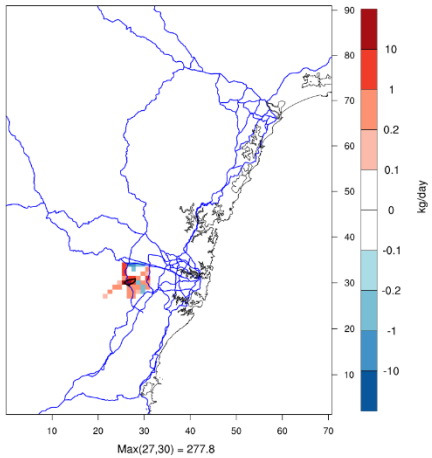
2030 Airport Case

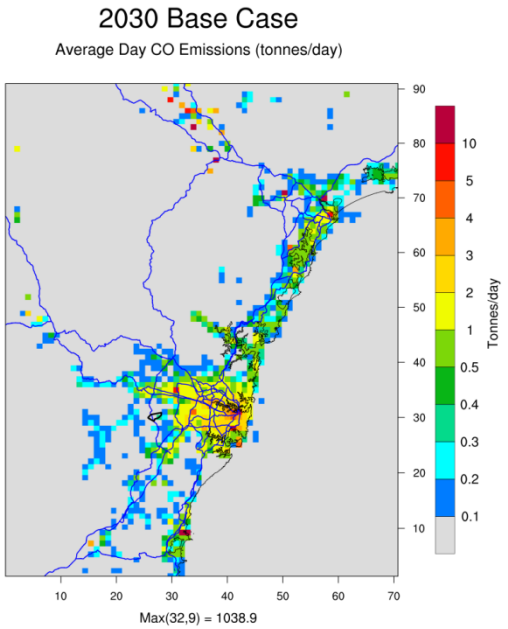
Average Day VOC Emissions (tonnes/day)

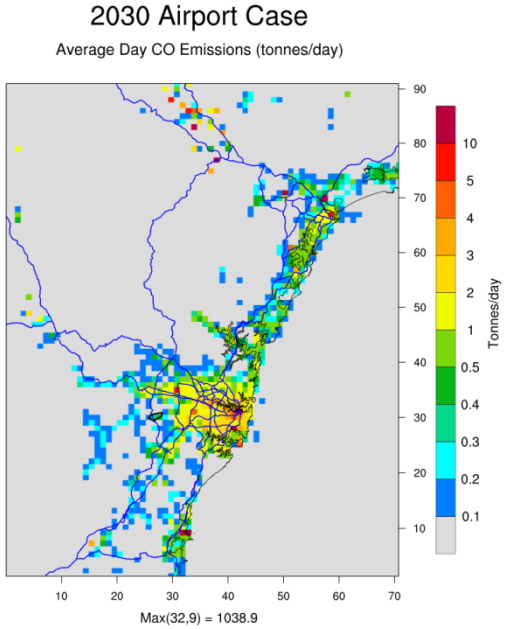


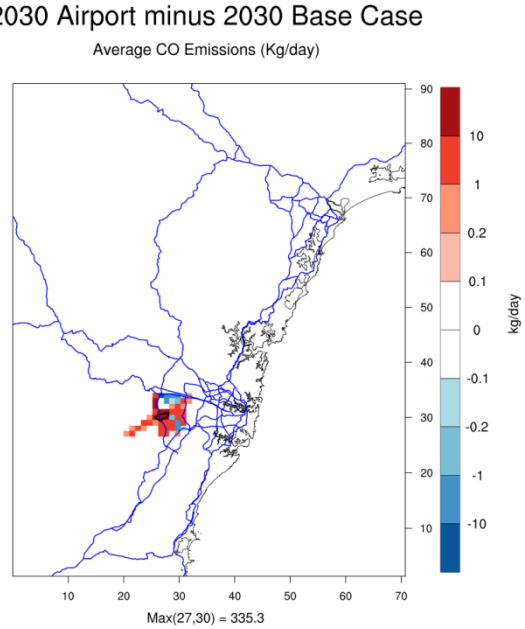
2030 Airport minus 2030 Base Case

Average VOC Emissions (Kg/day)




2030 Base Case
Average Day CO Emissions (tonnes/day)
Tonnes/day
10
5
4
3
2
1
0.5
0.4
0.3
0.2
0.1
Max(32,9) = 1038.9

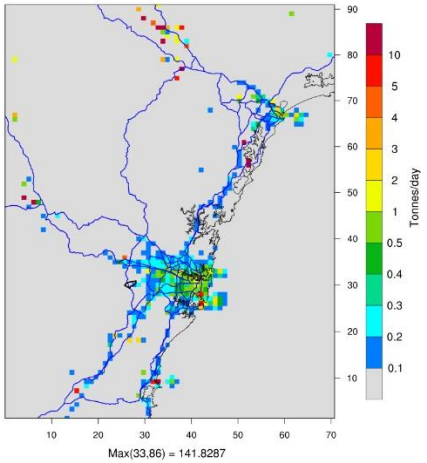

2030 Airport Case
Average Day CO Emissions (tonnes/day)
Tonnes/day
10
5
4
3
2
1
0.5
0.4
0.3
0.2
0.1
Max(32,9) = 1038.9


2030 Airport minus 2030 Base Case
Average CO Emissions (Kg/day)
kg/day
10
1
0.2
0.1
0
-0.1
-0.2
-1
-10
Max(27,30) = 335.3

2063

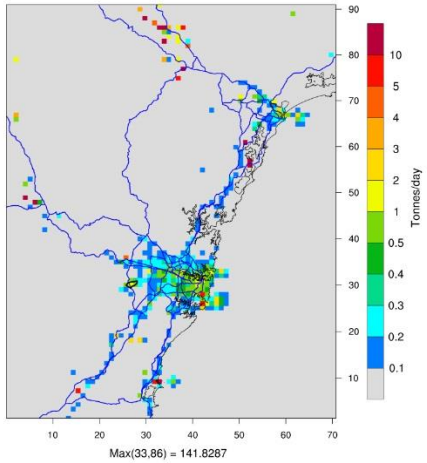
2030 Base Case

Average Day NOx Emissions (tonnes/day)



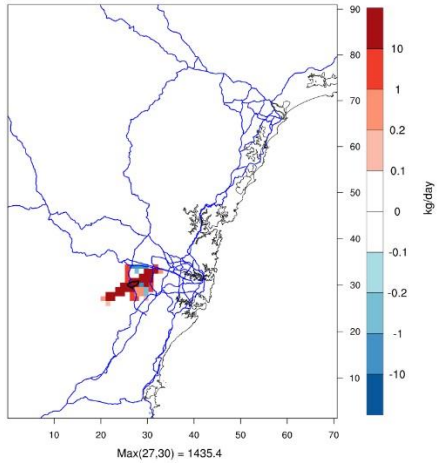
2063 Airport Case

Average Day NOx Emissions (tonnes/day)



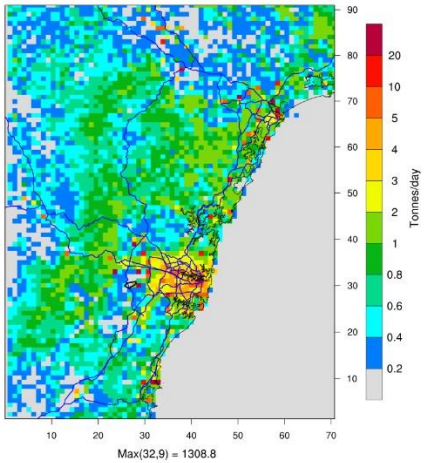
2063 Airport minus 2030 Base Case

Average NOX Emissions (Kg/day)



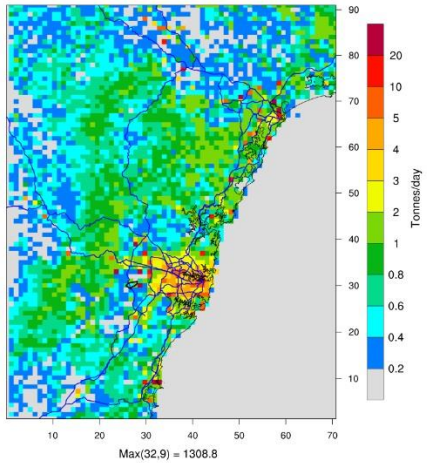
2030 Base Case

Average Day VOC Emissions (tonnes/day)



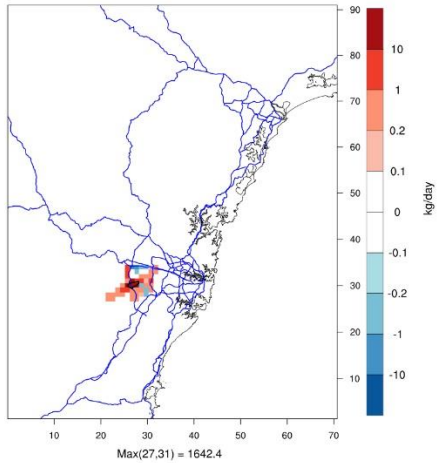
2063 Airport Case

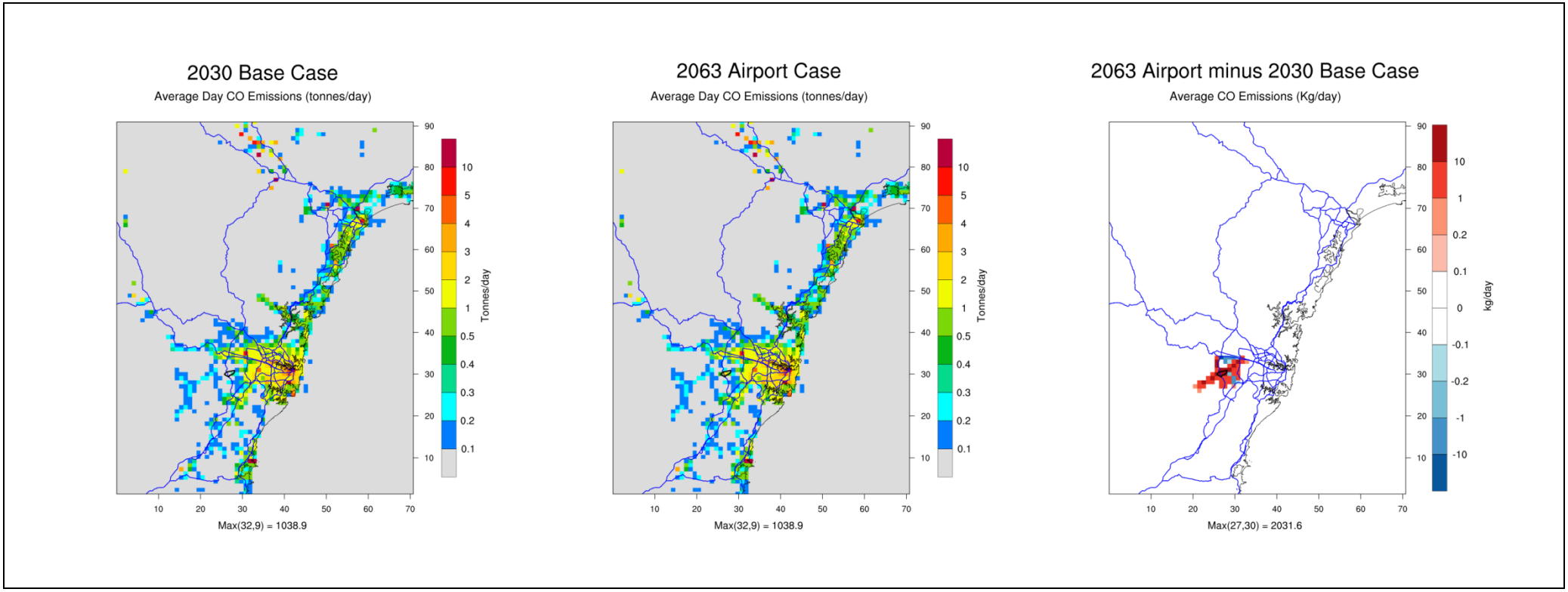
Average Day VOC Emissions (tonnes/day)



2063 Airport minus 2030 Base Case

Average VOC Emissions (Kg/day)




2030 Base Case
Average Day CO Emissions (tonnes/day)
Tonnes/day
10
5
4
3
2
1
0.5
0.4
0.3
0.2
0.1
Max(32,9) = 1038.9
2063 Airport Case
Average Day CO Emissions (tonnes/day)
Tonnes/day
Max(32,9) = 1038.9
2063 Airport minus 2030 Base Case
Average CO Emissions (Kg/day)
kg/day
10
1
0.2
0.1
0
-0.1
-0.2
-1
-10
Max(27,30) = 2031.6

VOLUME 4

Appendix G
Community health

Pacific Environment Limited

Consulting • Technologies • Monitoring • Toxicology



Report

Western Sydney Airport EIS - Health Risk Assessment

GHD Pty Ltd

September, 2015

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EXECUTIVE SUMMARY

A health risk assessment (HRA) has been undertaken to assess the potential risks associated with air and noise emissions and potential surface and groundwater contamination that may arise from the construction and operation of the proposed Western Sydney Airport at Badgerys Creek (the airport).

While the EIS Guidelines (EPBC 2014/7391) do not specifically require the conduct of a health study, they require that the EIS include assessment in relation to the principles of ecologically sustainable development, which include the principle of inter-generational equity - "*that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations*". The guidelines also require the EIS to consider impacts on the environment, which includes, amongst other things, impacts on people and communities.

Health is defined by the World Health Organization (WHO) as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 1948). Well-being is broadly described as an individual's self-assessment of their state of happiness, healthiness and prosperity. It relates to the quality of life and one's ability to enjoy it. There are many social and economic factors that influence well-being: including (enHealth 2012, NHC 2004):

- Social and cultural factors (e.g. social support, participation, access to cultural resources).
- Economic factors (e.g. income levels, access to employment).
- Environmental factors (e.g. land use, air quality).
- Population-based services (e.g. health and disability services, leisure services).
- Individual/behavioural factors (e.g. physical activity, smoking).
- Biological factors (e.g. biological age).

While the focus of this study is on the environmental factors and changes that might occur as a result of airport development, and the effects this may have on well-being, the social, cultural, economic and other environmental factors have also been analysed and documented in other parts of this EIS.

A HRA is an analysis that uses information about pollutants to estimate a theoretical level of risk for people who might be exposed to defined levels of these pollutants. The information on the pollutants comes from other technical papers that have been prepared for the Western Sydney Airport EIS, scientific studies and results if ambient monitoring and modelling. Where relevant, the results of international studies have been used to supplement the local evidence base of potential harmful effect on humans. The HRA is a document that assembles and synthesizes scientific information to determine whether a potential hazard exists and/or the extent of possible risk to human health.

The risk assessment process detailed in the enHealth HRA Guidelines, comprises five components which have been followed in the HRA:

1. **Issue Identification** – Identifies issues that can be assessed through a risk assessment and assists in establishing a context for the risk assessment.
2. **Hazard Assessment** – Identifies hazards and health endpoints associated with exposure to hazardous agents and provides a review of the current understanding of the toxicity and risk relationship of the exposure of humans to the hazards.
3. **Exposure Assessment** – This task identifies the groups of people who may be exposed to hazardous agents and quantifies the exposure concentrations.
4. **Risk Characterisation** – This task provides the qualitative evaluation of potential risks to human health. The characterisation of risk is based on the review of concentration response relationship and the assessment of the magnitude of exposure.

5. **Uncertainty Assessment** – identifies potential sources of uncertainty and qualitative discussion of the magnitude of uncertainty and expected effects on risk estimates.

Consultation was also conducted with NSW Health and local area health services and additional advice and requirements have also been incorporated into this report.

Three scenarios have been considered for the air quality and noise HRA:

1. Construction
2. Airport operations in 2030
3. Longer term airport operations in 2063.

Where data was available the airport operations for 2050 were also assessed for noise.

Air Quality

The HRA has examined the increase in risk resulting from air pollution generated by the construction and operation of the proposed airport. The health effects that have been considered are increases in both long-term and short-term mortality, increases in hospital admissions and increases in emergency department attendances for asthma. Emissions from construction activities, aircraft operations as well as on site and local road traffic have been included in the modelling. The pollutants considered were particulate matter, NO_2, SO_2, CO, benzene and diesel. Predictions of changes in local air quality were derived from the local air quality assessment (Pacific Environment 2015) which is included elsewhere in the EIS. For regional air quality, the health risk arising from changes to ozone levels was assessed. Changes in ozone levels were taken from the regional air quality assessment (Ramboll Environ 2015).

Mitigation measures to reduce NO_2 and PM are included in the local air quality technical report and when implemented, would have an effect of reducing PM and NO_2 emissions generated. It is also worth noting that particularly for the 2063 scenario assessment, the modelling assumed no future reductions in emissions technology either for aircraft or for vehicular traffic more generally. On the basis that emissions reduction has occurred over the past several decades and is expected to continue to occur in the future, the results of the HRA are likely to overestimate the actual level of risk that would be realised.

The predicted concentrations of all pollutants considered in this HRA are below the relevant NEPM standards. However, epidemiological studies into the health effects of air pollution have shown that there is no threshold for health effects associated with exposure to these pollutants. which means that there is a risk of health effects occurring below current air quality standards.

The highest risk during construction is predicted to be associated with PM_{10} during construction of aviation infrastructure. The highest predicted risk could result in an additional one additional death per hundred years from all causes (non-accidental). The most affected areas would be Luddenham, Bringelly, Kemps Creek and Badgerys Creek. As construction will only occur for a period of less than 10 years, the actual impact on the local community will be lower as the period of exposure is less.

Risks associated with air quality impacts from airport operation have been assessed for two scenarios:

- 2030 – the proposed Stage 1 airport development; and
- 2063 – a potential longer-term airport development scenario.

2030 operations

The results of the HRA show that the highest risk associated with airport operations relates to NO_2 concentrations. The highest risk would arise from a predicted increase in long-term mortality of an additional 5 deaths in 10 years. Increases in short-term mortality and hospital admissions are lower than

that for long-term mortality. The most affected areas are likely to be Luddenham, Bringelly, Kemps Creek, Mulgoa, Wallacia and Rossmore. It should be noted that these health predictions have been made based on the absence of mitigation measures, which will reduce the concentration of emissions generated and therefore also, the predicted health risks.

International agencies usually consider increases in risk of between 1 in one million and in in 100,000 as being acceptable. The predicted increase in mortality from NO_2 emissions exceeds this range. The predicted risks from PM_{10} and $PM_{2.5}$ are at the high end of the acceptable risk range established by international agencies but lower than that predicted for NO_2. The risks from all other pollutants, SO_2, CO, benzene and diesel articles are low and within the acceptable risk range.

2063 operations

For 2063, the levels of emissions are generally higher than in 2030 and the number of health outcomes attributable to the pollutants arising from airport operations is also higher. The highest predicted risk is associated with NO_2. The most affected areas are Luddenham, Bringelly, Kemps Creek, Mulgoa, Wallacia and Rossmore. The health risks for PM_{10} and $PM_{2.5}$ are at the higher end of the acceptable risk range established by international agencies. For all other pollutants the risk levels are all within the range established by international agencies.

The modelling used in the HRA has not considered the reductions that may occur due to the implementation of mitigation measures. The implementation of such measures will lead to reduction in ambient levels of the pollutants considered in this HRA and the associated health risk. In particular, it is assumed no future reductions in emissions technology either for aircraft or for vehicular traffic more generally. On the basis that emissions reduction has occurred over the past several decades and is expected to continue to occur in the future, the results of the HRA are likely to overestimate the actual level of risk that would be realised. Mitigation measures to reduce NO_2 and PM are included in the local air quality technical reports.

Aircraft and Ground Operations Noise

The HRA for noise has assessed three health outcomes – sleep disturbance (as awakenings), increases in ischaemic heart disease and impacts on cognitive development and learning in children and has been conducted for noise impacts from aircraft and ground operations noise sources. The results for the HRA show that ground-based operations may lead to a small increase in sleep disturbance (assessed as awakenings), increases in risk of cardiovascular disease and potential delays in childhood learning and cognitive development. Implementation of mitigation measures outlined in the noise technical reports will lead to reductions in these risks. These effects are predicted for suburbs close to the airport site, in particular Luddenham. The predicted impact of aircraft noise is less than for ground operations.

Based on the results of the noise assessment, the risk posed to the health of the exposed communities is generally low. No increase in cardiovascular outcomes is likely from aircraft noise as the predicted night noise levels are below the threshold for adverse effects. However, ground operations noise is predicted to be above the threshold value of 55 dB Lnight and may lead to a 10% increase in myocardial infarctions in Luddenham in 2063 if not mitigated.

A significant increase in EEG awakenings is predicted especially in Luddenham. In 2030, it is predicted that there would be 190 additional EEG awakenings per person per year and an additional 400 EEG awakenings per person per year with ground-based noise in 2063. For full awakenings, the number is lower but still highest in Luddenham. There is a greater predicted impact from ground- operations noise than aircraft noise. Mitigation measures in the noise assessment reports should be implemented and would reduce this impact.

Impacts on children's learning and cognitive development are predicted to be within acceptable risk levels for most locations for aircraft noise. The impact of ground operations noise is more substantial. In Luddenham, increases of up to 3 dB above the WHO guideline are predicted for outdoor noise levels in 2063. Mitigation measures should be implemented at these locations to reduce this risk to within acceptable levels. For the indoor assessment, assuming a 10 dB attenuation from predicted outdoor levels, the hazard quotients above 1 correspond to an increase in noise levels above the guideline value of between 19 and 23 dB in 2030 and 2063 respectively at Luddenham indicating a significant increase in noise levels. The risk of sleep disturbance and impacts on cognitive development are predicted to be higher for 2063 than 2030. Mitigation measures should be implemented to reduce this risk to within acceptable levels.

It should be noted that the noise HRA includes comparison of the runway operating mode options outlined in the EIS. As with the noise assessment results, the HRA will be considered in the process to finalise the flight paths and preferred operating mode.

The EIS noise assessment reports include mitigation and management measures which will reduce the potential impacts which have been assessed by the HRA. In particular, a noise amelioration strategy should be developed that considers both aircraft and ground operations in accordance with the requirements of AS202.

Surface and groundwater

There are 42 registered groundwater bores within a five kilometre radius of the centre of the site. Twelve of these bores are registered as being used for domestic, stock, industrial, farming and irrigation purposes. The depth of registered extraction bores indicates that the majority of groundwater users extract water from the Bringelly Shale and Hawkesbury Sandstone aquifers. The salinity in the Alluvial and Bringelly Shale aquifers is reported to be >1,000 mg/l (based on 1995-1998 data) and thus is considered unsuitable for potable uses.

The site has historically been used for a wide range of agricultural, industrial, commercial and rural-residential activities which have the potential to generate a range of contaminants in soil and groundwater. There is likely to be considerable overlap of those contaminants associated with historical site activities and the potential contaminants which may be associated with future construction and operation of the proposed airport. It is therefore important that baseline groundwater data are collected including all potential contaminants that may be already present, to enable identification of the current baseline conditions and from which to monitor future performance of the airport.

The contaminating activities which may occur during construction and operation of the airport may also have the potential to result in surface water contamination. Aircraft movements at the airport site during operation may result in increased deposition of particulates in surrounding waterways. Based on the results of the operational air quality modelling, the potential for deposition of particulates particularly at locations associated with potable water supply is very low with the maximum annual concentration of PM_{10} at Warragamba predicted to be 0.02 $\mu g/m^3$.

The commencement of aircraft operations at the proposed Western Sydney Airport also increases the potential for fuel jettisoning to occur on rare occasions. It is understood that the majority of fuel jettisoning instances for commercial aircraft occur in emergency conditions where an unscheduled landing is required. In 2014, there were only 10 reported instances nationwide of civilian aircraft fuel jettisoning out of 698,856 domestic and 31,345 international flights. Where fuel jettisoning is considered necessary, the pilot is required to take any reasonable precautions to ensure the safety of people and property on the ground and in the air, and where possible, undertake fuel jettisoning at a minimum altitude of 6,000 ft. Most fuel is considered to evaporate within 100 metres with only a small amount of fuel, if any, likely to reach ground level. There are no recorded instances in Australia of fuel reaching the ground after a fuel jettisoning incident.

Construction of the proposed airport also presents the potential for risks for contamination of groundwater and surface water. However these risks are common for other major infrastructure projects where standard construction measures are typically effective. Implementation of mitigation in the construction environmental management plans will minimise these risks.

The outcomes of the risk assessment suggest that it would be beneficial to collect additional data to inform the future management of potential risks to groundwater and surface water receptors. Consideration should be given to a pre-construction and post construction/operation monitoring program to test the quality of local tank water and monitor any changes to the quality of the water over time. This would enable informed decisions to be made about implementation of any mitigation measures in a timely manner.

GLOSSARY

µg/m3	Microgram per Cubic Metre
ACHAPS	Australian Child Health and Air Pollution Study
ADWG	Australian Drinking Water Guideline
AFFF	Aqueous Film Forming Foam
ANZECC	Australia New Zealand Environment Conservation Council
Airport	The proposed Western Sydney Airport
APHEA2	Air Pollution and Health a European Approach
APU	Auxiliary Power Unit
ASC NEPM	National Environment Protection (Assessment of Site Contamination) Measure
AWQG	Australian Water Quality Guideline
CAA	Civil Aviation Authority UK
CHETRE	Centre for Health Equity Training Research and Evaluation
CO	Carbon Monoxide
CoPC	Chemical of Potential Concern
COPD	Chronic Obstructive Pulmonary Disease
dB	Decibel
DEC	NSW Department of Environmental Conservation
DLWC	NSW Department of Land and Water Conservation
EC	European Commission
EC	Electrical Conductivity
ECG	Electrocardiography
EEG	Electroencephalography
EIS	Environmental Impact Statement
EMG	Electromyography
EOG	Electroculography
EPA	Environment Protection Authority

EPHC	Environment Protection and Heritage Council
EV	Environmental Value
FCV	Forced Vital Capacity
FEV1	Forced Expiratory Volume (in one second)
ft	Feet
GIL	Groundwater Investigation Level
GMRRW	Guideline for Managing Risks in Recreational Water
GSE	Ground Support Equipment
H2H	Head to Head
HIA	Health Impact Assessment
HQ	Hazard Quotient
HRA	Health Risk Assessment
HYENA	Hypertension and Exposure to Noise near Airports
IQ	Interquartile Range
km	Kilometre
L	Litres
L/day	Litres per Day
LAeq	Day-Time Aircraft Noise
Lday	Day-Time Noise Level Averaged between 9am-3pm
Lden	Day-Evening-Night Noise Level
Lnight	Aircraft noise at night averaged between 11pm and 7am
LOAEL	Lowest Observed Adverse Effects Level
m bgl	Metres Below Ground Level
MBA	Methylene Blue Activated Substances
min	Minutes
ml	Millilitres
NEPC	National Environment Protection Council
NEPM	National Environmental Protection Measure

NHMRC	National Health and Medical Research Council
NO	Nitric Oxide
NO2	Nitrogen Dioxide
NOEL	No Observed Effects Level
NREM	Non-Rapid Eye Movement
NSW	New South Wales
NSW GQPP	New South Wales Groundwater Quality Protection Policy
NWQMS	National Water Quality Management System
OEHHA	Office of Environmental Health Hazard Assessment
OR	Odds Ratio
PAH	Polycyclic Aromatic Hydrocarbons
PFC	Perfluorinated Compounds
PM	Particulate Matter
PM10	Particulate Matter (10 micrometre diameter or less)
PM2.5	Particulate Matter (2.5 micrometre diameter or less)
ppb	Parts per Billion
ppm	Parts per Million
RANCH	Road Traffic and Aircraft Noise and Children's Cognition and Health
REM	Rapid Eye Movement
REVIHAAP	Review of Evidence of Health Aspects of Air Pollution
RIVM	National Institute for Public Health and the Environment
SCEW	Standing Council on Environment and Water
SEIFA	Socio-Economic Indexes for Areas
SEL	Sound Exposure Level
SES	Socioeconomic Status
SO2	Sulphur Dioxide
TPH	Total Petroleum Hydrocarbon
UK	United Kingdom

URF	Unit Risk Factor
USEPA	United States Environment Protection Agency
WHO	World Health Organisation
WQO	Water Quality Objective

CONTENTS

Contents xiii
1 INTRODUCTION 18
1.1 Background 18
1.2 Objectives 19
2 OVERVIEW OF THE HEALTH RISK ASSESSMENT PROCESS 20
2.1 Approach to Health Risk Assessment 20
3 WESTERN SYDNEY AIRPORT SITE 22
4 POPULATION AND HEALTH PROFILE 24
5 HEALTH RISK ASSESSMENT – AIR QUALITY 28
5.1 Introduction 28
5.2 PM_{10} and $PM_{2.5}$ 28
5.2.1 Literature Review of the Health Effects of PM_{10} and $PM_{2.5}$ 28
5.2.2 Exposure Assessment 30
5.2.3 Risk Characterisation 36
5.3 Nitrogen Dioxide (NO_2) 52
5.3.1 Literature Review of the Health Effects of NO_2 52
5.3.2 Risk Characterisation 55
5.4 Sulfur Dioxide (SO_2) 64
5.4.1 Literature Review of the Health Effects of SO_2 64
5.4.2 Exposure Assessment 66
5.5 Health Effects of Carbon Monoxide (CO) 69
5.5.1 Literature Review of the Health Effects of CO 69
5.5.2 Exposure Assessment 70
5.6 Risk Characterisation 70
5.7 Health Effects of Air Toxics 72
5.7.1 Literature Review of the Health Effects of Benzene 72
5.7.2 Exposure Assessment 73
5.7.3 Risk Characterisation Benzene 73
5.8 Diesel 73
5.8.1 Literature Review of the Health Effects of Diesel Emissions 74
5.8.2 Exposure Assessment 74
5.8.3 Risk Characterisation 75
5.9 Regional Air Quality – Ozone 76
5.9.1 Literature Review of the Health Effects of Ozone 76
5.9.2 Exposure Assessment 78
5.9.3 Risk Characterisation 79
5.10 Summary 81
6 HEALTH RISK ASSESSMENT – NOISE 83
6.1 Literature Review on Health Effects related to Noise 83
6.1.1 Annoyance 83
6.1.2 Sleep Disturbance 84
6.1.3 Cardiovascular Disease 86
6.1.4 Children's Learning and Cognitive Development 88
6.1.5 Psychological health 90
6.2 Exposure Assessment 91
6.3 Risk Characterisation 103
6.3.1 Awakenings 106
6.3.2 Cardiovascular Effects 117
6.3.3 Learning and Cognitive Development in Children 117
6.4 Summary 124

7 HEALTH RISK ASSESSMENT – GROUNDWATER AND SURFACE WATER 126
7.1 Existing Groundwater Conditions 126
7.1.1 Local Hydrogeology 126
7.1.2 Use of Groundwater in Study Area 126
7.1.3 Groundwater Environmental Values 126
7.1.4 Source of Potential Groundwater Contamination 127
7.1.5 Hazard Identification 129
7.1.6 Identification of Contaminants of Potential Concern 131
7.1.7 Potential Exposure Pathways 132
7.1.8 Risk Characterisation 134
7.2 Existing Surface Water Conditions 135
7.2.1 Identification of Existing Water Bodies 135
7.2.2 Use of Surface Water in the Study Area 135
7.2.3 Surface Water Environmental Values 136
7.2.4 Sources of Potential Surface Water Contamination 137
7.2.5 Hazard Identification 137
7.2.6 Identification of Contaminants of Potential Concern 138
7.2.7 Potential Exposure Pathways 139
7.2.8 Risk Characterisation 140
7.3 Conclusions and Recommended Mitigation Measures 142
7.4 Limitations of the Groundwater and Surface Water Assessment 143
8 CONCLUSIONS 144
9 REFERENCES 147
APPENDIX A DATA TABLES A-1

LIST OF TABLES

Table 1: Demographic Profile for Suburbs included in HRA 25

Table 2: Baseline Health Status Liverpool LGA 27

Table 3 Exposure Response Functions for PM_{10} Selected Health Outcomes (Taken from EPHC, 2011; HEI, 2009) 37

Table 4: Exposure Response Functions for $PM_{2.5}$ Selected Health Outcomes Taken from EPHC, 2011; HEI, 2009) 38

Table 5: Predicted attributable health outcomes due to PM_{10} from Stage 1 operation (2030) 40

Table 6: Predicted attributable health outcomes due to $PM_{2.5}$ from Stage 1 operation (2030) 42

Table 7: Predicted attributable health outcomes due to PM_{10} from longer term airport operation (2063) 44

Table 8: Predicted attributable health outcomes due to $PM_{2.5}$ from longer term airport operation in (2063) 45

Table 9: Predicted attributable health outcomes due to PM_{10} from construction bulk earthworks 47

Table 10: Predicted attributable health outcomes due to PM_{10} from construction of aviation infrastructure 48

Table 11: Predicted attributable health outcomes due to $PM_{2.5}$ from construction bulk earthworks 49

Table 12: Predicted attributable health outcomes due to $PM_{2.5}$ from construction of aviation infrastructure 50

Table 13: Exposure Response Functions for NO_2 Selected Health Outcomes (EPHC, 2005; Cesaroni et al. 2013) 56

Table 14: Predicted attributable health outcomes due to NO_2 from 2030 operations, including traffic 57

Table 15: Predicted attributable health outcomes due to NO_2 from 2063 operations, including traffic 58

Table 16: Predicted attributable health outcomes due to NO_2 from 2030 operations excluding traffic 60

Table 17: Predicted attributable health outcomes due to NO_2 from 2063 operations excluding traffic 62

Table 18: Exposure Response Functions for SO_2 67

Table 19: Predicted attributable health outcomes due to SO_2 from Stage 1 operation (2030) 68

Table 20: Exposure response functions for CO selected health outcomes 71

Table 21: Predicted Number of Attributable Cases due to Airport Operations in 2030 72

Table 22: Annual Average Diesel PM Concentrations 75

Table 23: Predicted Increase in Cancer Risk attributable to diesel particles 76

Table 24: Maximum 1-hour ozone concentrations for Sydney region 79

Table 25: Exposure Response Functions 80

Table 26: Attributable Risk from Ozone on Peak Ozone Days 80

Table 27: Stages of Sleep (taken from Clark and Stansfeld 2012) 85

Table 28: WHO Community Noise Guidelines School Environments (WHO, 1999) 90

Table 29: Representative Sensitive Receptors 92

Table 30: Measured Background Noise Levels around Western Sydney Airport (source Wilkinson-Murray, 2015b) 93

Table 31: Daytime L_{Aeq} values 9am-3pm (dB) – aircraft noise (WHO Guideline 55 dB) 97

Table 32: L_{Night} outside (equivalent to Leq 11pm-7am)– aircraft noise (WHO Guidelines – night 40 dB, interim target of 55 dB) 99

Table 33: Predicted noise levels for day and night from ground operations noise (WHO Guidelines – night 40 dB, interim target 55 dB; daytime 55 dB) 102

Table 34: Effects of Different Levels of Night Noise on Population Health (WHO, 2009). 105

Table 35: Predicted Number of Additional EEG Awakenings Per Person Per Year due to aircraft noise 108

Table 36: Predicted Number of additional EEG Awakenings Per Person Per Year due to Ground Operations Noise 111

Table 37: Predicted Number of Additional Awakenings per person per Year due to Aircraft Noise under each Operating Scenario 113

Table 38: Predicted Number of Full Awakenings Per Person Per Year from Ground Operations 116

Table 39: Hazard Quotients for Learning and Cognitive Development in Children – outside for aircraft noise (WHO Guideline 55dB) 118

Table 40: Hazard Quotients for Learning and Cognitive Development in Children – inside assuming 10 dB attenuation (WHO Guideline 35dB) 120

Table 41: Hazard Quotients for Learning and Cognitive Development in Children – inside for ground-based noise assuming 10 dB attenuation (WHO guideline 35 dB) 123

Table 42: Hazard Quotients for Learning and Cognitive Development in Children – outside (WHO Guideline 55 dB) 124

Table 43: Potentially Contaminating Activities - Current 128

Table 44: Potentially Contaminating Activities – Airport Construction and Operation 129

Table 45: Adopted Groundwater Guidelines 131

Table 46: Groundwater Chemicals of Potential Concern 132

Table 47: Groundwater Exposure Pathway Linkages 133

Table 48: Adopted Surface Water Guidelines 138

Table 49: Surface Water Chemicals of Potential Concern 139

Table 50: Surface Water Exposure Pathway Linkages 140

LIST OF FIGURES

Figure 1: Site Location 23

Figure 2: Predicted Population Growth Liverpool LGA 24

Figure 3: Predicted 24-hour Average PM_{10} Bulk Earthworks 31

Figure 4: Predicted 24-hour average $PM_{2.5}$ Bulk Earthworks 31

Figure 5: 24 Hour Average PM_{10} Aviation Infrastructure 32

Figure 6: 24 hour Average $PM_{2.5}$ Aviation Infrastructure 33

Figure 7: Daily average PM_{10} from operations 2030 34

Figure 8: Daily average $PM_{2.5}$ from operations 2030 34

Figure 9: 24 Hour Average PM_{10} Operations 2063 35

Figure 10: Daily average $PM_{2.5}$ from operations 2063 35

Figure 11: Predicted daily average NO_2 concentrations for 2030 operations 54

Figure 12: Predicted daily average NO_2 concentrations for 2063 operations 54

Figure 13: Predicted daily 24-hour Average SO_2 for operations in 2030 66

Figure 14: Predicted daily maximum 8-hour CO concentrations from Airport Operations in 2030 70

Figure 15: Locations of Sensitive Receptors for Noise HRA 95

Figure 16: Potential Airport Operating Mode Options for WSA (Taken from Wilkinson Murray, 2015) 96

Figure 17: Dose Response Relationships for Aircraft Noise Related Health Effects (Reproduced from WHO, 2009; original source European Commission, 2002). The noise metric used is $L_{night, outside}$. 103

Figure 18: Dose Response Curves for EEG Awakenings due to Aircraft Noise (reproduced from EEA, 2010) 107

1 INTRODUCTION

Pacific Environment Limited (PEL) was engaged by GHD Pty Ltd (GHD) to undertake a health risk assessment (HRA) to assess risks associated with noise, air emissions, and risks to surface water and groundwater resulting from the proposed Western Sydney Airport (the airport). The risk assessment will be incorporated into the environmental impact statement, for the proposed Western Sydney Airport at Badgerys Creek (the airport site).

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, a delegate of the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport

operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Objectives

The EIS Guidelines for the Western Sydney Airport (EPBC 2014/7391) specify the information that must be included in the EIS. In particular, Section 5g lists a range of potential impacts on the environment and specific issues which must be analysed.

Attachment 1 of the EIS Guidelines outlines the objects and principles of the EPBC Act which include "*to promote ecologically sustainable development*". One of the key elements of ecologically sustainable development includes the principle of inter-generational equity which states "*that the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations*".

While not specifically included in the EIS Guidelines, a Health Risk Assessment (HRA) has been undertaken to inform decision makers of the potential for effects on human health. While the other EIS technical studies report impacts in relation to relevant Commonwealth and State criteria, which are often set in order to protect the environment and human health, it is considered that a specific health study is required to further analyse the potential impacts, particularly in relation to a number of recent literature studies linking health effects to aviation activity. Potential health effects may also be linked to different criteria and measures than examined elsewhere in the EIS.

This report provides the results of the HRA for air quality and noise as well as the potential impacts on surface and groundwater. The HRA has been conducted in accordance with the EIS Guidelines and the Australian Government *Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazard* 2012" (enHealth, 2012) as well as publications from other agencies such as the World Health Organisation (WHO).

2 OVERVIEW OF THE HEALTH RISK ASSESSMENT PROCESS

A Health Risk Assessment (HRA) aims to quantify the potential health effects arising from exposure to, in this case, environmental pollution. The information in this report on the pollutants comes from other studies undertaken for the Western Sydney Airport EIS, peer reviewed scientific studies, ambient monitoring and modelling. The HRA is a document that assembles and synthesizes scientific information to determine whether a potential hazard exists, the exposure to the hazard and the resultant risk to human health.

Risk assessments are often conducted by considering possible or theoretical community exposures predicted from air dispersion modelling or using environmental concentrations that have been measured in the potentially affected population. Conservative safety margins are built into a risk assessment analysis to ensure protection of public health. During the risk assessment analysis, the most vulnerable people (e.g. children, the sick and elderly) are carefully considered to make sure that all the risk to these more vulnerable groups is considered.

For air quality risk assessments the key health effects that are considered include increases in mortality and morbidity (eg. Hospital admissions for respiratory disease) which have been associated with exposure to air pollution in population based epidemiological studies. For noise the main health effects that are considered are sleep disturbance, increases in ischaemic heart disease and impacts on children's learning and cognitive development. These outcomes have been considered in this HRA.

The Australian guidance for conducting HRAs is set out in the enHealth Guidelines (2012). For the assessment of health risks from air pollution, the National Health and Medical Research Council (NHMRC) *Approach to Hazard Assessment for Air Quality*, 2006 and the National Environment Protection Council (NEPC) *Methodology for Setting Air Quality Standards in Australia*, 2011 provide detailed frameworks to assess health risks associated with air pollution.

2.1 Approach to Health Risk Assessment

Health is defined by the World Health Organization (WHO) as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO, 1948). Well-being is broadly described as an individual's self-assessment of their state of happiness, healthiness and prosperity. It relates to the quality of life and one's ability to enjoy it. There are many social and economic factors that influence well-being:, including (enHealth 2012, NHC 2004):

- Social and cultural factors (e.g. social support, participation, access to cultural resources).
- Economic factors (e.g. income levels, access to employment).
- Environmental factors (e.g. land use, air quality).
- Population-based services (e.g. health and disability services, leisure services).
- Individual/behavioural factors (e.g. physical activity, smoking).
- Biological factors (e.g. biological age).

While the focus of this study is on the environmental factors and changes that might occur as a result of the proposed airport development, the social, cultural, economic and other environmental factors have also been analysed and documented in other parts of this EIS.

The risk assessment process detailed in the enHealth HRA Guidelines comprises five components as outlined below:

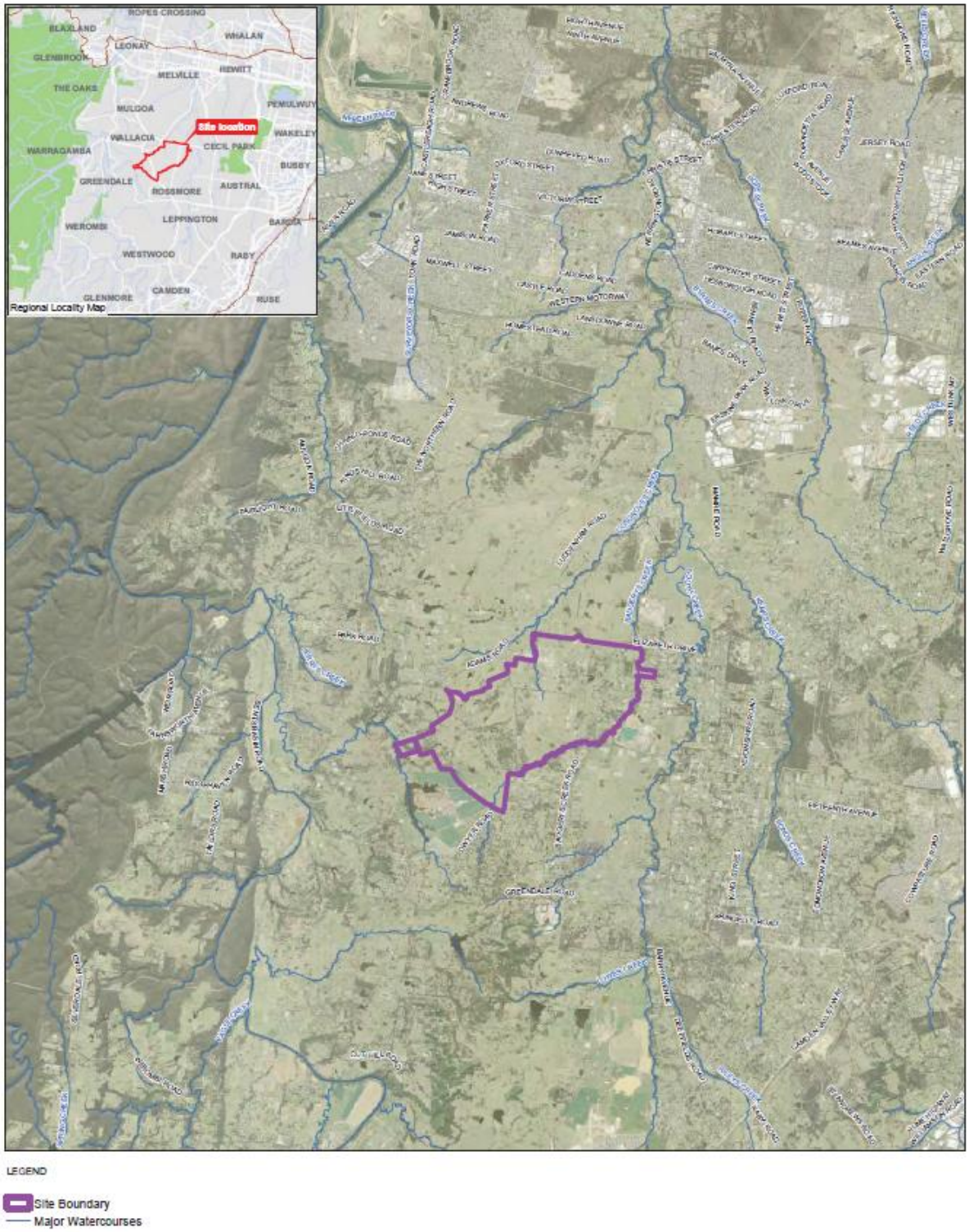
1. **Issue Identification** – Identifies issues that can be assessed through a risk assessment and assists in establishing a context for the risk assessment.
2. **Hazard Assessment** – Identifies hazards and health endpoints associated with exposure to hazardous agents and provides a review of the current understanding of the toxicity and risk relationship of the exposure of humans to the hazards.
3. **Exposure Assessment** – This task identifies the groups of people who may be exposed to hazardous agents and quantifies the exposure concentrations.
4. **Risk Characterisation** – This task provides the qualitative evaluation of potential risks to human health. The characterisation of risk is based on the review of concentration response relationship and the assessment of the magnitude of exposure.
5. **Uncertainty Assessment** – identifies potential sources of uncertainty and qualitative discussion of the magnitude of uncertainty and expected effects on risk estimates.

3 WESTERN SYDNEY AIRPORT SITE

The site for the proposed Western Sydney Airport covers an area of approximately 1,700 hectares located at Badgerys Creek in Western Sydney as shown in **Figure 1.** The site is located around 50 kilometres west of Sydney's Central Business District and 15 to 20 kilometres from major population centres such as Liverpool, Fairfield, Campbelltown and Penrith. The nearest suburbs include Luddenham, Badgerys Creek, Kemps Creek and Bringelly.

The Northern Road transects the western end of the airport site and Elizabeth Drive borders the site to the north. Badgerys Creek flows in a north-easterly direction and forms the south eastern boundary of the airport site. The airport site is located on undulating topography that has been extensively cleared with the exception of stands of remnant vegetation located predominantly along Badgerys Creek and the south western portion of the site.

Figure 1: Site Location



4 POPULATION AND HEALTH PROFILE

The airport site is located within the Liverpool LGA in the south west of Sydney. The Liverpool LGA encompasses a total land area of 305 square kilometres and it borders Fairfield and Penrith cities in the north, Camden Council and Campbelltown City areas in the south, the Wollondilly Shire in the west and Bankstown City in the east.

According to the Liverpool Community Health Profile (SWSLHD, 2014), the population in the Liverpool LGA is predicted to increase significantly from 188,088 people in 2011 to 288,959 in 2031. The predicted population growth in various age groups is shown in Figure 2 (taken from Liverpool Community Health Profile, SWSLHD, 2014).

Figure 2: Predicted Population Growth Liverpool LGA

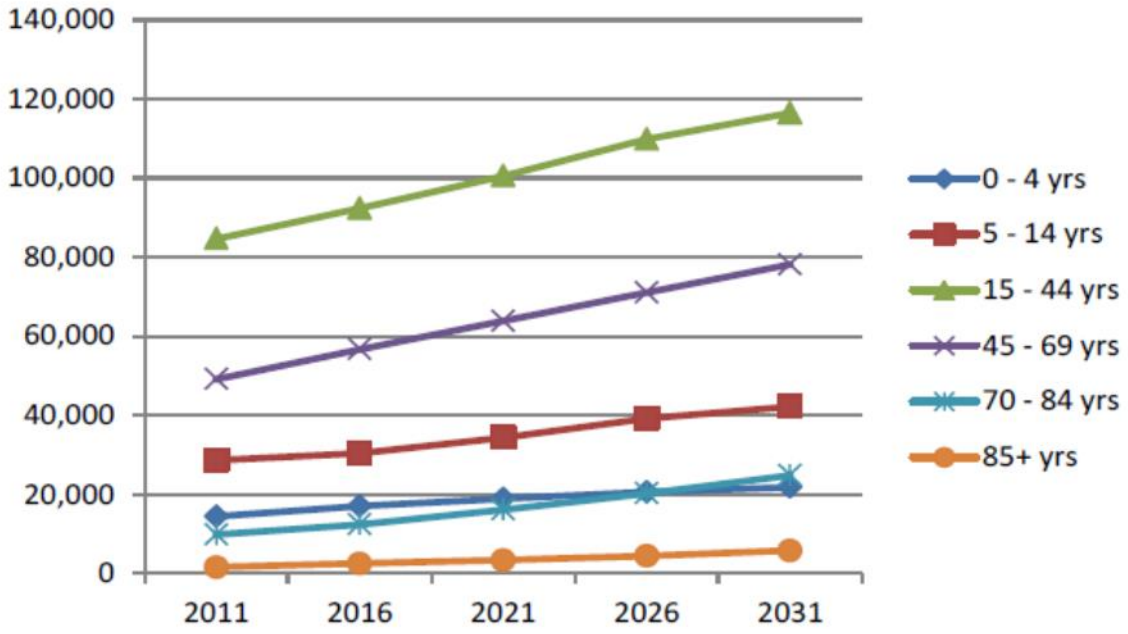


Figure 2 shows that the most significant population growth is predicted for people 15-44 and 45-69 years of age.

Population statistics for the 2011 Census have been obtained from ABS for the each of the suburbs which have been considered in the health risk assessment. These statistics are shown in Table 1 in order of increasing population size. It should be noted that the airport site will occupy significant parts of Badgerys Creek and Luddenham and a number of current residents will be relocated. Therefore the future populations in these areas is likely to be much lower than that recorded in 2011.

Table 1: Demographic Profile for Suburbs included in HRA

Suburb	Approx. distance to airport site (km)[1]	Total Population	% > 65 years of age	%< 15 years of age	SEIFA Index
Australia - avg	-	-	14	19	1000
Sydney – avg	-	-	13	19	1025
Greendale	8	352	11	22	986
Badgerys Creek	3	455	12	20	913
Mt Vernon	8	1036	11	20	1102
Warragamba	11	1236	12	22	914
Luddenham	3	1496	12	22	1034
Wallacia	8	1700	10	21	1032
Mulgoa	8.5	1792	12	20	1065
Horsley Park	13	1936	16	18	1007
Kemps Creek	6	2309	15	19	993
Bringelly	6	2387	10	21	1036
Rossmore	8	2412	13	22	997
Silverdale	11	3439	7	24	1077
Prospect	21	4621	9	21	1031
Erskine Park	11.5	6668	4	23	1041
Colyton	13	7993	11	22	930
Plumpton	18.5	8244	6	25	999
St Mary's	14	10961	14	21	881
Mt Druitt	16	15794	8	26	895
Rooty Hill	17	13377	12	22	970
St Clair	12	19837	6	21	1013

1. Distances estimated from approximate centre of the airport site to each town.
2. Demographic information based on ABS figures for 2011

People who are of low socioeconomic status (SES) have been identified as a vulnerable group for the effects of air and noise pollution. This is largely due to the fact that people within these groups usually have poorer health status than people within higher SES groups. They may also have poorer access to medical care. In addition, they usually live in areas that are more polluted (e.g., near major roads or near industry) as property is generally cheaper in these areas.

There are several indices of social deprivation used to assess SES status in Australia. One commonly used is the Socio-Economic Indexes for Areas (SEIFA) index. The SEIFA index is a measure of relative social disadvantage and takes into account 20 variables to assess relative social disadvantage. The lower the SEIFA index the greater the level of disadvantage. The index is relative to a score of 1000 which is considered as the Australian average.

The SEIFA Index of Relative Socio-Economic Advantage/Disadvantage is derived from attributes such as low income, low educational attainment, high unemployment, jobs in relatively unskilled occupations and variables that broadly reflect disadvantage rather than measuring specific aspects of disadvantage (e.g. Indigenous and Separated/Divorced). At the advantage end of the scale, households with high incomes, high education levels, large dwellings, high numbers of motor vehicles, spare bedrooms and professional occupations contribute to a higher score.

The SEIFA scores shown in Table 1 indicate that there are areas considered in the HRA that have a lower SES than the Australian average (1000) or Sydney as a whole (1025). In particular, Badgerys Creek, St Marys, Mount Druitt, Rooty Hill, Colyton and Warragamba all have low SEIFA scores indicating that the populations in these suburbs may form a vulnerable group to the effects of air pollution and noise from the proposed airport.

The Liverpool Community Health Profile (SWSLHD, 2014) presents the baseline health statistics for the local population. These are shown in Table 2:

Table 2: Baseline Health Status Liverpool LGA

Indicator	Liverpool	Proportion of NSW average (%)
Hospitalisations		
Hospitalisations (2009/10 to 2010/11) per year	58,010	99.9
Potentially preventable hospitalisations per year (2010/11 to 2011/12)	3,850	95.4
Alcohol attributable hospitalisations per year (2010/11 to 2011/12)	934	81.8
Smoking attributable hospitalisations per year (2010/11 to 2011/12)	905	100.5
High body mass index attributable hospitalisations per year (2010/11 to 2011/12)	719	101
Coronary heart disease hospitalisations per year (2009/10 to 2010/11)	821	91.2
Chronic obstructive pulmonary disease hospitalisations (persons aged over 65) per year (2009/10 to 2010/11)	262	112.9
Diabetes hospitalisations per year (2009/10 to 2010/11)	515	132.1
Fall-related injury overnight hospitalisations (persons aged 65 years and over) per year (2010/2011 to 2011/12)	572	116.9
Stroke hospitalisations per year (2010/11 to 2011/12)	196	97.6
Deaths		
Potentially avoidable deaths (persons aged under 75 years) per year (2006 to 2007)	211	99.5
Potentially avoidable deaths from preventable causes (persons aged under 75 years) (2006 to 2007)	122	96.6
Potentially avoidable deaths from causes amenable to health care (persons aged under 75 years) per year (2006 to 2007)	84	97.8
High body mass index attributable deaths (2006 to 2007)	46	91.1
Alcohol attributable deaths per year (2006 to 2007)	23	94.6
Smoking attributable deaths per year (2006 to 2007)	79	99.2

The data shown in Table 2 indicate that the baseline health status of the Liverpool LGA does not differ significantly from the data for NSW as a whole. Although the data for the whole LGA does not differ from NSW as a whole there may be parts of the LGA that have a lower health status due in part to having a lower SES.

According to the Liverpool Community Health Profile (SWSLHD), the asthma prevalence rate in people over 16 years of age in the area is 6.3%. This is lower than the NSW average for the same age group.

5 HEALTH RISK ASSESSMENT – AIR QUALITY

5.1 Introduction

The health effects attributable to PM_{10}, $PM_{2.5}$, NO_2, SO_2 and CO have been assessed in this HRA for increases in mortality, hospital admissions for respiratory and cardiovascular disease, and emergency department visits for asthma in children that may be attributable to emissions from the construction and operation of the proposed airport. Baseline health statistics for Sydney have been used in the assessment and the risk has been assessed for suburbs within 5 km from the airport site boundary (Pacific Environment, 2015). These include Bringelly, Luddenham, Greendale, Kemps Creek, Mulgoa, Wallacia, Badgerys Creek, Rossmore and Mount Vernon. The cancer risk due to diesel emissions and benzene has also been calculated for these areas. The focus of this HRA is on the potential health effects of local air quality which includes emissions from aircraft overflights, ground based airport sources and traffic to and from the airport site. The potential health risk from construction activities has also been assessed.

The predicted future air quality data used in the HRA have been generated by the EIS local air quality study (Pacific Environment, 2015) conducted for the initial and longer term airport developments which are expected to occur in or about 2030 and 2063 respectively. The modelling results that have been used in the HRA represent the worst case emission scenarios. The 2030 scenario involves a single runway with approximately 10 million passenger movements per year. The 2063 scenario includes two runways with approximately 82 million passenger movements per year. Given the uncertainties associated with predicting baseline emissions in 2063, as well as emissions from a future aircraft fleet, only PM_{10}, $PM_{2.5}$, and NO_2 have been assessed. Further details of these limitations are provided in the local air quality report and relevant EIS chapters.

The risk assessment for each of the pollutants is presented in the following sections in accordance with the enHealth HRA Guidelines (enHealth, 2012).

5.2 PM_{10} and $PM_{2.5}$

According to the local air quality study, the main source of PM_{10} and $PM_{2.5}$, would be airport traffic on roadways external to the airport site. Aside from road traffic, aircraft movements would be the next largest source of PM_{10}, $PM_{2.5}$, NO_X and SO_2. The operation of Auxiliary Power Units (APUs) and ground support equipment (GSE) would also have an influence on the predicted pollutant concentrations. The largest contributor of on-site emissions is anticipated to be associated with aircraft taking off and landing, for both Stage 1 and longer term development scenarios. The external road infrastructure was shown to be a significant contributor to predicted off-site ground level concentrations, particularly for those receptors located in close proximity to existing or proposed new roadways.

A key assumption integral to the assessment of the longer term development is that no improvement in aircraft emissions, either due to improvements in fuel or engine emissions was able to be incorporated into the modelling. This is based on the inability to predict the effect of future policies or technological developments which are expected to occur and which are likely to result in improvements in levels of combustion emissions and pollutants. This assumption embeds a high degree of conservatism into the longer term development assessment (Pacific Environment, 2015).

5.2.1 Literature Review of the Health Effects of PM_{10} and $PM_{2.5}$

The health effects of particles linked to ambient exposures have been well studied and reviewed by international agencies (NEPC, 2010; USEPA, 2004, 2009, 2012; WHO, 2013, 2006; OEHHA, 2000). Most information comes from population-based epidemiological studies that find increases in daily mortality, as well as morbidity outcomes such as increases in hospital admissions and emergency room attendances, and exacerbation of asthma associated with daily changes in ambient particle levels. In

recent years, there has been an increasing focus on the association between exposure to particles and cardiovascular outcomes. In addition to studies on the various size metrics for particles, recent research has also investigated the role of particle composition in the observed health effects.

Several studies conducted in Australia also show adverse effects of both PM_{10} and $PM_{2.5}$ on mortality and morbidity outcomes (Simpson et al., 2005a, b; Barnett et al., 2005; 2006) similar to those observed in overseas studies. The effects observed in the Australian studies appear to be greater per 1 µg/m increase in PM than those observed in the US and Europe but comparable to the results of Canadian studies.

A recent review conducted by the World Health Organization (WHO, 2013) concluded that both PM_{10} and $PM_{2.5}$ are related to increases in mortality from respiratory and cardiovascular causes, hospital admissions and emergency department attendances for respiratory and cardiovascular causes including asthma, exacerbation of asthma and increases in respiratory symptoms. In recent years, studies have provided much stronger evidence for the cardiovascular effects of particles, in particular $PM_{2.5}$. There has also been an increase in evidence to support a biological mechanism, the cardiovascular effects of which include interference with electrical process within the heart, systemic inflammation and oxidative stress. The WHO concluded that long-term exposure to $PM_{2.5}$ is the cause of both cardiovascular mortality and morbidity. The USEPA (2012) concluded that there was new evidence regarding cardiovascular mortality showing strong effects between $PM_{2.5}$ exposure and cardiovascular mortality, especially in women. In addition, there is evidence for long-term exposure to $PM_{2.5}$ and respiratory effects, including the incidence of lung cancer. Studies of cardiovascular effects provided evidence of an association between long-term exposure to $PM_{2.5}$ and myocardial infarction (heart attack), hypertension, diabetes and stroke especially among women.

A number of new studies as reported by WHO (2013) and USEPA (2012) linking long-term exposures have examined additional health outcomes apart from the previoulsy identified respiratory and cardiovascular outcomes. These outcomes include atherosclerosis, adverse birth outcomes and childhood respiratory disease. Studies have also shown possible links between long-term exposure to $PM_{2.5}$ and neurodevelopment and cognitive function as well as other chronic conditions such as diabetes. In recent years, the evidence for a link between exposure to particles and diabetes has been strengthened.

Birth cohort studies from Europe and elsewhere have found associations between $PM_{2.5}$ and respiratory infections and asthma in young children. Reduced lung function is also linked to $PM_{2.5}$ exposure. Findings of a cohort study conducted in the Netherlands supports the findings of previous studies conducted in the US and Europe linking exposure to particles and these health outcomes. Associations with birth outcomes such as low-birth-weight, preterm birth and small gestation age at birth have also been found with long-term exposure to $PM_{2.5}$. These outcomes may affect a child's development later in life. The USEPA (2012) also identified several recent studies that showed associations between long-term exposure to $PM_{2.5}$ and respiratory morbidity including hospital admissions and respiratory symptoms as well is the incidence of asthma. Studies of reproductive and developmental effects also provided evidence for long-term exposure to $PM_{2.5}$ and reduced birth weight.

With respect to short-term effects, the USEPA (2012) found that there were important new studies that increase the evidence for an association between $PM_{2.5}$ and mortality and morbidity outcomes and strengthen the previous US EPA conclusion that there is a causal association between short-term exposure to $PM_{2.5}$ and these outcomes. Associations were found for hospital admissions and emergency department attendances for all cardiovascular and respiratory causes as well as cause specific outcomes, in particular asthma.

The Australian Child Health and Air Pollution Study (ACHAPS), which used a similar study design as that used in the Southern Californian Children's Health Study, was conducted to inform the review of the

particle standards in the Ambient Air Quality NEPM (Standing Council on Environment and Water (SCEW, 2011). The results of a cross-sectional study of approximately 4,000 Australian school children aged 7-11 years showed varied results for the particulate matter exposures used in ACHAPS. PM_{10} was associated with a decline in lung function (FEV_1) post-bronchodilator use and increase in exhaled NO (an indicator of airway inflammation), but no overall increase in current respiratory symptoms. $PM_{2.5}$ was associated with an adverse effect on lung function (measured as Forced Vital Capacity (FVC)) post-bronchodilator use and on exhaled NO, with no overall effects on current symptoms, but showed increased risk of lifetime wheezing, asthma, and asthma medication use, and current asthma, use of beta-agonists and itchy rash in non-atopic children. Females had an increase in FEV_1/FVC ratio pre-bronchodilator for recent $PM_{2.5}$, and recent PM_{10} exposures, with non-significant effects in males. Despite the absence of effect on current symptoms, a reduction in lung volume at this age may have longer-term adverse consequences if it persists into later life (SCEW, 2011).

No studies investigating the long term effects of exposure to PM_{10} on health have been conducted in Australia, however there have been several international studies that have shown strong associations between long-term exposure to PM_{10} and increases in mortality (WHO, 2013; USEPA, 2012, 2009).

5.2.2 Exposure Assessment

The residential locations that have been used for the air quality HRA are Bringelly, Luddenham, Badgerys Creek, Greendale, Rossmore, Mount Vernon, Wallacia, Mulgoa and Kemps Creek. The data in the following sections have been predicted for these locations. The total population covered by these areas is 13,939 people.

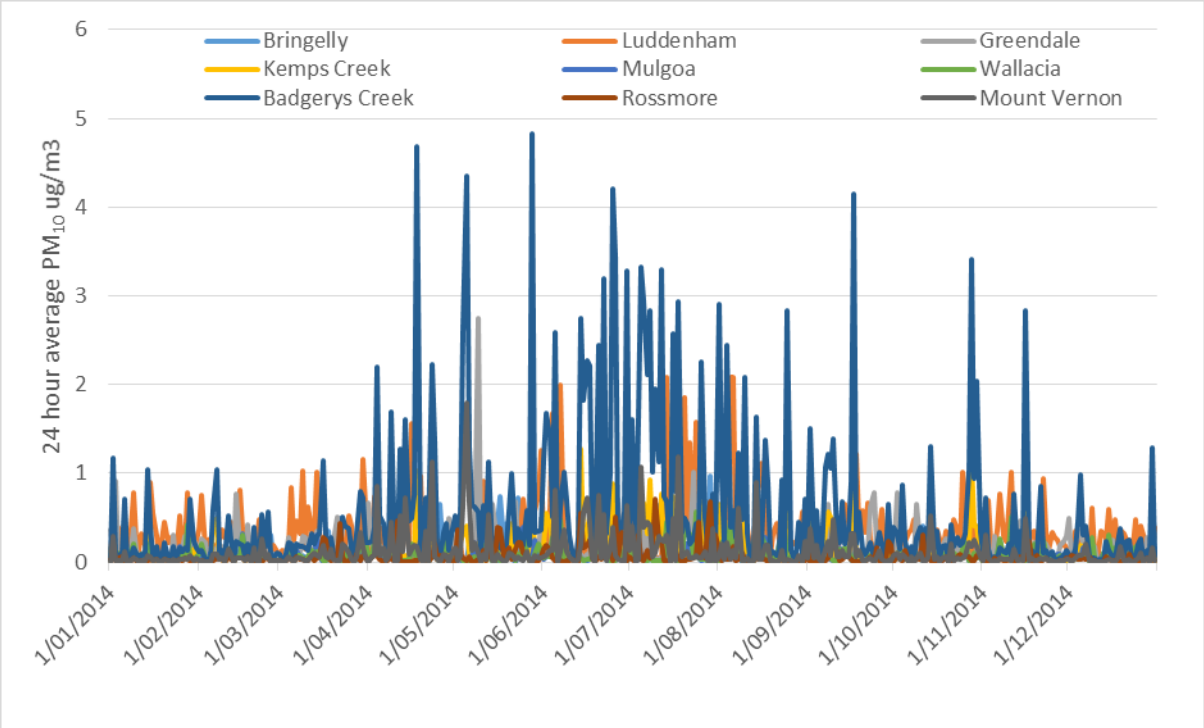
5.2.2.1 Construction phase

Air quality modelling conducted for the construction phase has provided annual average and 24-hour average PM_{10} and $PM_{2.5}$ for the following:

- bulk earthworks
- aviation infrastructure works
    - machinery, trucks, graders etc.
    - concrete batching plant

Details of the modelling and sources considered are provided in the Local Air Quality Assessment (Pacific Environment (2015). The 24 hour average PM_{10} and $PM_{2.5}$ concentrations predicted for each of the residential locations listed above are shown in Figures 3-6.

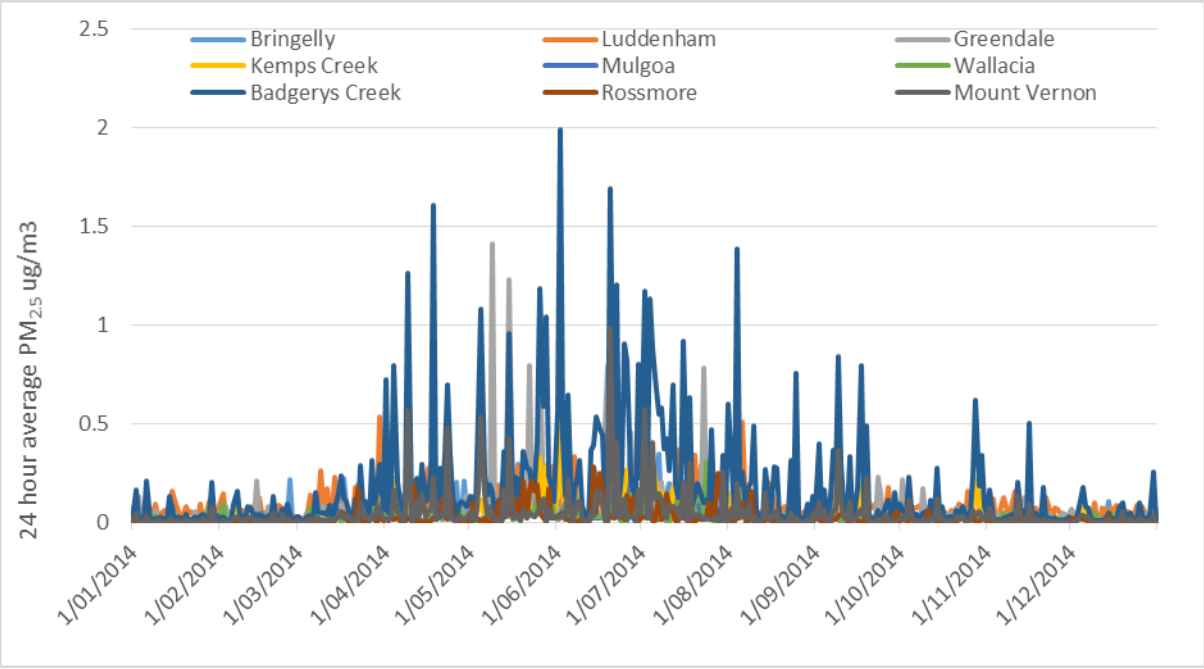
Figure 3: Predicted 24-hour Average PM_{10} Bulk Earthworks



The data shown in Figure 3 indicate that the PM_{10} levels from earthworks during construction are predicted to be well below the current NEPM standard of 50 µg/m³ at all residential locations assessed. The highest impact is predicted for Badgerys Creek.

Figure 4 shows the predicted $PM_{2.5}$ concentrations from the construction earthworks.

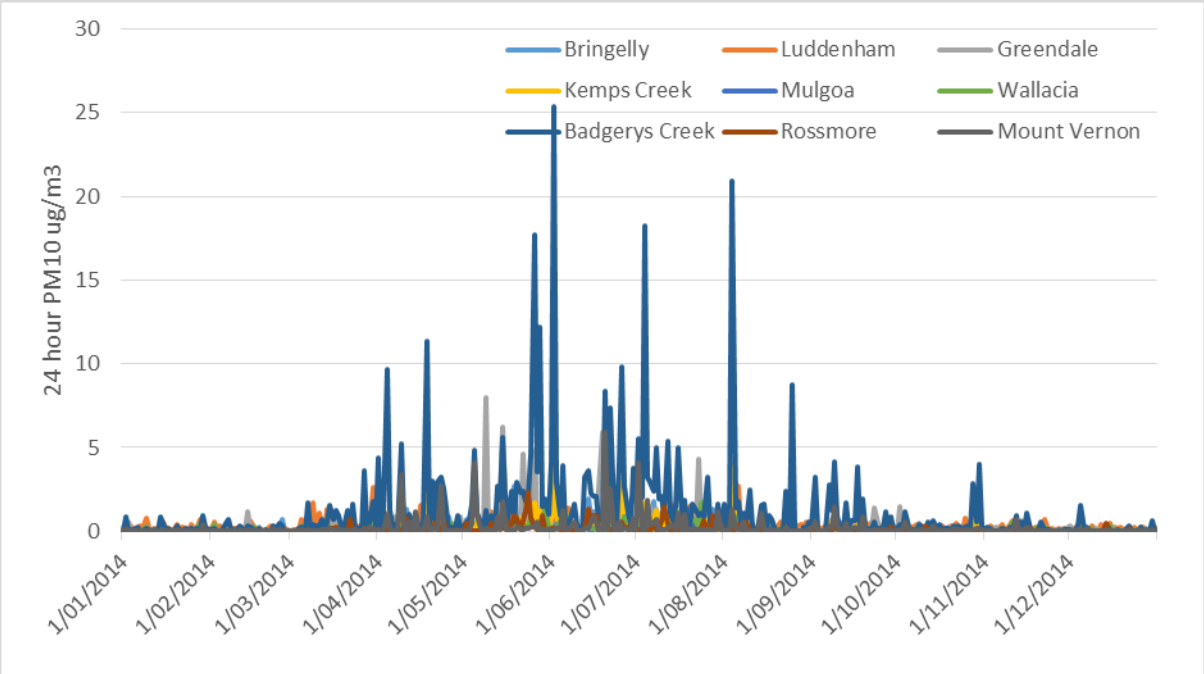
Figure 4: Predicted 24-hour average $PM_{2.5}$ Bulk Earthworks



As with the PM_{10}, the predicted $PM_{2.5}$ concentrations are low and below the advisory reporting standard of 25 µg/m^3 in the NEPM. The highest impacts are predicted for Greendale and Badgerys Creek.

Figure 5 shows the predicted PM_{10} concentrations from the construction of the aviation infrastructure.

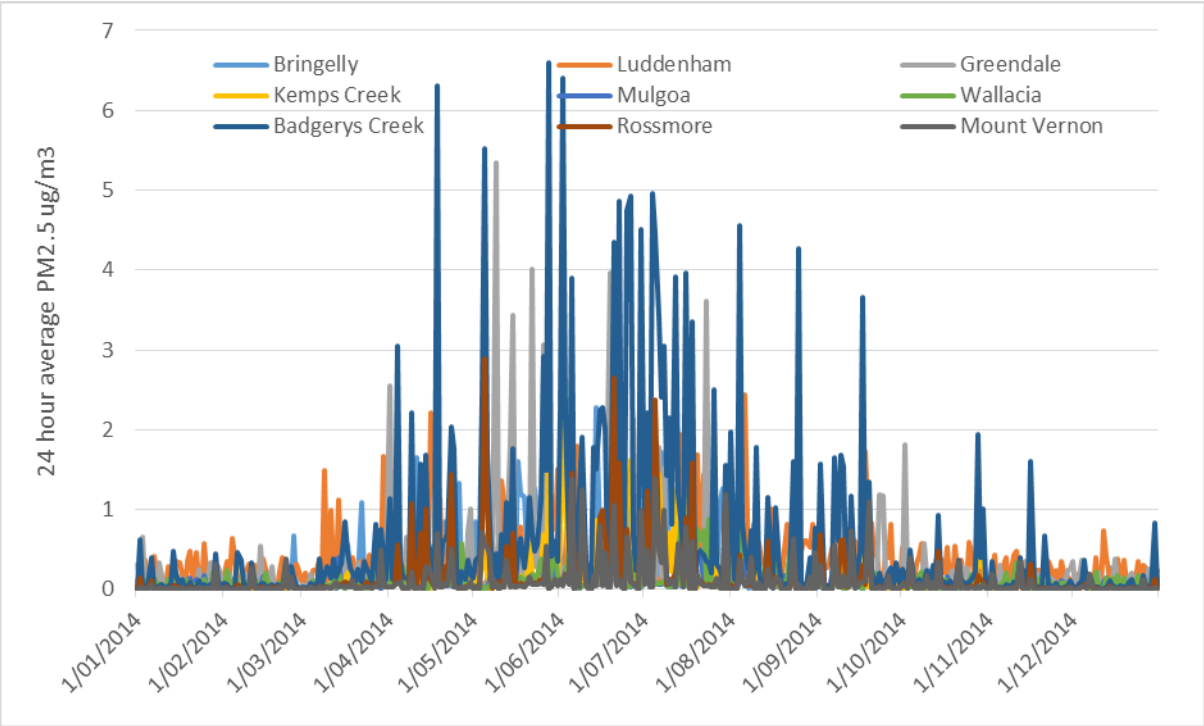
Figure 5: 24 Hour Average PM_{10} Aviation Infrastructure



The predicted PM_{10} concentrations are higher than those predicted during the bulk earthworks but are still below the NEPM standard of 50 µg/m^3. The highest impact is again at Badgerys Creek.

The data for $PM_{2.5}$ are shown in Figure 6.

Figure 6: 24 hour Average $PM_{2.5}$ Aviation Infrastructure



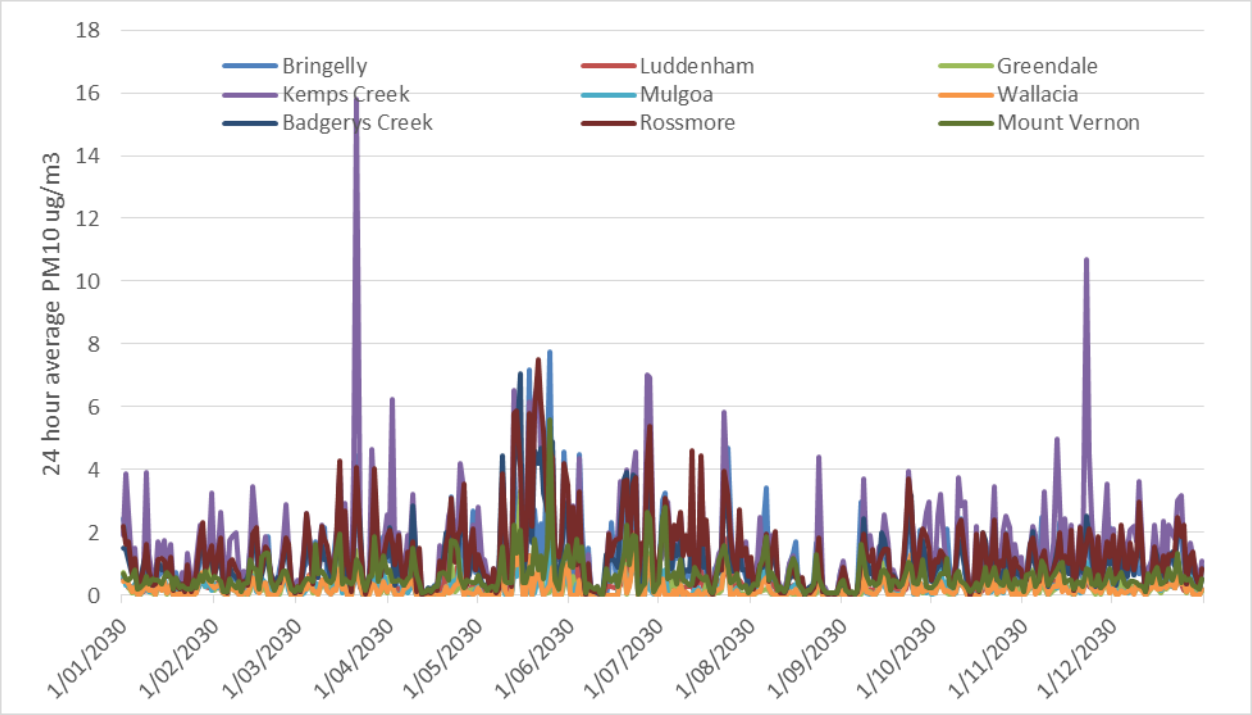
As with PM_{10}, the predicted concentrations are higher than those predicted for the bulk earthworks but still below the NEPM Advisory Reporting Standard of 25 µg/m^3. The highest concentrations are predicted for Badgerys Creek, Greendale and Rossmore.

5.2.2.2 Operation

Annual average and 24-hour PM_{10} and $PM_{2.5}$ have been modelled as part of the local air quality assessment for both 2030 and 2063. Figures 7 to 10 show the predicted 24-hour averages for the residential receptors in the surrounding area. The air quality standards for PM_{10} and $PM_{2.5}$ contained in the Ambient Air Quality NEPM are 50 µg/m^3 and 25 µg/m^3 respectively. The data shown in Figures 7 to 10 are below these standards.

The PM_{10} and $PM_{2.5}$ data generated by the local air quality assessment has been used to calculate the risk of adverse health outcomes associated with exposure to PM_{10} and $PM_{2.5}$ from the operation of the airport in 2030 and 2063 as well as the construction activities.

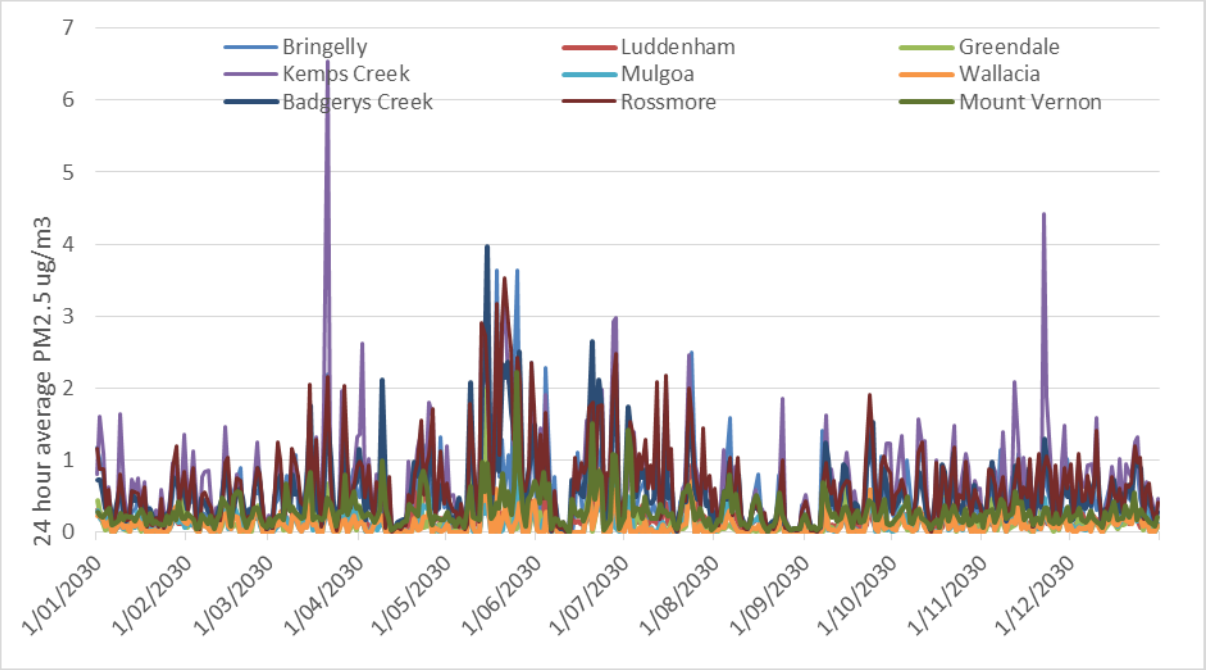
Figure 7: Daily average PM_{10} from operations 2030



The data shown in Figure 7 indicate that the highest impact of airport operations in 2030 is predicted for Kemps Creek and Rossmore.

Figure 8 shows the predicted concentrations for $PM_{2.5}$ for operations in 2030.

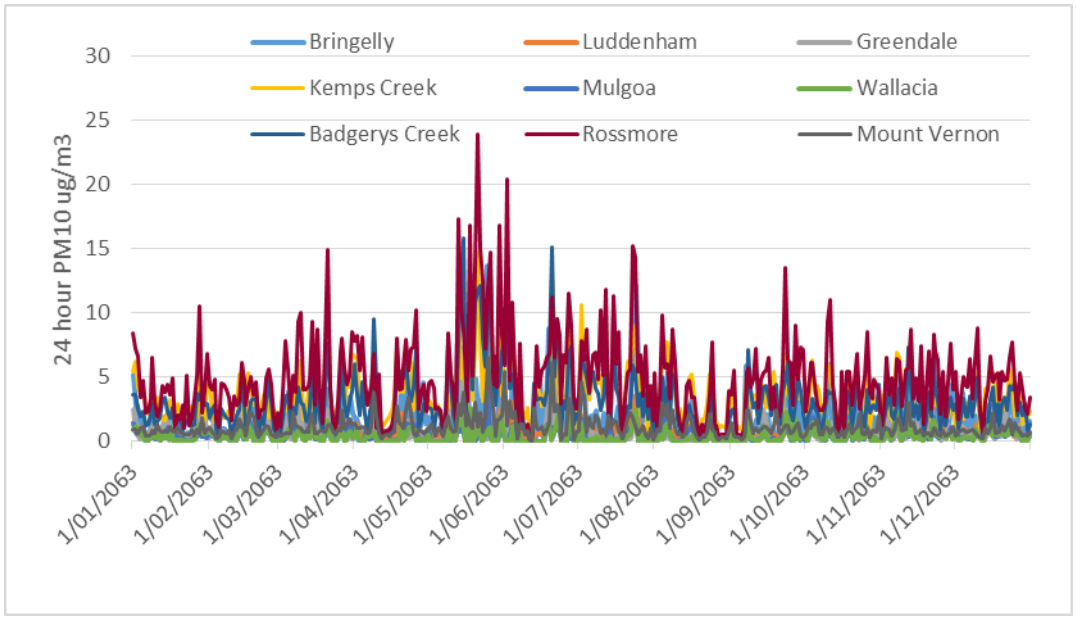
Figure 8: Daily average $PM_{2.5}$ from operations 2030



The data in Figure 8 show that the highest predicted impact is for Kemps Creek, Badgerys Creek, Rossmore and Mulgoa. All predicted concentrations are below the NEPM Advisory Reporting Standard of 25 µg/m^3.

The predicted PM_{10} concentrations for operations in 2063 are shown in Figure 9.

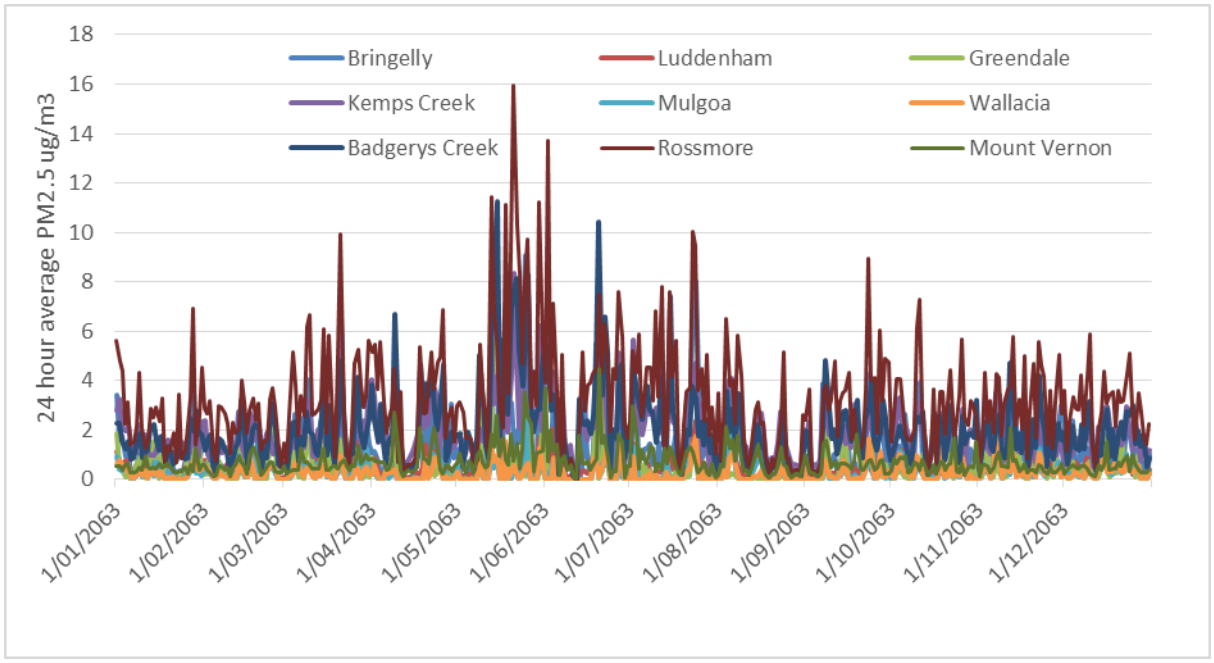
Figure 9: 24 Hour Average PM_{10} Operations 2063



As shown in Figure 9, the predicted PM_{10} concentrations are higher than predicted in 2030. The highest impact is at Rossmore and Mulgoa. The predicted concentrations are below the NEPM standard of 50 $\mu g/m^3$.

The $PM_{2.5}$ data for 2063 are shown in Figure 10.

Figure 10: Daily average $PM_{2.5}$ from operations 2063



As with PM_{10}, the predicted $PM_{2.5}$ concentrations in 2063 are higher than those predicted in 2030 but still below the NEPM standard. Again, the highest impact is predicted for Rossmore and Badgerys Creek.

5.2.3 Risk Characterisation

The results of epidemiological studies have shown that a wide range of health effects are associated with exposure to PM_{10}. Australian studies (NEPC, 2012; EPHC 2006) have found associations between PM_{10} levels currently experienced in Australian cities and the following health outcomes:

- increases in daily mortality
- increases in hospital admissions
    - respiratory disease
    - cardiovascular disease
    - cardiac disease
    - pneumonia and bronchitis
- increases in emergency room attendances for asthma

These health outcomes have been assessed in this health risk assessment for the relevant age groups.

Although no studies investigating the long term effects of exposure to PM_{10} on health have been conducted in Australia, there have been several international studies that have shown strong associations between long-term exposure to PM_{10} and increases in mortality. On the basis of the findings of these studies, long-term mortality has also been assessed.

There are several groups within the general population that have been identified as being more vulnerable to the effects of air pollution. These include:

- the elderly
- people with existing cardiovascular and respiratory disease
- people with asthma
- low socio-economic groups
- children

Compared to healthy adults, children are generally more sensitive to air pollutants as their exposure is generally higher. The reasons for this are that children inhale more air per minute and have a larger contact lung surface area relative to their size compared to adults. Other factors that increase the potential for exposure in children are that children generally spend more time outdoors and more time exercising.

Recent studies have shown that people who have a low socioeconomic status (SES) also form a group within the population that is particularly vulnerable to the effects of air pollution. This is largely due to the fact that people within these groups usually have poorer health status than people within higher SES groups. They may also have poorer access to medical care. In addition, they usually live in areas that are more polluted (e.g., near major roads or near industry) as property is generally cheaper in these areas.

To calculate the number of people that might be affected by air pollution, exposure-response functions for each outcome being assessed are required. These functions are a measure of the change in the health outcome within the population for a given change in PM_{10} or $PM_{2.5}$ concentration.

The exposure-response functions in Table 3 and 4 have been taken from Australian studies and in particular two multicity meta-analyses (Simpson et al., 2005; EPHC, 2011). The use of Australian meta-analyses is consistent with the NHMRC (2006) and NEPC (2011) recommendations for selecting exposure-response functions.

The exposure-response functions for long-term exposure to PM_{10} and $PM_{2.5}$ have been taken from the American Cancer Society study (HEI, 2009). This study is considered by the WHO as the most reliable

study to assess long-term effects of air pollution. The use of these values is also consistent with the recommendations made by NHMRC (2006) and NEPC (2011).

Table 3 Exposure Response Functions for PM_{10} Selected Health Outcomes (Taken from EPHC, 2011; HEI, 2009)

Outcome	Averaging Period	Exposure Response Function per 1 µg/m³ increase in PM_{10}
Annual all-cause mortality (non-accidental) 30+ years	Annual Average	0.004
Daily all-cause mortality (non-accidental) all ages	24 hours	0.002
Daily mortality cardiovascular disease - all ages	24 hours	0.002
Hospital Admissions respiratory disease 65+ years	24 hours	0.003
Hospital Admissions cardiac disease 65+ years	24 hours	0.002
Hospital Admissions pneumonia and bronchitis 65+ years	24 hours	0.0013
Hospital Admissions respiratory disease 15-64 years	24 hours	0.003
ED Visits Asthma 1-14 years	24 hours	0.015

Table 4 shows the exposure response functions used for $PM_{2.5}$.

Table 4: Exposure Response Functions for $PM_{2.5}$ Selected Health Outcomes Taken from EPHC, 2011; HEI, 2009)

Outcome	Averaging Period	Exposure Response Function per 1 µg/m³ increase in $PM_{2.5}$
Annual all-cause mortality (non-accidental) 30+ years	Annual Average	0.006
Annual cardiopulmonary mortality 30+	Annual average	0.014
Annual mortality ischemic heart disease 30+ years	Annual average	0.024
Annual mortality lung cancer 30+ years	Annual average	0.014
Daily all-cause mortality (non-accidental) all ages	24 hours	0.0023
Daily mortality cardiovascular disease - all ages	24 hours	0.0013
Hospital Admissions respiratory disease 65+ years	24 hours	0.004
Hospital Admissions cardiac disease 65+ years	24 hours	0.005
Hospital Admissions cardiovascular disease 65+ years	24 hours	0.003
Hospital Admissions ischemic heart disease 65+ years	24 hours	0.004
Hospital Admissions COPD 65+ years	24 hours	0.004
Hospital Admissions pneumonia and bronchitis 65+ years	24 hours	0.005
Hospital Admissions respiratory disease 15-64 years	24 hours	0.003
ED Visits Asthma 1-14 years	24 hours	0.0015

Using the predicted annual average and 24 hour average PM_{10} and $PM_{2.5}$ concentrations for the residential receptors previously identified, the population in each of these locations (see Table 1) and the exposure response function in Tables 3 and 4, the health effects attributable to PM_{10} and $PM_{2.5}$ have been calculated using the following equation:

Number of attributable cases = exposure response function (Change in health outcome) per 1 µg/m³ increase in PM x PM concentration x baseline health incidence rate / 100,000 population x actual population

In this assessment it, is assumed that the data for each receptor point, e.g., Bringelly, are representative of the whole population of that suburb.

The baseline health statistics for Sydney were used in this assessment. The number of attributable cases is shown in Table 5 (PM_{10}) and Table 6 ($PM_{2.5}$) for operations in 2030. The number of attributable cases is the increase in the number, for example hospital admissions for respiratory disease, that may arise from exposure to PM from Stage 1 airport operations. If the same example is used, the results in Table 5 show that for Rossmore, based on the predicted increase in daily PM_{10} concentrations, there would be an additional 0.05 hospital admissions per year which is equivalent to 5 additional hospital admissions per 100 years which may be attributed to emissions of PM_{10} from the Stage 1 operations of the airport. This

increase is the increase in the admissions relative to the existing situation for a given area, eg., Rossmore using the example above.

Table 5: Predicted attributable health outcomes due to PM_{10} from Stage 1 operation (2030)

Health Outcome	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
Annual Mortality 30+ years	0.06	0.01	0.002	0.1	0.001	0.03	0.013	0.08	0.02
Daily Mortality all causes all ages	0.03	0.005	0.001	0.05	0.005	0.01	0.006	0.04	0.007
Daily Mortality Cardiovascular Disease all ages	0.01	0.002	0.0003	0.02	0.002	0.004	0.002	0.01	0.003
Hospital Admissions Respiratory Disease 65+	0.03	0.007	0.001	0.07	0.006	0.01	0.007	0.05	0.009
Hospital Admissions Cardiac Disease 65+	0.03	0.007	0.001	0.07	0.006	0.01	0.007	0.05	0.009
Hospital Admissions Pneumonia and Bronchitis 65+	0.003	0.0008	0.0001	0.008	0.0007	0.002	0.0008	0.006	0.001
Hospital Admissions Respiratory Disease 15-64 years	0.04	0.007	0.001	0.06	0.007	0.02	0.008	0.05	0.01
Emergency Department Visits 0-14 years	0.009	0.002	0.0003	0.01	0.001	0.004	0.002	0.01	0.002

As can be seen from Table 5, the predicted number of attributable cases due to PM_{10} from proposed Stage 1 operation is low. The highest risk would be for all-cause mortality from long-term exposures with between 1 additional death per 1000 years and 1 additional death per 10 years attributable to PM_{10} from the airport operation in 2030. The highest risk is predicted for Kemps Creek with an additional 1 death per 10 years predicted in a population of 2,309 (Table 1). All other risks are lower than that predicted for long-term mortality. According to Health Statistics NSW in 2012-13 there were 10,127 deaths in the Western Sydney Local Health District due to all causes. This is in a population of 904,886 people.

The results for $PM_{2.5}$ for 2030 are shown in Table 6.

Table 6: Predicted attributable health outcomes due to $PM_{2.5}$ from Stage 1 operation (2030)

HEALTH OUTCOME	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
All-cause mortality 30+years (long-term)	0.05	0.009	0.002	0.06	0.008	0.006	0.01	0.06	0.01
Cardiopulmonary mortality 30+years (long-term)	0.05	0.009	0.002	0.06	0.008	0.006	0.01	0.06	0.01
Ischemic Heart Disease 30+ years (long-term)	0.03	0.006	0.001	0.04	0.005	0.004	0.006	0.04	0.007
Lung cancer mortality 30+ years (long-term)	0.007	0.001	0.0002	0.009	0.001	0.0009	0.001	0.009	0.002
Daily mortality all causes all ages	0.02	0.003	0.0006	0.02	0.003	0.003	0.004	0.02	0.004
Daily mortality cardiovascular disease all ages	0.003	0.006	0.0001	0.004	0.0005	0.0005	0.0006	0.004	0.0007
Hospital admissions respiratory disease 65+ years	0.02	0.005	0.008	0.04	0.004	0.003	0.005	0.03	0.005
Hospital admissions cardiac disease 65+ years	0.04	0.01	0.002	0.08	0.008	0.006	0.01	0.06	0.01
Hospital admissions pneumonia and bronchitis 65+ years	0.006	0.002	0.0002	0.01	0.001	0.001	0.002	0.01	0.002
Hospital admissions cardiovascular disease 65+ years	0.03	0.008	0.001	0.07	0.007	0.005	0.009	0.06	0.009
Hospital admissions respiratory disease 15-64 years	0.02	0.004	0.0007	0.03	0.003	0.003	0.004	0.03	0.005
Emergency Department visits asthma 1-14 years	0.004	0.001	0.0002	0.006	0.0007	0.0007	0.0009	0.006	0.001

As with PM_{10}, the predicted number of attributable cases from $PM_{2.5}$ from proposed Stage 1 operation of the airport is low. The highest predicted risk is for all-cause mortality and cardiopulmonary mortality from long-term exposures with between 1 additional death per 1000 years and 6 additional deaths per 100 years that are attributable to $PM_{2.5}$. The highest risks are predicted for Kemps Creek and Rossmore which is a total population of 4,721. This increase in deaths is relative to the current situation in these areas. As previously noted, according to Health Statistics NSW in 2012-13 there were 10,127 deaths in the Western Sydney Local Health District due to all causes. This is in a population of 904,886 people. All other risks are lower than that predicted for these outcomes.

Tables 7 and 8 show the predicted health effects attributable to PM_{10} and $PM_{2.5}$ for the airport operation in 2063.

Table 7: Predicted attributable health outcomes due to PM_{10} from longer term airport operation (2063)

Health Outcome	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
Annual Mortality 30+ years	0.2	0.03	0.006	0.3	0.03	0.07	0.05	0.4	0.08
Daily Mortality all causes all ages	0.08	0.02	0.003	0.2	0.01	0.03	0.02	0.2	0.04
Daily Mortality Cardiovascular Disease all ages	0.03	0.006	0.001	0.05	0.004	0.01	0.007	0.06	0.01
Hospital Admissions Respiratory Disease 65+	0.08	0.02	0.004	0.2	0.02	0.03	0.03	0.2	0.04
Hospital Admissions Cardiac Disease 65+	0.08	0.02	0.004	0.2	0.02	0.04	0.03	0.3	0.05
Hospital Admissions Pneumonia and Bronchitis 65+	0.009	0.003	0.0004	0.03	0.002	0.004	0.003	0.03	0.005
Hospital Admissions Respiratory Disease 15-64 years	0.1	0.02	0.004	0.2	0.02	0.04	0.03	0.3	0.05
Emergency Department Visits 0-14 years	0.02	0.006	0.001	0.04	0.004	0.01	0.007	0.06	0.01

Table 8: Predicted attributable health outcomes due to $PM_{2.5}$ from longer term airport operation in (2063)

HEALTH OUTCOME	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
All-cause mortality 30+years (long-term)	0.1	0.05	0.005	0.2	0.02	0.02	0.03	0.3	0.03
Cardiopulmonary mortality 30+years (long-term)	0.1	0.05	0.005	0.2	0.02	0.02	0.03	0.3	0.03
Ischemic Heart Disease 30+ years (long-term)	0.07	0.03	0.003	0.1	0.01	0.01	0.02	0.2	0.02
Lung cancer mortality 30+ years (long-term)	0.02	0.007	0.0007	0.02	0.003	0.002	0.005	0.04	0.004
Daily mortality all causes all ages	0.04	0.02	0.002	0.06	0.007	0.006	0.01	0.1	0.01
Daily mortality cardiovascular disease all ages	0.007	0.004	0.004	0.01	0.001	0.001	0.002	0.02	0.002
Hospital admissions respiratory disease 65+ years	0.04	0.03	0.003	0.1	0.01	0.008	0.02	0.2	0.01
Hospital admissions cardiac disease 65+ years	0.09	0.06	0.005	0.2	0.02	0.01	0.03	0.3	0.03
Hospital admissions pneumonia and bronchitis 65+ years	0.02	0.01	0.0009	0.04	0.003	0.003	0.008	0.05	0.004
Hospital admissions cardiovascular disease 65+ years	0.08	0.05	0.005	0.2	0.02	0.01	0.03	0.3	0.02
Hospital admissions respiratory disease 15-64 years	0.3	0.02	0.002	0.07	0.008	0.007	0.01	0.1	0.01
Emergency Department visits asthma 1-14 years	0.01	0.01	0.0006	0.02	0.002	0.002	0.003	0.03	0.002

The risks predicted for 2063 for both PM_{10} and $PM_{2.5}$ are higher than those predicted for 2030 operations. As can be seen from Table 7, the highest risk is for all-cause mortality from long-term exposures with between 5 additional deaths per 1000 years and 3 additional deaths per 10 years that are attributable to PM_{10}. This increase in deaths is relative to the current situation (10,127 deaths from all causes in 2012-13) in these areas. All other risks are lower than that predicted for long-term mortality.

As with PM_{10}, the number of attributable cases from $PM_{2.5}$ from the operations in 2063 at the airport are higher than those predicted for 2030. The highest predicted risk is for all-cause mortality and cardiopulmonary mortality from long-term exposures with between 5 additional deaths per 1000 years and 3 additional deaths per 10 years attributable to $PM_{2.5}$. All other risks are lower than that predicted for these outcomes. The highest predicted impacts are at Rossmore and Kemps Creek.

The potential health risks associated with proposed construction works have been calculated for the same receptors as used for the operational stages. The predicted results are shown in Tables 9 and 10 for earthworks and aviation infrastructure respectively for PM_{10} and Tables 11 and 12 for $PM_{2.5}$.

Table 9: Predicted attributable health outcomes due to PM_{10} from construction bulk earthworks

Health Outcome	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
Annual Mortality 30+ years	0.006	0.01	0.001	0.007	0.003	0.003	0.006	0.004	0.003
Daily Mortality all causes all ages	0.003	0.006	0.0006	0.003	0.001	0.002	0.003	0.002	0.001
Daily Mortality Cardiovascular Disease all ages	0.001	0.002	0.0002	0.001	0.0004	0.0005	0.001	0.0005	0.0005
Hospital Admissions Respiratory Disease 65+	0.003	0.007	0.0007	0.005	0.001	0.002	0.004	0.002	0.002
Hospital Admissions Cardiac Disease 65+	0.003	0.007	0.0007	0.005	0.001	0.002	0.004	0.002	0.002
Hospital Admissions Pneumonia and Bronchitis 65+	0.0003	0.0008	0.00007	0.0006	0.0002	0.0002	0.0004	0.0002	0.0002
Hospital Admissions Respiratory Disease 15-64 years	0.004	0.007	0.008	0.004	0.002	0.002	0.004	0.002	0.002
Emergency Department Visits 0-14 years	0.0009	0.002	0.0002	0.0009	0.0003	0.0003	0.0009	0.0005	0.0004

Table 10: Predicted attributable health outcomes due to PM_{10} from construction of aviation infrastructure

Health Outcome	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
Annual Mortality 30+ years	0.01	0.01	0.002	0.01	0.004	0.006	0.01	0.006	0.005
Daily Mortality all causes all ages	0.006	0.006	0.001	0.007	0.002	0.003	0.006	0.003	0.002
Daily Mortality Cardiovascular Disease all ages	0.002	0.002	0.0004	0.002	0.0007	0.0009	0.002	0.001	0.0003
Hospital Admissions Respiratory Disease 65+	0.006	0.007	0.001	0.009	0.003	0.003	0.008	0.004	0.003
Hospital Admissions Cardiac Disease 65+	0.006	0.008	0.002	0.01	0.003	0.003	0.008	0.004	0.003
Hospital Admissions Pneumonia and Bronchitis 65+	0.0007	0.0008	0.0002	0.001	0.0003	0.0003	0.0009	0.0005	0.0003
Hospital Admissions Respiratory Disease 15-64 years	0.008	0.008	0.002	0.009	0.003	0.003	0.009	0.004	0.003
Emergency Department Visits 0-14 years	0.002	0.002	0.0004	0.002	0.0006	0.0008	0.002	0.001	0.0007

Table 11: Predicted attributable health outcomes due to $PM_{2.5}$ from construction bulk earthworks

HEALTH OUTCOME	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
All-cause mortality 30+years (long-term)	0.004	0.004	0.0007	0.003	0.001	0.002	0.003	0.002	0.002
Cardiopulmonary mortality 30+years (long-term)	0.004	0.004	0.0007	0.003	0.001	0.002	0.003	0.002	0.002
Ischemic Heart Disease 30+ years (long-term)	0.002	0.002	0.0005	0.002	0.0008	0.001	0.002	0.001	0.0009
Lung cancer mortality 30+ years (long-term)	0.0005	0.0005	0.0001	0.005	0.0002	0.0003	0.0005	0.0003	0.0002
Daily mortality all causes all ages	0.0009	0.001	0.0003	0.001	0.0005	0.0006	0.001	0.0007	0.0006
Daily mortality cardiovascular disease all ages	0.0002	0.0002	0.00005	0.0002	0.00008	0.0001	0.0002	0.0001	0.0001
Hospital admissions respiratory disease 65+ years	0.001	0.002	0.0004	0.002	0.0007	0.0007	0.002	0.001	0.0008
Hospital admissions cardiac disease 65+ years	0.002	0.004	0.0007	0.004	0.001	0.001	0.003	0.002	0.001
Hospital admissions pneumonia and bronchitis 65+ years	0.0003	0.0007	0.0001	0.0007	0.0002	0.0002	0.0005	0.0004	0.0003
Hospital admissions cardiovascular disease 65+ years	0.002	0.003	0.0003	0.004	0.001	0.001	0.003	0.003	0.001
Hospital admissions respiratory disease 15-64 years	0.007	0.002	0.00008	0.001	0.0006	0.0007	0.001	0.001	0.0007
Emergency Department visits asthma 1-14 years	0.0002	0.0004	0.0006	0.003	0.0001	0.0002	0.0003	0.0003	0.0002

Table 12: Predicted attributable health outcomes due to $PM_{2.5}$ from construction of aviation infrastructure

HEALTH OUTCOME	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
All-cause mortality 30+years (long-term)	0.02	0.02	0.003	0.01	0.005	0.006	0.01	0.008	0.006
Cardiopulmonary mortality 30+years (long-term)	0.02	0.02	0.003	0.01	0.005	0.006	0.01	0.008	0.006
Ischemic Heart Disease 30+ years (long-term)	0.009	0.01	0.002	0.009	0.003	0.004	0.006	0.005	0.004
Lung cancer mortality 30+ years (long-term)	0.002	0.002	0.007	0.002	0.0007	0.0009	0.001	0.001	0.0008
Daily mortality all causes all ages	0.005	0.007	0.001	0.005	0.002	0.003	0.004	0.003	0.002
Daily mortality cardiovascular disease all ages	0.001	0.001	0.002	0.0009	0.0004	0.0005	0.007	0.0005	0.0004
Hospital admissions respiratory disease 65+ years	0.006	0.009	0.002	0.009	0.003	0.003	0.005	0.004	0.003
Hospital admissions cardiac disease 65+ years	0.01	0.02	0.003	0.02	0.005	0.006	0.01	0.008	0.005
Hospital admissions pneumonia and bronchitis 65+ years	0.002	0.003	0.0005	0.003	0.0009	0.001	0.002	0.001	0.0009
Hospital admissions cardiovascular disease 65+ years	0.01	0.02	0.003	0.006	0.005	0.005	0.007	0.007	0.005
Hospital admissions respiratory disease 15-64 years	0.007	0.008	0.001	0.001	0.002	0.003	0.005	0.003	0.003
Emergency Department visits asthma 1-14 years	0.001	0.002	0.0003	0.02	0.0005	0.0007	0.001	0.0008	0.0005

The risks predicted for the construction scenarios – bulk earthworks and aviation infrastructure - for both PM_{10} and $PM_{2.5}$ are lower than those predicted for both the 2030 and 2063 operational scenarios. As can be seen from Table 9, the highest predicted risk is for all-cause mortality from long-term exposures with between 1 additional death per 1000 years and 1 additional death per 100 years that are attributable to PM_{10}. All other risks are lower than that predicted for long-term mortality. For construction of aviation infrastructure, risks are similar to bulk earthworks with the highest risks for all-cause mortality from long-term exposures with between 2 additional death per 1000 years and 1 additional death per 100 years that are attributable to PM_{10}. The highest impacts are predicted at Luddenham, Bringelly, Kemps Creek and Badgerys Creek.

As with PM_{10}, the number of attributable cases from $PM_{2.5}$ from the construction scenarios are lower than those predicted for the operational scenarios in both 2030 and 2063. The highest predicted risk is for all-cause mortality and cardiopulmonary mortality from long-term exposures with between 7 additional deaths per 10,000 years and 4 additional deaths per 1000 years that are attributable to $PM_{2.5}$ from construction of bulk earthworks and between 3 additional deaths per 1000 years and 2 additional deaths per 100 years that are attributable to $PM_{2.5}$ from aviation infrastructure construction. All other risks are lower than that predicted for these outcomes. The highest predicted impacts are at Bringelly and Luddenham.

It should be noted that the construction of the airport will occur for a period of less than 10 years. Therefore the predicted risk levels associated with the construction phase discussed above are unlikely to be realised as they are predicted to occur over much longer timeframes – 100 to 10,000 years.

5.3 Nitrogen Dioxide (NO_2)

As with PM_{10} and $PM_{2.5}$, the main sources of NO_2 are roadways external to the airport site. The next main contributor would be aircraft movements. The operation of Auxiliary Power Units (APUs) and ground support equipment (GSE) would also influence the predicted pollutant concentrations. The largest contributor of on-site emissions is anticipated to be associated with aircraft taking off and landing, for both Stage 1 and longer term development scenarios. The external road infrastructure was shown to be a significant contributor of predicted off-site ground level concentrations, particularly for those receptors located in close proximity to existing or proposed new roadways.

5.3.1 Literature Review of the Health Effects of NO_2

In recent years, there has been an increased interest in the health effects of nitrogen dioxide. The REVIHHAP study (WHO, 2013) investigated the new studies of both long-term and short-term exposure to NO_2 and associations with mortality, hospital admissions and respiratory symptoms and concluded that these new studies show that short-term exposure to NO_2 is associated with increases in these outcomes. Studies of the long-term effects of exposure to NO_2 have shown associations with both mortality and morbidity outcomes. The effects that have been observed for both long-term and short-term exposure are occurring below current WHO air quality guidelines for NO_2 which are lower than the current NEPM standards. Controlled human exposure and toxicological studies provide support for biological mechanisms for the effects that are observed in epidemiological studies and provide evidence for a causal relationship between exposure to NO_2 and these outcomes. The most recent studies have provided evidence that NO_2 has an independent effect from other pollutants. Epidemiological studies of long-term effects of NO_2 exposure on mortality (both respiratory and cardiovascular causes) and with children's respiratory symptoms and lung function also support the conclusion that NO_2 has an independent effect on health.

Controlled human exposure studies show increased inflammation of the airways and airway hyper responsiveness at nitrogen dioxide levels down to 0.2 ppm in healthy individuals. As previously mentioned, the general population includes sensitive populations and effects are likely to occur at lower levels of NO_2 than those where adverse effects have been observed in controlled human exposure studies.

Short-term exposure to NO_2 has been linked to increases in 'all-cause', cardiovascular and respiratory mortality. The effects were greater in people 65 years of age and older and for respiratory mortality (WHO, 2013). Epidemiological studies provide no evidence of a threshold for the effect. Recent studies have provided evidence that has strengthened the association with hospital admissions and emergency department visits for respiratory disease including all respiratory causes, asthma and chronic obstructive pulmonary disease (COPD) (WHO, 2013). Strong associations have been observed for all respiratory causes in people 65 years and older and for children with asthma. The effects are not as strong for cardiovascular causes and in some cases, there is no consistent effect observed with cardiovascular effects. There is some evidence for an association with cardiac hospital admissions but these findings are not consistent across studies.

Panel studies of children with asthma show associations between nitrogen dioxide and reductions in lung function, increases in cough, night-time asthma and school absenteeism. There is also an increase in symptoms in asthmatic children and changes in lung function observed, as well as increases in airway inflammation and hyper responsiveness. Controlled human exposure and animal toxicological studies support the findings of the epidemiological and panel studies.

Long-term exposure to NO_2 has been linked to deficits in lung function growth. These findings have been found in studies in California, Mexico and Sweden. In these studies, the effects on nitrogen dioxide were greater than those observed for other pollutants including $PM_{2.5}$. There is also strong evidence of an association between long-term exposure to NO_2 and the incidence of asthma and

wheezing. This new evidence suggests that NO_2 exposure may actually cause asthma rather than just exacerbate existing asthma (WHO, 2013; USEPA, 2014). There have also been studies that have shown increases in mortality with long-term exposure NO_2 including all-cause, cardiovascular (especially ischaemic heart disease) lung cancer and respiratory mortality. These effects are similar to those observed for $PM_{2.5}$ if not larger and are independent of $PM_{2.5}$.

Australian studies have reported similar associations as overseas studies between hospitalisation for respiratory effects, including asthma, and daily NO_2 (Morgan et al. 1998a; Barnett et al. 2005; Erbas et al., 2005; Jalaludin et al. 2004; Rodriguez et al., 2007). In a meta-analysis of results from five Australian and two New Zealand cities, Barnett et al. (2005) analysed hospital admissions for three age groups of children. Significant increases in hospital admissions for respiratory disease (1–4, 5–14 years) and asthma (5–14 years) were associated with interquartile range increases in either 1-hr or 24-hr NO_2. The largest association reported was a 6.0% increase in asthma admissions with a 5.1 part per billion (ppb) increase in 24- 30 hr NO_2 and the effect was not reduced by inclusion of PM_{10} in the analysis. A meta-analysis of the associations between pollutants and cardiovascular hospital admissions in the elderly in Brisbane, Canberra, Melbourne, Perth, Sydney, Auckland and Christchurch found significant associations between CO, NO_2, and particles and five categories of cardiovascular disease admissions. The two largest statistically significant increases were for cardiac failure, with a 6.9% increase for a 5.1-ppb unit increase in NO_2 and a 6.0% increase for a 0.9-ppm increase in CO (Barnett et al, 2006).

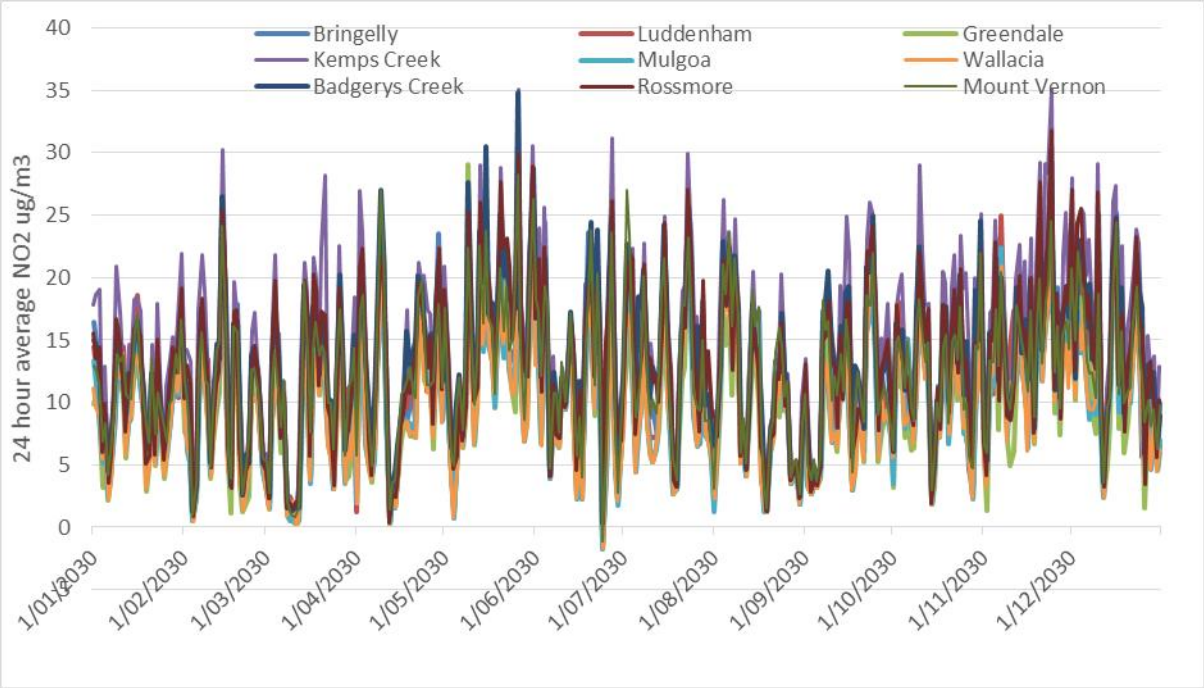
In the ACHAPS panel study (SCEW, 2012), the most consistent adverse effect was that increased NO_2 exposure was associated with an increased risk of cough and wheezing during the day and night, and increased use of bronchodilators for symptom relief. Relationships between NO_2 and night symptoms and effects were greater for NO_2 24-hr than for NO_2 1-hr and were more consistent.

The ACHAPS cross-sectional study shows consistent evidence of respiratory adverse effects of NO_2 for both recent and life-time exposure (SCEW, 2012). These adverse effects are manifested as increased risk of asthma-like symptoms (in particular, wheeze), increased airway inflammation and reduced lung volumes. For current asthma and per ppb recent exposure NO_2, the odds ratio (OR) was 1.06 (1.02, 1.10), with OR per interquartile range (IQR) NO_2 1.26 (1.08, 1.48). For recent wheeze after exercise, the OR was 1.07 (1.03, 1.120) per ppb and 1.32 (1.12, 1.57) per IQR. Airways inflammation as measured by exhaled nitric oxide (NO) increased by 3% (1%-5%) and lung volume as measured by pre-bronchodilator forced expiratory volume (FEV1) and forced vital capacity (FVC) decreased by 7.1 ml (2.8-11.4) and 6.8 ml (2.7-10.9) per ppb respectively. Effect estimates were slightly smaller for lifetime exposure. Per IQR decreases in lung function measured by FEV1 and FVC, pre- and post-bronchodilator ranged from 27.5 to 29 ml.

5.3.1.1 Exposure Assessment

Air dispersion modelling conducted as part of the local air quality assessment has predicted maximum 1-hour, 24-hour average and annual average NO_x concentrations for a range of residential receptors within a 5km radius from the airport site. The daily 24-hour NO_2 concentrations at the residential receptors used in the HRA are shown in Figures 11 and 12 for 2030 and 2063 respectively.

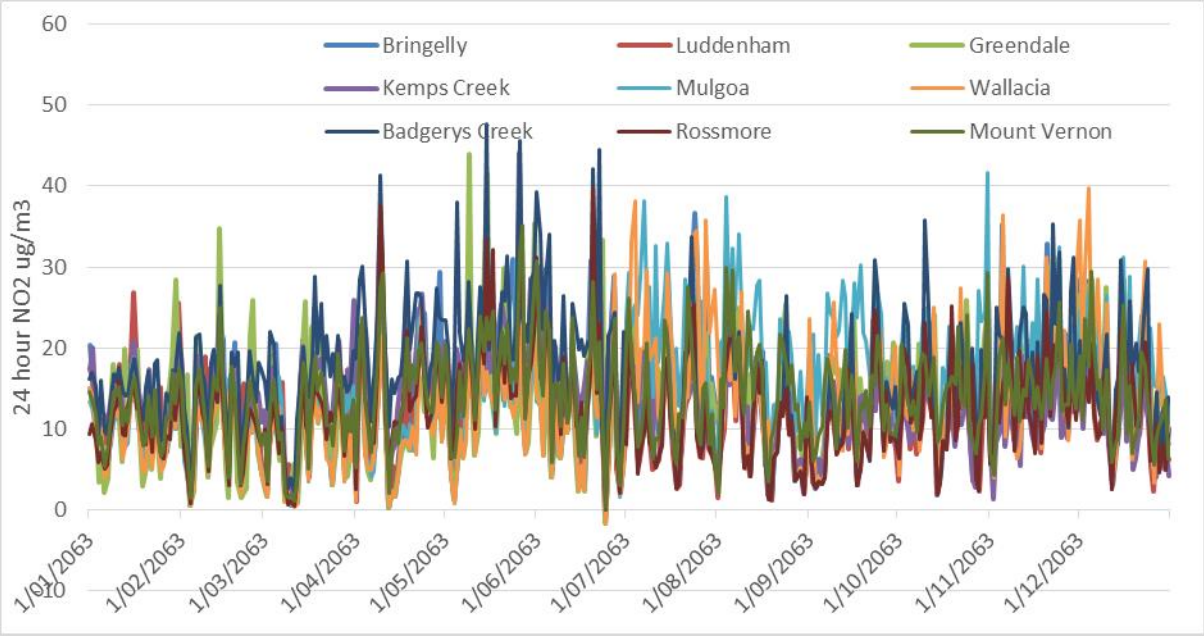
Figure 11: Predicted daily average NO_2 concentrations for 2030 operations



The data shown in Figure 11 show that all predicted levels are low. The local air quality assessment shows that for all relevant averaging periods, the predicted NO_2 levels due to the airport operations in 2030 are well below the current NEPM air quality standards. Note that the NEPM standards apply to 1-hour max and annual average concentrations. For health risk assessment the exposure response relationships are most reliable for 24-hour averages. The levels predicted at all residential locations are similar with slightly higher levels at Kemps Creek.

The data for 2063 is shown in Figure 12.

Figure 12: Predicted daily average NO_2 concentrations for 2063 operations



5.3.2 Risk Characterisation

The results of epidemiological studies have shown that a wide range of health effects are associated with exposure to NO_2. Australian studies (NEPC, 2012; EPHC 2006) have found associations between NO_2 levels currently experienced in Australian cities and the following health outcomes:

- increases in daily mortality
- increases in hospital admissions
    - respiratory disease
    - cardiovascular disease
- increases in emergency room attendances for asthma

These health outcomes have been assessed in this health risk assessment for the relevant age groups.

Although no studies investigating the long term effects of exposure to NO_2 on health have been conducted in Australia, there have been several international studies that have shown strong associations between long-term exposure to NO_2 and increases in mortality. On the basis of the findings of these studies, long-term mortality has also been assessed.

The groups that were identified as being susceptible to the effects of NO_2 are:

- Elderly
- People with existing cardiovascular and respiratory disease
- People with asthma
- Low socioeconomic groups
- Children

The exposure-response functions in Table 13 have been taken from Australian studies and in particular two multicity meta-analyses (Simpson et al., 2005; EPHC, 2006). Exposure response functions are the increase in a health outcome observed per 1 $\mu g/m^3$ increase in pollutant concentration. The use of Australian meta-analyses is consistent with the NHMRC (2006) and NEPC (2011) recommendations for selecting exposure response functions.

The exposure-response functions for long-term exposure to NO_2 have been taken from the results of a cohort of more than a million adults in Rome (Cesaroni et al., 2013). This study was reviewed by the WHO as part of the REVIHHAP review (WHO, 2013). The use of this value is also consistent with the recommendations made by NHMRC (2006) and NEPC (2011).

Table 13: Exposure Response Functions for NO_2 Selected Health Outcomes (EPHC, 2005; Cesaroni et al. 2013)

Outcome	Averaging Period	Exposure Response Function per 1 µg/m³ increase in NO_2
Annual all-cause mortality (non-accidental) 30+ years	Annual Average	0.0028
Annual cardiovascular mortality 30+ years	Annual Average	0.0028
Annual respiratory mortality 30+ years	Annual Average	0.0028
Daily all-cause mortality (non-accidental) all ages	24 –hour average	0.001
Daily mortality respiratory disease - all ages	24 –hour average	0.0023
Daily mortality cardiovascular disease - all ages	24 –hour average	0.001
Hospital Admissions respiratory disease 65+ years	24 –hour average	0.003
Hospital Admissions cardiovascular disease 65+ years	24 –hour average	0.0014
Hospital Admissions respiratory disease 15-64 years	24 –hour average	0.001
ED Visits Asthma 1-14 years	24 –hour average	0.0006

The data shown in Figures 11 and 12 have been combined with the exposure response functions in Table 13 and baseline health statistics for Sydney to calculate the number of cases attributable to NO_2 from Stage 1 operations, including traffic from roads outside of the airport site. The local population data have been used to estimate the number of people impacted in each suburb (Table 1). The number of attributable cases has been calculated using the following equation:

Number of attributable cases = exposure response function (increase in health outcome) per 1µg/m³ increase in NO_2 x NO_2 concentration x baseline health incidence rate/ 100,000 population x actual population

The number of attributable cases are summarised in Table 14 for 2030 and Table 15 for 2063.

Table 14: Predicted attributable health outcomes due to NO_2 from 2030 operations, including traffic

OUTCOME	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
All-cause mortality 30+years (long-term)	0.5	0.3	0.06	0.6	0.3	0.3	0.1	0.5	0.3
Cardiovascular mortality 30+years (long-term)	0.2	0.09	0.02	0.2	0.1	0.1	0.03	0.2	0.09
Respiratory Mortality 30+ years (long-term)	0.05	0.03	0.005	0.06	0.03	0.03	0.009	0.05	0.03
Lung cancer mortality 30+ years (long-term)	0.04	0.02	0.005	0.05	0.03	0.03	0.008	0.04	0.02
Daily mortality all causes all ages	0.2	0.1	0.02	0.2	0.1	0.1	0.03	0.2	0.09
Daily mortality cardiovascular disease all ages	0.05	0.03	0.007	0.06	0.03	0.03	0.01	0.06	0.03
Daily mortality respiratory disease all ages	0.03	0.02	0.004	0.04	0.02	0.02	0.007	0.04	0.02
Hospital admissions respiratory disease 65+ years	0.4	0.2	0.05	0.6	0.3	0.2	0.09	0.5	0.2
Hospital admissions cardiovascular disease 65+ years	0.4	0.3	0.05	0.6	0.3	0.2	0.09	0.5	0.2
Hospital admissions respiratory disease 15-64 years	0.2	0.09	0.02	0.2	0.1	0.09	0.03	0.2	0.09
Emergency Department visits asthma 1-14 years	0.04	0.02	0.005	0.05	0.02	0.02	0.008	0.05	0.02

Table 15: Predicted attributable health outcomes due to NO_2 from 2063 operations, including traffic

OUTCOME	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
All-cause mortality 30+years (long-term)	0.6	0.3	0.08	0.6	0.5	0.4	0.1	0.6	0.2
Cardiovascular mortality 30+years (long-term)	0.2	0.1	0.03	0.2	0.2	0.1	0.04	0.2	0.07
Respiratory Mortality 30+ years (long-term)	0.05	0.03	0.007	0.05	0.04	0.03	0.01	0.06	0.02
Lung cancer mortality 30+ years (long-term)	0.05	0.02	0.006	0.05	0.04	0.03	0.01	0.05	0.02
Daily mortality all causes all ages	0.2	0.1	0.03	0.2	0.2	0.1	0.04	0.2	0.07
Daily mortality cardiovascular disease all ages	0.06	0.03	0.009	0.06	0.05	0.04	0.01	0.07	0.02
Daily mortality respiratory disease all ages	0.04	0.02	0.006	0.04	0.03	0.03	0.009	0.04	0.02
Hospital admissions respiratory disease 65+ years	0.4	0.2	0.07	0.5	0.4	0.3	0.1	0.6	0.2
Hospital admissions cardiovascular disease 65+ years	0.09	0.07	0.02	0.1	0.09	0.07	0.02	0.1	0.05
Hospital admissions respiratory disease 15-64 years	0.2	0.09	0.03	0.2	0.2	0.1	0.04	0.2	0.07
Emergency Department visits asthma 1-14 years	0.04	0.03	0.007	0.04	0.04	0.03	0.01	0.06	0.02

The results shown in Tables 14 and 15 show that the risk from exposure to NO_2 from the operations in 2030 and 2063 are predicted to be higher than that predicted for PM_{10} and $PM_{2.5}$. Although the predicted NO_2 levels meet the NEPM standards, it is accepted that there is no threshold for exposure to NO_2 below which adverse health effects are not observed. This means that even meeting the air quality standards means that there is a level of risk associated with exposure to the relevant pollutant including NO_2.

Based on the modelling data provided for the HRA, the highest predicted risk is for long-term mortality in people over 30 years of age with between 6 additional deaths every 100 years and 6 additional deaths every 10 years predicted for 2030 and similar risks predicted for 2063. Evidence provided by NSW Health to a Parliamentary Inquiry into health effects of pollution showed that in 2006 it was estimated that between 600 and 1400 deaths per year were attributed to air pollution in the Sydney basin (NSW Parliament 2006). Based on these figures, the health impact associated with NO_2 emissions from the airport is expected to represent a small increase in current rates of long-term mortality associated with air pollution.

The results shown in Tables 14 and 15 are for the combined NO_2 emissions from traffic as well as emissions from the airport operations. To enable an assessment of the risk posed by NO_2 emissions from the airport operations in isolation, additional air dispersion modelling was conducted in the absence of traffic. This enabled an assessment of the contribution of the airport operations to the overall risk from exposure to NO_2 and helped to identify what mitigation could be implemented to reduce the overall risk. The results for 2030 and 2063 for airport operations alone are shown in Tables 16 and 17.

Table 16: Predicted attributable health outcomes due to NO_2 from 2030 operations excluding traffic

OUTCOME	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
All-cause mortality 30+years (long-term)	0.4	0.2	0.05	0.4	0.3	0.3	0.07	0.3	0.2
Cardiovascular mortality 30+years (long-term)	0.1	0.08	0.02	0.1	0.09	0.08	0.02	0.1	0.05
Respiratory Mortality 30+ years (long-term)	0.03	0.02	0.005	0.03	0.03	0.02	0.006	0.03	0.01
Lung cancer mortality 30+ years (long-term)	0.03	0.02	0.004	0.03	0.02	0.02	0.006	0.03	0.01
Daily mortality all causes all ages	0.1	0.08	0.02	0.1	0.09	0.09	0.03	0.1	0.05
Daily mortality cardiovascular disease all ages	0.04	0.03	0.006	0.04	0.03	0.03	0.008	0.04	0.02
Daily mortality respiratory disease all ages	0.02	0.02	0.04	0.02	0.02	0.02	0.005	0.02	0.01
Hospital admissions respiratory disease 65+ years	0.2	0.2	0.01	0.3	0.2	0.2	0.06	0.3	0.1

Hospital admissions cardiovascular disease 65+ years	0.3	0.2	0.05	0.4	0.2	0.2	0.06	0.3	0.1
Hospital admissions respiratory disease 15-64 years	0.1	0.08	0.02	0.1	0.09	0.09	0.02	0.1	0.05
Emergency Department visits asthma 1-14 years	0.03	0.02	0.005	0.03	0.02	0.02	0.006	0.03	0.01

Table 17: Predicted attributable health outcomes due to NO_2 from 2063 operations excluding traffic

OUTCOME	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
All-cause mortality 30+years (long-term)	0.4	0.3	0.06	0.4	0.4	0.3	0.1	0.4	0.2
Cardiovascular mortality 30+years (long-term)	0.1	0.09	0.02	0.1	0.1	0.1	0.04	0.1	0.07
Respiratory Mortality 30+ years (long-term)	0.04	0.02	0.005	0.04	0.03	0.03	0.01	0.04	0.02
Lung cancer mortality 30+ years (long-term)	0.03	0.02	0.005	0.03	0.03	0.03	0.008	0.03	0.02
Daily mortality all causes all ages	0.1	0.09	0.02	0.1	0.1	0.1	0.04	0.1	0.07
Daily mortality cardiovascular disease all ages	0.05	0.03	0.007	0.04	0.04	0.04	0.01	0.05	0.02
Daily mortality respiratory disease all ages	0.03	0.02	0.004	0.03	0.03	0.02	0.007	0.03	0.01
Hospital admissions respiratory disease 65+ years	0.3	0.2	0.05	0.4	0.3	0.2	0.09	0.4	0.2

Hospital admissions cardiovascular disease 65+ years	0.09	0.2	0.05	0.4	0.4	0.3	0.1	0.4	0.2
Hospital admissions respiratory disease 15-64 years	0.1	0.08	0.02	0.2	0.1	0.1	0.03	0.1	0.06
Emergency Department visits asthma 1-14 years	0.03	0.02	0.006	0.03	0.03	0.03	0.008	0.04	0.02

As can be seen from Tables 16 and 17, the predicted impact of the airport operations in isolation on surrounding suburbs is variable. By removing traffic emissions, there was a reduction in risk in both 2030 and 2063 in Bringelly, Kemps Creek and Rossmore but there was no change in Luddenham in 2030 and a small reduction in 2063. At Rossmore, the modelling indicates that traffic emissions may contribute to the predicted risk in that area. However, even without traffic emissions, the airport operations alone may lead to 4 additional deaths every 10 years due to NO_2. As outlined earlier, evidence provided by NSW Health to a Parliamentary Inquiry into health effects of pollution showed that in 2006 it was estimated that between 600 and 1400 deaths per year were attributed to air pollution in the Sydney basin (NSW Parliament 2006). Based on these figures, the health impact associated with the NO_2 emissions from the airport are expected to represent a small increase in current rates of long-term mortality associated with air pollution.

These results suggest that mitigation measures outlined in the local air quality report should be implemented to reduce community exposure to NO_2. It should be noted that the air quality predictions used in the HRA do not include the implementation of any mitigation measures to reduce NO_x emissions.

The dispersion modelling conducted for the local air quality assessment (Pacific Environment, 2015) identified that NO_x emissions contributed 91% of the emissions from the airport and therefore mitigation and management measures focus on reducing NO_x emissions. It is noted that NO_x emissions from GSE and APUs also play an important role, so the mitigation measure such as the installation of fixed system APU and GSE should reduce NO_x emissions for the longer term development as well.

A literature review was conducted of NO_x mitigation measures that have been used at other airports to mitigate NO_x emissions. These are discussed in the Local Air Quality Report Pacific Environment, 2015 , Section 5.4.2) and include a range of measures that would lead to reduction in NO_2 concentrations and associated health risks.

5.4 Sulfur Dioxide (SO_2)

The main sources of SO_2 with the exception of roadways external to the airport site were aircraft movements. The operation of Auxiliary Power Units (APUs) and ground support equipment (GSE) also had an influence on the predicted pollutant concentrations. The largest contributor of on-site emissions is anticipated to be associated with aircraft taking off and landing, for both the proposed Stage 1 and longer term development. The external road infrastructure was shown to be a significant contributor to predicted off-site ground level concentrations, particularly for those receptors located in close proximity to existing or proposed new roadways.

5.4.1 Literature Review of the Health Effects of SO_2

The health effects of sulfur dioxide (SO_2) linked to ambient air exposures have been well studied and reviewed by international agencies such as NEPC (2010), USEPA (2008), WHO (2005) and California EPA (OEHHA, 2011, 2000).

A large number of population-based epidemiological studies have reported a link between short term SO_2 exposure and daily mortality and respiratory and cardiovascular effects. The associations persist when other pollutants, such as particles, are controlled for. The epidemiological evidence is supported by controlled human exposure studies and animal toxicology studies. The strongest evidence comes from controlled human exposure studies examining short term exposure to SO_2 and respiratory effects. These studies have exposed volunteers to SO_2 for periods ranging from 5–10 min up to one hour. Adverse effects, such as sneezing or shortness of breath, occur within the first few minutes after inhalation and are not changed by further exposure. The effects are greater when the person is exercising, and are most pronounced in people with asthma and other respiratory conditions such as COPD, and particularly in exercising asthmatics.

A large number of epidemiological studies in cities in various parts of the world, including the United States, Canada and Europe, have reported associations between exposure to ambient levels of sulfur dioxide and increases in all-cause (non-accidental) and respiratory and cardiovascular mortality, often at mean 24-h average levels of <10ppb (Biggeri et al. 2005; Samet et al., 2000a; Dominici et al., 2003; Burnett et al., 1998a, 2000, 2004; Katsouyanni et al. 1997, 2006; Samoli et al., 2001, 2003; US EPA, 2008; Stieb et al. 2002, 2003). The mortality effect estimates for cardiovascular and respiratory causes are generally larger than for all-cause mortality (Zmirou et al., 1998), and the effect estimates for respiratory mortality are larger than the cardiovascular mortality, suggesting a stronger association of SO_2 with respiratory mortality compared to cardiovascular mortality. The mortality effect estimates from the multipollutant models in the multicity studies suggest some extent of confounding between SO_2 and particles and/or NO_2 (USEPA, 2008).

The epidemiological evidence, supported by controlled human exposure studies and a limited number of animal toxicological studies conducted at near ambient concentrations, indicate an association between short-term exposure to SO_2 and several measures of respiratory health, including respiratory symptoms, inflammation, and airway hyperresponsiveness.

The epidemiological evidence further indicates that the SO_2-related respiratory effects (≥ 1-hour to 24-h average) are more pronounced in asthmatic children and older adults (65+ years). In the limited number of studies that examined potential confounding by co-pollutants through multipollutant models, the SO_2 effect was generally found to be robust after adjusting for particles and other co-pollutants (USEPA, 2008).

The strongest evidence for a causal relationship between respiratory morbidity and short term exposure to SO_2 comes from human clinical studies reporting respiratory symptoms and decreased lung function following peak exposures of 5–10min duration to SO_2. The exact duration is not critical, however, because responses occur very rapidly, within the first few minutes from commencement of inhalation; continuing the exposure further does not increase the effects. These effects have been observed consistently across studies involving mild to moderate asthmatics during exercise. Statistically significant decrements in lung function accompanied by respiratory symptoms including wheeze, chest tightness and shortness of breath have been clearly demonstrated following exposure to 0.4–0.6ppm SO_2.

Several studies have observed positive associations between ambient SO_2 concentrations and emergency department visits or hospital admissions for cardiovascular diseases (e.g., all cardiovascular diseases, cardiac diseases, cerebrovascular diseases) particularly among individuals 65+ years of age, but results are not consistent across studies. The strongest evidence comes from a large multicity study conducted in Spain (Ballester et al. 2006) that observed statistically significant positive associations between ambient SO_2 and cardiovascular disease admissions.

A large body of epidemiological studies generally report consistent and robust associations between ambient SO_2 concentrations and emergency department visits and hospitalizations for all respiratory causes, particularly among children and older adults (65+ years), and for asthma and chronic obstructive pulmonary disease (COPD) (USEPA, 2008).

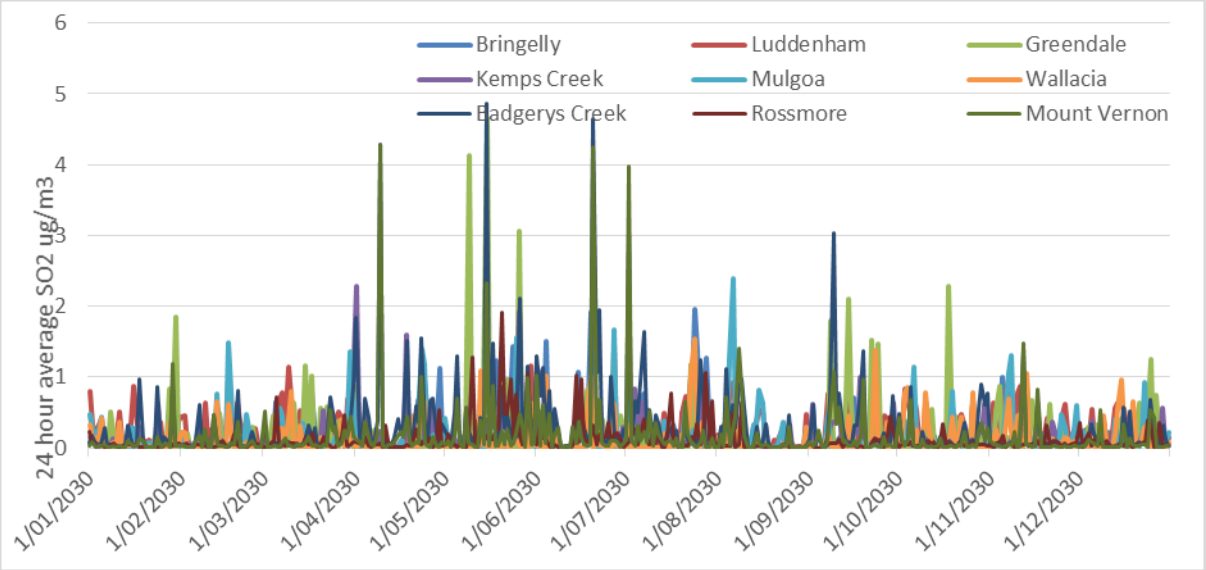
In a case-crossover study of air pollution and child respiratory health undertaken in five Australian and two New Zealand cities, Barnett et al. (2005) found a statistically significant increase in hospital admissions and SO_2 with an interquartile range of 5.4ppb for 1-hour SO_2. The ambient levels recorded during the study included: SO_2 1-hour mean (3 cities) 7.1ppb, range of means 3.7 to 10.1ppb; 24-hour mean (4 cities) 4.5ppb, range of means 0.9 to 4.3ppb. In the 1–4 year age group there was evidence of seasonal impacts on pneumonia and acute bronchitis admissions for SO_2 (May to October 4.9% increase 95% CI, 0.6–10.8%, November to April 10.4% increase 95% CI, 2.1–19.4%) (Barnett et al. 2005).

A study of 123,840 singleton births of over 20 weeks gestation in Sydney, between 1998 and 2000, found that 4.9% of babies were born at less than 37 weeks gestation. The mean of the one-hour maximum SO_2 levels was 3.6ppb. SO_2 level in early pregnancy had a large adverse impact on gestational age in those infants conceived in autumn and winter for a 1ppb increase in SO_2. The authors noted that SO_2 appears to be an important pollutant, despite SO_2 levels in Sydney being well below the national standard, with vehicular traffic being the primary source and it is conceivable that SO_2 is a marker for traffic related air pollutants in the study (Jalaludin et al 2007).

5.4.2 Exposure Assessment

Air dispersion modelling conducted as part of the local air quality assessment has predicted maximum 1-hour, 24-hour average and annual average SO_2 concentrations for a range of receptors within the surrounding suburbs. The daily 24-hour SO_2 concentrations at the most affected receptors used in the HRA are shown in Figure 13 for 2030. Air dispersion modelling for SO_2 for 2063 was not conducted.

Figure 13: Predicted daily 24-hour Average SO_2 for operations in 2030



The data in Figure 13 show that all levels are well below the current NEPM air quality standards of 228 µg/m^3. The levels are similar across most locations but higher at the Badgerys Creek, Greendale and Mount Vernon locations. The SO_2 data generated in the local air quality assessment has been used to calculate the risk of adverse health outcomes associated with exposure to SO_2 from the airport operations in 2030.

5.4.2.1 Risk Characterisation

The results of epidemiological studies have shown that a wide range of health effects are associated with exposure to SO_2. Australian studies (NEPC, 2012; EPHC 2006) have found associations between SO_2 levels currently experienced in Australian cities and the following health outcomes:

- increases in daily mortality
- hospital admissions
  - respiratory disease
  - cardiovascular disease
- emergency room attendances for asthma

These health outcomes have been assessed in this health risk assessment for the relevant age groups. The groups that were identified as being susceptible to the effects of SO_2 are:

- the elderly
- people with existing cardiovascular and respiratory disease
- people with asthma
- children

The exposure-response functions in Table 18 for mortality outcomes, have taken from the results of the APHEA2 study in Europe (Katsouyanni et al., 2006). This study was a large meta-analysis across a number of cities and provides a robust exposure-response function in the absence of Australian data. The exposure-response function for hospital admission for respiratory disease has been taken from an Australian multicity meta-analysis (Simpson et al., 2005). A study by Jalaudin et al., (2008) examining the association between emergency department attendances for asthma in children conducted in Sydney has been used as the basis for the exposure-response function for this outcome. No studies investigating the long term effects of exposure to SO_2 on health were identified.

Table 18: Exposure Response Functions for SO_2

Outcome	Averaging Period	Exposure Response Function per 1 µg/m³ increase in SO_2
Daily all-cause mortality (non-accidental) all ages	24 –hour average	0.0006
Daily mortality respiratory disease - all ages	24 –hour average	0.0013
Daily mortality cardiovascular disease - all ages	24 –hour average	0.0008
Hospital Admissions respiratory disease 65+ years	1 –hour maximum	0.002
ED Visits Asthma 1-14 years	24 –hour average	0.008

The data shown in Figure 14 have been combined with the exposure response functions in Table 18 and baseline health statistics for Sydney to calculate the number of cases attributable to SO_2 from the airport operations. The number of attributable cases has been calculated using the following equation:

Number of attributable cases = exposure response function (increase in health outcome) per 1µg/m³ increase in SO_2 x SO_2 concentration x baseline health incidence rate/ 100,000 population x actual population

The number of predicted attributable cases are summarised in Table 19.

Table 19: Predicted attributable health outcomes due to SO_2 from Stage 1 operation (2030)

OUTCOME	Bringelly	Luddenham	Greendale	Kemps Creek	Mulgoa	Wallacia	Badgerys Creek	Rossmore	Mount Vernon
Daily mortality all causes all ages	0.001	0.001	0.0002	0.001	0.0008	0.0007	0.0005	0.0009	0.0006
Daily mortality cardiovascular disease all ages	0.0005	0.0005	0.00009	0.0005	0.0004	0.0003	0.0002	0.0004	0.0003
Daily mortality respiratory disease all ages	0.0002	0.0002	0.00004	0.0002	0.0002	0.0001	0.00009	0.0002	0.0001
Hospital admissions respiratory disease 65+ years	0.003	0.003	0.0005	0.004	0.002	0.002	0.001	0.003	0.002
Emergency Department visits asthma 1-14 years	0.006	0.007	0.001	0.006	0.004	0.004	0.002	0.005	0.003

The results in Table 19 show that the predicted risk from exposure to SO_2 from the airport operations in 2030 is very low. Based on the modelling data provided for the HRA, the highest risk is for hospital admissions from respiratory causes with approximately 3 additional admissions per thousand years. All other predicted risks are lower than this.

5.5 Health Effects of Carbon Monoxide (CO)

5.5.1 Literature Review of the Health Effects of CO

The health effects of carbon monoxide are based on the ability of carbon monoxide to remove haemoglobin from blood forming carboxyhaemoglobin (COHb). The clearest evidence of the health effects associated with short-term exposure to CO is provided by studies of cardiovascular morbidity. The combined health effects evidence supports a likely causal relationship for this outcome. Controlled human exposure studies provide strong evidence of independent effects of CO on cardiac function with effects being observed in patients with chronic airways disease following short-term CO exposures resulting in 2 to 2.4% of COHb. Epidemiological studies of emergency department visits and hospital admissions for ischaemic heart disease report consistent positive associations with additional preliminary evidence for an increase in cardiovascular-related mortality provided by multi-city studies. This epidemiological evidence is coherent with ischemia related effects observed in control human exposure studies. New toxicological evidence suggests that other mechanisms involving altered cellular signalling may play a role in cardiovascular disease outcomes following carbon monoxide exposure.

Consistent decreases in time to onset of exercise induced angina along with changes in the heart that are indicative of myocardial ischaemia were observed in individuals with coronary artery disease (CAD) following controlled CO exposures resulting in COHb concentrations of 2 to 6% with no evidence of a threshold at the lowest levels tested. Volunteers who participated in controlled exposure studies were diagnosed with moderate to severe CAD may not be representative of the most sensitive individuals in the population. Variability in activity pattern and severity of disease combined with daily fluctuations in baseline COHb levels may influence a critical level of increased COHb which can lead to adverse cardiovascular effects in a particular individual.

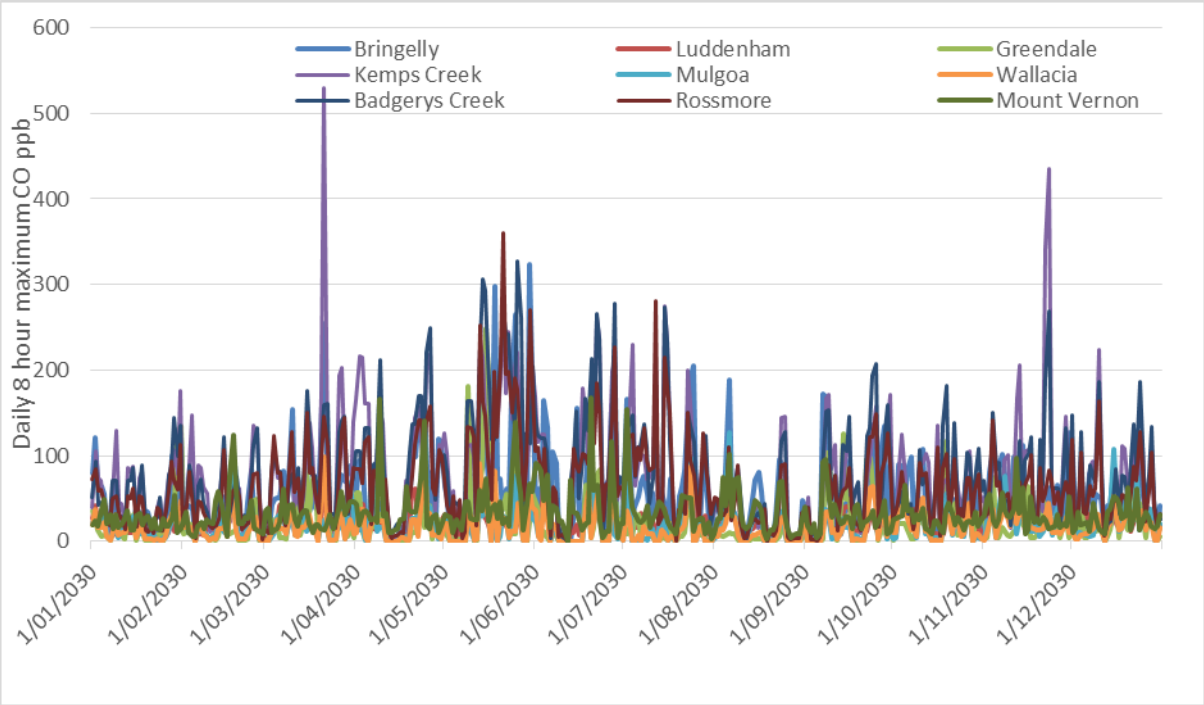
Controlled human exposure studies reviewed by the USEPA showed definitive evidence of cardiovascular effects among individuals with CAD following short-term CO exposure resulting in COHb concentrations as low as 2 to 2.4%. Evidence from control human exposure studies provide evidence of a causal relationship and reduce the uncertainties of previous assessments on the health effects of carbon monoxide. It is the consistent and coherent evidence from epidemiologic and human clinical studies along with biological plausibility provided by the role of CO in limiting oxygen availability that is sufficient for the US EPA to conclude that a causal relationship is likely to exist between relevant short-term carbon monoxide exposures and cardiovascular morbidity.

Recent studies observed associations between ambient CO concentration and emergency department visits and hospital admissions for ischaemic heart disease, congestive heart failure and cardiovascular diseases as a whole in locations with mean 24-hour average CO concentrations ranging from 0.5 ppm to 9.4 ppm. All but one of these studies that evaluated these outcomes reported positive associations. Although CO is often considered a marker of the effects of other traffic related pollutants or mix of pollutants, evidence indicates that CO associations generally remain robust in two pollutant models and supports a direct effect of short-term ambient CO exposure on cardiovascular morbidity. The known role of CO in limiting oxygen availability lends biological plausibility to ischaemia-related health outcomes following CO exposure, however it is not clear whether small changes in COHb associated with ambient CO exposures result in substantially reduced oxygen delivery to the tissues.

5.5.2 Exposure Assessment

The air dispersion modelling conducted as part of the local air quality assessment has provided daily 8-hour maximum CO levels for worst affected locations in the surrounding suburbs. These data are shown in Figure 14.

Figure 14: Predicted daily maximum 8-hour CO concentrations from Airport Operations in 2030



The data shown in Figure 14 indicates that the predicted CO levels are higher at Kemps Creek, Bringelly, Rossmore and Badgerys Creek. All predicted CO concentrations are well below the NEPM standard of 10 mg/m^3. The data from all locations have been used in the calculation of risk from CO for the proposed Stage 1 airport operations.

5.6 Risk Characterisation

The results of epidemiological studies have shown that a wide range of health effects are associated with exposure to CO. Recent Australian studies (NEPC, 2012; EPHC 2006) have found associations between CO levels currently experienced in Australian cities and the following health outcomes:

- increases in daily mortality
- increases in hospital admissions
    - cardiac disease
    - cardiovascular disease

These health outcomes have been assessed in this health risk assessment for the relevant age groups.

No studies investigating the long term effects of exposure to CO on health have been identified.

The groups that have been identified as being susceptible to the effects of CO are:

- the elderly
- people with existing cardiovascular disease

- low socioeconomic groups
- foetus

The exposure-response functions in Table 20 have been taken from Australian studies and in particular two multicity meta-analyses (Simpson et al., 2005; EPHC, 2006).

No exposure-response functions for long-term exposure to CO have been identified.

Table 20: Exposure response functions for CO selected health outcomes

Outcome	Averaging Period	Exposure Response Function per 1 mg/m³ increase in CO
Daily all-cause mortality (non-accidental) all ages	8 hours	0.001
Hospital admissions cardiac disease 65+ years	8 hours	0.003
Hospital admissions cardiovascular disease 65+ years	8 hours	0.0014

The number of attributable cases has been calculated using the following equation:

Number of attributable cases = exposure response function(increase in health outcome) per 1mg/m^3 increase in CO x CO concentration x baseline health incidence rate/ 100,000 population x actual population

The number of cases for each outcome was calculated for the population in each of the potentially affected suburbs using the data from the worst impacted residential receptor in each area. The number of cases for each day of the year were calculated and then summed to give the annual total. Table 21 shows the results for each study population for CO.

Table 21: Predicted Number of Attributable Cases due to Airport Operations in 2030

	Daily Mortality all causes all ages	Hospital Admissions Cardiac Disease 65+ years	Hospital Admissions Cardiovascular Disease 65+ years
Badgerys Creek	0.0002	0.0006	0.0008
Bringelly	0.0008	0.002	0.002
Greendale	0.00004	0.0001	0.0002
Luddenham	0.0002	0.0005	0.0007
Kemps Creek	0.001	0.003	0.005
Mulgoa	0.0002	0.0005	0.0008
Wallacia	0.0002	0.0004	0.0005
Rossmore	0.0009	0.003	0.004
Mount Vernon	0.0002	0.0005	0.0007

The results shown in Table 21 indicate that the predicted health effects attributable to CO arising from the Stage 1 airport operation are very low. The highest risk is for hospital admissions for cardiovascular disease in people 65 years of age and older with a maximum of an additional 5 hospital admissions in one thousand years due to the emissions from the operations in 2030. This risk is negligible.

5.7 Health Effects of Air Toxics

A number of air toxics are emitted from airport operations. As part of the local air quality assessment, air dispersion modelling has been conducted for benzene, toluene, xylenes and formaldehyde. The most significant potential health risk is cancer from exposure to benzene. The predicted data for benzene have been used in the risk assessment for the airport operations in 2030.

5.7.1 Literature Review of the Health Effects of Benzene

Acute (short-term) inhalation exposure of humans to benzene may cause drowsiness, dizziness, headaches, as well as eye, skin, and respiratory tract irritation, and, at high levels, unconsciousness. Chronic (long-term) inhalation exposure has caused various disorders in the blood, including reduced numbers of red blood cells and aplastic anaemia, in occupational settings. Reproductive effects have been reported for women exposed by inhalation to high levels, and adverse effects on the developing foetus have been observed in animal tests. Increased incidence of leukaemia (cancer of the tissues that form white blood cells) have been observed in humans occupationally exposed to benzene.

Benzene is a well-established cause of cancer in humans. The International Agency for Research on Cancer has classified benzene as carcinogenic to humans (Group 1). Benzene causes acute myeloid leukaemia (acute non-lymphocytic leukaemia), and there is limited evidence that benzene may also cause acute and chronic lymphocytic leukaemia, non-Hodgkin's lymphoma and multiple myeloma.

Individuals who have experienced benzene poisoning requiring treatment show a substantially increased risk of mortality from leukaemia. Benzene is a genotoxic carcinogen and does not have a threshold for effect.

Chronic inhalation of certain levels of benzene causes disorders in the blood in humans. Benzene specifically affects bone marrow (the tissues that produce blood cells). Aplastic anaemia (a risk factor for acute non-lymphocytic leukaemia), excessive bleeding, and damage to the immune system (by changes in blood levels of antibodies and loss of white blood cells) may develop. In animals, chronic inhalation and oral exposure to benzene produces the same effects as seen in humans.

5.7.2 Exposure Assessment

From the review of the health effects of the benzene presented above, the critical health endpoint for evaluation is cancer. To enable the potential increased risk of cancer arising from the airport operations to be evaluated, annual average concentrations of benzene have been modelled as part of the Air Quality Assessment (Pacific Environment, 2015). The maximum concentration predicted at any location was 0.1 µg/m^3. This value has been used to calculate the maximum cancer risk from benzene in the surrounding area.

5.7.3 Risk Characterisation Benzene

The lifetime (assumed to be 70 years) increase in cancer risk has been calculated for the inhalation pathway. International agencies have published unit risk factors (URF) for benzene. The URF is an estimate of the increase in risk with exposure to 1 µg/m^3 of the pollutant over a lifetime. To calculate the lifetime cancer risk associated with the concentrations of benzene predicted to arise from emissions from the airport operations the following equation has been used:

Increase in lifetime cancer risk = annual average concentration x unit risk factor (URF)

A review of the available unit risk factors has been undertaken. The derivation of these factors, like any standard or guideline, is based on a range of assumptions and key information on the concentrations at which these effects can be observed. To enable the risk from each of these substances to be compared, it is important that as far as practicable, all URFs are obtained from the same source and that the derivation of these values is well documented. Based on the review undertaken, the URF from the Californian EPA Office of Environmental Health Hazard Assessment (OEHHA) has been used in this study. The URFs used to calculate the increased risk of cancer in the HRA is 2.9 x 10^{-5}.

Combining the maximum annual average concentrations of 0.1 µg/m^3 and the unit risk factor using the equation shown above the increase in cancer risk has been calculated. The maximum predicted cancer risk is 2.9 x 10^{-6}.

It is generally accepted by regulatory agencies that an increase in risk between 1 x 10^{-6} (1 in a million) and 1x10^{-5} (1 in 100,000) is considered to be a low risk and within acceptable criteria. The maximum predicted cancer risk from exposure to benzene from the airport operation in 2030 is within this range. Therefore the emissions from the proposed Stage 1 development of the airport would pose a very small increase in cancer risk which is within the acceptable levels established by national and international agencies.

5.8 Diesel

Diesel emissions associated with the proposed Western Sydney airport would arise from machinery used during construction activities as well as truck movements and diesel powered equipment used on site during operation. In recent years, there has been increased community concern about the health effects of diesel emissions. The local air quality assessment has modelled diesel emissions from the construction activities for the airport development.

5.8.1 Literature Review of the Health Effects of Diesel Emissions

Exposure to diesel exhaust can have immediate health effects. Diesel exhaust can irritate the eyes, nose, throat and lungs, and it can cause coughs, headaches, light headedness and nausea. In studies with human volunteers, diesel exhaust particles made people with allergies more susceptible to the materials to which they are allergic, such as dust and pollen. Exposure to diesel exhaust also causes inflammation in the lungs, which may aggravate chronic respiratory symptoms and increase the frequency or intensity of asthma attacks.

In experimental studies, healthy subjects have shown increased symptoms of irritation and compromised pulmonary function after short-term exposure to diesel exhaust. Additional studies have shown that diesel exhaust particles influence localised immunological components involved with allergic reactions. There have also been cases of newly developed asthma reported in workers exposed to diesel exhaust.

The inhalation or direct application of diesel particles into the respiratory tract of animals in acute and sub chronic studies induced inflammatory airway changes, lung function changes, and increased susceptibility of exposed animals to lung infection. The morphological effects observed in the lungs of animals in chronic inhalation exposures are mainly related to chronic inflammatory responses. Animal data indicate that chronic respiratory disease can result from long-term exposure to diesel exhaust. In rats, laboratory studies have shown that exposure to diesel exhaust can decrease resistance to infection and increase chronic inflammation. Rats, mice, rabbits, guinea pigs, and other primates all exhibit significant adverse pulmonary non-carcinogenic effects from long-term exposures to diesel exhaust.

Diesel exhaust and many individual substances contained in it (including arsenic, benzene, formaldehyde and nickel) have the potential to contribute to mutations in cells that can lead to cancer. A meta-analysis of 30 studies showed that occupational exposure to diesel exhaust is associated with an increased risk of lung cancer. Pooled relative risk estimates from 30 studies clearly reflect the existence of a positive relationship between diesel exhaust and lung cancer in a variety of diesel-exposed occupations. Based upon a review of these epidemiological studies conducted by OEHHA and the meta-analysis, it was concluded that these epidemiological studies provide evidence consistent with a causal relationship between occupational diesel exhaust exposure and lung cancer. The majority of these studies have reported elevated estimates of relative risk for lung cancer, many of which are statistically significant. The WHO and OEHHA have classified diesel particles and diesel exhaust as a known human carcinogen.

5.8.2 Exposure Assessment

The carcinogenic effects of diesel are associated primarily with particle fraction of the diesel. The unit risk factors for diesel are for diesel particles. Air dispersion modelling conducted by Pacific Environment (2015) has included modelling of diesel emissions from the proposed airport. The annual average diesel PM concentrations are shown in Table 22.

Table 22: Annual Average Diesel PM Concentrations

Location	Annual Average Diesel PM (µg/m³)
Bringelly	0.000064
Luddenham	0.0004
Greendale	0.0004
Kemps Creek	0.0002
Mulgoa	0.0001
Wallacia	0.0002
Badgerys Creek	0.0008
Rossmore	0.0001
Mount Vernon	0.0002

These concentrations represent the highest predicted concentrations within the surrounding suburbs. These values have been used in the calculation of the cancer risk associated with diesel emissions from the operation of the airport in 2030.

5.8.3 Risk Characterisation

As with the risk characterisation for the air toxics, the URF from OEHHA has been used in the assessment of the increase in cancer risk associated with diesel particles from the operations of the airport at 2030. The URF from OEHHA for diesel particles is $3x10^{-4}$ per 1 µg/m^3 increase in diesel particles. The resultant cancer risk is shown in Table 23:

Table 23: Predicted Increase in Cancer Risk attributable to diesel particles

Location	Lifetime Excess Cancer Risk
Bringelly	1.3×10^{-6}
Luddenham	8.4×10^{-6}
Greendale	8.4×10^{-6}
Kemps Creek	4.4×10^{-6}
Mulgoa	2.3×10^{-6}
Wallacia	3.2×10^{-6}
Badgerys Creek	1.6×10^{-5}
Rossmore	2.7×10^{-6}
Mount Vernon	4.2×10^{-6}

The risk estimates shown in Table 22 fall within the acceptable level for risk generally adopted by international agencies. International agencies have generally adopted risk levels of being between 1 in a million and 1 in 100,000 as being within an acceptable risk range.

5.9 Regional Air Quality – Ozone

A regional air quality assessment has been conducted to assess the impact of the airport operations on ozone levels in Sydney (Ramboll – Environ, 2015). Ozone is one of the key pollutants of concern in the Sydney region with exceedances of the NEPM standards observed each year.

The approach to the regional air quality assessment differs from that adopted for the local air quality assessment. The NSW EPA has established guidelines for modelling of ozone which focuses on identifying peak ozone periods with potential exceedances of the air quality standards. The regional modelling has been conducted in accordance with these guidelines. The results of the regional air quality assessment are based on a small selection of days when exceedances of the standards are predicted and when there is good correlation between the model outputs and existing monitoring data obtained from NSW EPA monitoring stations.

Given that there is only a limited ozone prediction dataset available to assess the potential risk associated with exposure to changes in ozone levels across Sydney, a full risk characterisation was not possible. This would require predictions of ozone concentrations for every day of the year as has been done with the other pollutants. A different approach has therefore been necessary which focusses on the increase in risk due to changes in ozone levels only on the peak ozone days that have been assessed and where exceedances are predicted. This necessarily constrained the assessment of the potential risk posed by changes in ozone concentrations and could under estimate or overestimate the results.

5.9.1 Literature Review of the Health Effects of Ozone

Ozone is a secondary pollutant and is formed from precursors such as oxides of nitrogen and VOCs. Ambient monitoring shows that there is significant year-to-year variability in the ozone levels observed in

the Sydney region. Ozone levels are influenced by meteorology and seasonality (i.e. warmer seasons, cloudless skies, stable atmosphere) and bushfires.

The main health effects associated with exposure to ozone are associated with effects on the respiratory tract. The mechanism by which ozone affects the respiratory tract includes the formation of secondary oxidation products in the lung, activation of neural reflexes, initiation of inflammation, alterations of epithelial barrier function, sensitization of bronchial smooth muscle, changes in immunity and airway remodelling. Systemic inflammation and oxidative stress, may be critical to the effects of ozone on the cardiovascular system that have been observed in some studies.

The REVIHAAP study (WHO, 2013) found that there are both long-term and short-term effects of ozone on health. Studies reviewed by WHO have shown that long-term exposure to ozone has an impact on people with existing disease, in particular people with chronic obstructive pulmonary disease (COPD), diabetes, congestive heart failure and myocardial infarction. Long term exposure to ozone has also been associated with an increase in asthma incidence, asthma severity, hospital care for asthma and lung function growth. In regards to long-term exposures, there was new epidemiological evidence and experimental animal studies showing inflammatory responses, lung damage and persistent structural airway muscle tissue changes early in life indicating that there were long-term effects of exposure to ozone. The findings were supported by the USEPA (2013). No dose-response relationships are available to quantify the long-term effects of ozone.

Short-term effects associated with daily maximum one hour and eight-hour ozone concentrations include all cause, cardiovascular and respiratory mortality as well as cardiovascular and respiratory hospital admissions (WHO, 2013). In the 2006 review of the ozone standards, the USEPA concluded that there was clear, consistent evidence of a causal relationship between short-term exposure to ozone and respiratory health effects (USEPA, 2006). This finding was supported by the coherence of effects across a range of epidemiological, controlled human exposure and toxicological studies. These findings indicated that the effects of short-term exposure to ozone can impact a range of respiratory health endpoints ranging from respiratory tract inflammation to respiratory-related emergency department visits and hospital admissions.

There is strong evidence that short-term ozone exposures induced or were associated with statistically significant declines in lung function (USEPA (2006). An equally strong body of evidence from controlled human exposure and toxicological studies demonstrated that ozone induced inflammatory responses, increased epithelial permeability and airway hyperresponsiveness. These findings supported the findings of epidemiological studies which showed that short-term increases in ozone concentrations were consistently associated with increases in respiratory symptoms and asthma medication use in children with asthma, respiratory-related hospital admissions and asthma-related emergency department visits.

In the 2013 review, the USEPA concluded that more recent studies built on the findings of the previous review and strengthened the evidence that short-term exposure to ozone is causally associated with respiratory health effects. Recent controlled human exposure studies have shown that ozone levels as low as 60-70ppb are associated with statistically significant group mean decreases in pulmonary function in young healthy adults. These results are supported by the findings of epidemiological studies that provide strong evidence of associations between ozone exposure and respiratory hospital admissions and emergency department visits across the US, Canada and Europe. Several multicity studies and multi-continent studies reported associations between short-term increases in ambient ozone concentrations and increases in respiratory mortality. A large body of individual level epidemiological panel studies have demonstrated associations between exposure to ozone and respiratory symptoms in children with asthma. The findings of these studies are supported by recent studies that found ozone-associated increases in indicators of airway inflammation and oxidative stress in children with asthma (USEPA, 2013).

The toxicological data supports the findings of epidemiological studies and has strengthened in recent years. The toxicological studies show evidence of chronic injury and long-term structural change to the airways of animals exposed to prolonged periods of ozone as well as ozone and allergens combined. The strongest evidence for a relationship between long-term exposure to ozone and respiratory morbidity comes from studies that demonstrate long-term exposures to ozone are associated with new onset asthma in children as well as increases in respiratory symptom effects in children with asthma.

Studies that have investigated the presence of a threshold for the effects of ozone have found no evidence of a threshold for long-term effects, in particular mortality. Controlled human exposure studies show that ozone at 60ppb causes impaired lung function and inflammation of the airways in healthy adults. It is expected that effects would occur at lower levels in susceptible groups, however controlled exposure studies cannot include these groups as only healthy volunteers or people with mild disease can be included. Studies conducted at children's summer camps have seen adverse effects at lower concentrations of ozone than those observed in controlled human exposure studies. This is thought to reflect the response of susceptible groups in the general population. The multi-city studies on mortality and hospital admission outcomes have shown no evidence for a threshold for adverse effects. The WHO concluded that if a threshold does occur, that it is below 45ppb one hour maximum ozone (WHO, 2013).

In 2008, the WHO published a report on the long-range transport of air pollution. The study focused on the health effects associated with ozone exposures related to long-term transport of ozone across Europe (WHO, 2008). The WHO identified that in terms of short-term exposures to ozone, that the recent epidemiological studies had strengthened the evidence that daily exposures to ozone increased mortality and respiratory morbidity rates. Studies on pulmonary function, lung inflammation, lung permeability, respiratory symptoms, increased medication usage, morbidity and mortality, indicated that ozone appears to have an effect independent of other pollutants including particulate matter. The WHO concluded that evidence that ozone may act independently of other pollutants is supported by the results of controlled human exposure studies and toxicological studies showing the potential of ozone to cause adverse health effects especially vulnerable people.

5.9.2 Exposure Assessment

Peak daily ozone concentrations have been predicted for a number of days for airport operations in both 2030 and 2063, as well as the largest change in ozone concentration. The data reported in the regional air quality assessment is shown in Table 24. Peak daily ozone levels for the Liverpool air monitoring station is also shown for the 2008/2009 summer period. The choice of 2008/2009 as the base year was made in the Regional Air Quality Assessment (Ramboll – Environ, 2015) as this is the ozone season with the highest number of exceedances in the previous 10 years.

Table 24: Maximum 1-hour ozone concentrations for Sydney region

Date	2009 (Liverpool data)	2030	2063
6/1/2009	86	149.1	149.3
7/1/2009	106	129.8	130.3
14/1/2009	95	106.6	106.7
29/1/2009	-	124.1	124.1
30/1/2009	-	107.4	107.4
31/1/2009	75	109.4	109.4
4/2/2009	-	103.8	103.8
5/2/2009	-	119.6	119.6
6/2/2009	-	112.5	112.5
7/2/2009	92	133.7	133.7
8/2/2009	91	148.6	148.8
20/2/2009	51	98.3	98.5

The data shown in Table 24 is the peak daily 1-hour ozone concentrations that were predicted across the modelling grid. The location at which peak concentrations were predicted are identified in contour plots presented in the regional air quality assessment, however results are presented on a regional scale. Decreases in daily maximum ozone occur only in the vicinity of the airport and are attributable to ozone suppression by fresh NOx emissions. Increases in ozone occur downwind of the airport which, on most days, is to the south and southwest.

For the purposes of the risk assessment, the ozone data from the Liverpool EPA monitoring station has been used as the background dataset as this was the most complete dataset for 2009 and that the maximum concentrations did not occur adjacent to the airport site.

5.9.3 Risk Characterisation

The review of the health effects of ozone has identified that the health endpoints that have reliable exposure-response functions are short-term increases in daily mortality from all causes (non-accidental), respiratory and cardiovascular disease as well as emergency department visits for asthma in children aged 1-14 years. The exposure response functions used in the risk characterisation are shown in Table 25 and have been taken from EPHC, 2005 and Jalaludin et al., 2008.

Table 25: Exposure Response Functions

Health Outcome	Exposure Response Function (% increase per 1ppb increase in daily 1-hour max ozone)
Daily all-cause mortality (all ages)	0.0014
Daily cardiovascular mortality (all ages)	0.0021
Daily respiratory mortality (all ages)	0.0023
Emergency Department Attendances Asthma 1-14 years	0.001

The increase in risk per 100,000 population has been calculated using the following equation:

Increase in Risk (per 100,000) = Daily 1-hour max ozone concentration (ppb) x exposure response function (% increase in health outcome per 1ppb increase in ozone concentration) x baseline incidence rate/100,000 population.

The resulting risk per 100,000 population for all days assessed in the Regional Air Quality Assessment is shown in Table 26 for the Base Year 2009, Airport Operations in 2030 and 2063.

Table 26: Attributable Risk from Ozone on Peak Ozone Days

Outcome	Base Year 2009	2030 Airport Operations	2063 Airport Operations
Daily All-Cause Mortality (all ages)	1.3×10^{-5}	2×10^{-5}	2×10^{-5}
Daily Cardiovascular Mortality (all ages)	7×10^{-6}	1×10^{-5}	1×10^{-5}
Daily Respiratory Mortality (all ages)	2×10^{-6}	3×10^{-6}	3×10^{-6}
Emergency Department Attendances 1-14 years	1.8×10^{-5}	2.7×10^{-5}	2.7×10^{-5}

For the base year, the resulting risk for the outcomes assessed is between 2 in a million (respiratory mortality) and 1.8 in 100,000. For the 2030 operations, the increase in risk ranges from 1 in 1 million for respiratory mortality to 9 in 1 million for emergency department attendances for asthma in children. There is no difference between the maximum risk between 2030 and 2063. This is because the peak predicted daily ozone is largely unchanged between base case (all other emissions source) and the airport case and for both 2030 and 2063 the base case is the same. The largest predicted ozone concentration changes from the airport occur in a different location to the predicted daily peak ozone concentrations.

There is general agreement by international agencies including the WHO and USEPA that acceptable risk levels fall between 1 in a million and 1 in 100,000. The increases in risk for the days assessed in the regional air quality assessment fall within these limits.

As indicated in the introduction, there are limitations to this assessment. The regional air quality assessment has been undertaken in accordance with NSW EPA guidelines and is limited to a small number of days when exceedances of ozone standards are likely. This approach does not provide a full dataset that would typically enable a full quantitative risk assessment to be conducted using a full year of data. Therefore the risk characterisation is limited to the number of exceedance days.

The location of the maximum ozone concentrations is not identified in the Regional Air Quality Assessment, therefore the risk analysis has been conducted using the Liverpool air quality data as the baseline dataset against which the increase in risk due to predicted ozone levels has been assessed. This may lead to an overestimate or underestimate of the risk. As no spatial data was available, the difference in risk at different locations was not possible to infer. There may be variability in the risk estimates based on variability in predicted ozone levels across the Sydney airshed.

5.10 Summary

The health risk assessment for the emissions to air from the operation of the airport in 2030 and 2063 as well as the construction activities has shown that the predicted highest risk arises from exposure to PM_{10}, $PM_{2.5}$ and NO_2. The predicted levels of these pollutants in 2030 did not exceed the NEPM standards. IN 2063 some exceedances of the NEPM standards were predicted (Pacific-Environment, 2015).

The results of the HRA show that the predicted risk from exposure to NO_2 from the airport operations in both 2030 and 2063 is higher than that predicted for PM_{10} and $PM_{2.5}$. Based on the modelling data provided for the HRA, the highest risk is for long-term mortality in people over 30 years of age with 6 additional deaths per 10 years predicted for 2063. The highest risk predicted for 2030 is 5 deaths in 10 years. As outlined earlier, evidence provided by NSW Health to a Parliamentary Inquiry into health effects of pollution showed that in 2006 it was estimated that between 600 and 1400 deaths per year were attributed to air pollution in the Sydney basin (NSW Parliament 2006). Based on these figures, the health impact associated with the emissions from the airport are expected to represent a small increase in current rates of long-term mortality associated with air pollution.

Nevertheless, these results suggest that mitigation strategies should be implemented to reduce community exposure to these pollutants. A range of mitigation measures are discussed in the local air quality report (Pacific-Environment, 2015.)The greatest impact is for Bringelly, Rossmore and Kemps Creek.

The increased cancer risk from benzene is low. It is generally accepted by regulatory agencies that an increase in risk between 1×10^{-6} (1 in a million) and 1×10^{-5} (1 in 100,000) is considered to be a low risk and within acceptable criteria. The maximum predicted cancer risk is well below these criteria. Therefore the predicted emissions of benzene from the Stage 1 operation of the airport pose a very small increase in cancer risk which is well within the acceptable levels established by national and international agencies.

For diesel emissions, the predicted cancer risk is also low and within acceptable risk criteria established by international agencies.

A risk assessment based on a small number of days with predicted ozone exceedance has been conducted to provide an indication of the potential risk associated with increases in ozone concentrations due to the airport operations in 2030 and 2063.

The risk assessment has shown that for these days, there are small increases in risk of daily mortality from all causes, cardiovascular and respiratory causes as well as emergency department visits for asthma in children. The risk estimates are within acceptable risk levels generally accepted by international agencies. There is no difference in risk associated with the maximum predicted levels between 2030 and 2063 airport operations. This is because the peak predicted daily ozone is largely unchanged between base case (all other emissions source) and the airport case and for both 2030 and 2063 the base case is the same. The largest predicted ozone concentration changes from the airport occur in a different location to the predicted daily peak ozone concentrations.

6 HEALTH RISK ASSESSMENT – NOISE

The health risk assessment for noise has been undertaken following the enHealth Guidance *Health Effects of Environmental Noise other than Hearing Loss* (enHealth, 2004) and WHO guidelines (2009; 1999). EnHealth are currently updating their environmental noise guidelines. Discussions with NSW Health and the Local Health Districts affected by the airport identified sleep disturbance – in particular awakenings, cardiovascular disease and cognitive impairment as the issues of main concern with respect to the development of Western Sydney Airport. The HRA has focussed on these issues.

6.1 Literature Review on Health Effects related to Noise

In recent years, evidence has accumulated regarding the health effects of environmental noise. Epidemiological studies have found that cardiovascular diseases are consistently associated with exposure to environmental noise. The WHO has released three reports on the health effects of environmental noise: *Guidelines for Community Noise* (1999), Night Noise Guidelines (2009) and the *Burden of Disease from Environmental Noise* (2011). In these documents, the main health effects associated with environmental noise are:

- Annoyance
- Sleep disturbance
- Cardiovascular disease
- Cognitive impairment

An increasing body of literature has shown traffic noise to have adverse short- and long-term health effects (Babisch 2006; Berglund et al. 1999; Bluhm et al. 2007; Stansfeld et al. 2000, 2005). One of the suggested mechanisms by which noise affects nonauditory health is through indirect or direct activation of the sympathetic nervous system and endocrine systems (Ising and Kruppa 2004; Stansfeld and Matheson 2003), resulting in autonomic reactions, including increased blood pressure, heart rate, and arrhythmia (Berglund et al. 1999). Therefore, research has focused on the impact of transportation noise on cardiovascular health. There is suggestive evidence that transportation noise, including aircraft noise, exposure is associated with an increase in ischemic heart disease (Babisch 2006). Associations between transportation noise and hypertension have been inconsistent (Babisch et al. 2006; Chang et al. 2009; Jarup et al. 2008; van Kempen et al. 2006).

6.1.1 Annoyance

Annoyance is the most prevalent community response in a population exposed to environmental noise. It is not in itself considered to be a health effect (WHO, 2009; enHealth, 2004). The term annoyance is used to describe negative reactions to noise such as disturbance, irritation, dissatisfaction and nuisance (Guski, 1999). Annoyance can also be accompanied by stress-related symptoms, leading to changes in heart rate and blood pressure. Acoustic factors, such as the noise source and sound level, account for only a small to moderate amount of annoyance responses: other factors such as the fear associated with the noise source, interference with activities, ability to cope, noise sensitivity, expectations, anger, attitudes to the source – both positive or negative, and beliefs about whether noise could be reduced by those responsible influence annoyance responses (WHO, 2000).

Exposure to aircraft noise at 60 dB Lden is estimated to be associated with 38% of the population reporting being "annoyed" and 17% being "highly annoyed" (EC, 2002). Exposure to aircraft noise at 65 dB Lden is estimated to be associated with 48% of the population reporting being "annoyed" and 26% being "highly annoyed" (EC, 2002). However, in recent years, several studies have suggested that aircraft noise annoyance around major airports in Europe has increased (Babisch et al., 2009; Janssen et al., 2011; Schreckenberg et al., 2010) indicating that the percentage of the population reporting

being "annoyed" or "highly annoyed" at each noise exposure level may have increased since these figures were put forward by the European Commission in 2002 (EC, 2002).

Annoyance responses can also increase in relation to a change in airport operations. A study around Zurich airport found that residents who experienced a significant increase in aircraft noise exposure due to an increase in early morning and late evening flight operations had a pronounced over-reaction of annoyance i.e. the annoyance reaction was greater than that which would be predicted by the level of noise exposure (Brink et al., 2008).

Children also report annoyance responses, although it is not known at what age children begin to exhibit annoyance responses. The RANCH study found that children aged 9-11 years of age living near London Heathrow, Amsterdam Schiphol, and Madrid Barajas airports, reported annoyance for aircraft noise exposure at school and at home (van Kempen et al., 2009). For school exposure the percentage of "highly annoyed" children increased from about 5.1% at 50 dB LAeq 16 hour, to 12.1% at 60 dB LAeq 16 hour.

The results for daytime noise impacts on learning and cognitive development in children are shown in Table 34. The results show that for both the 2030 and 2063 assessment scenarios, all predicted noise levels are below the WHO guideline criteria of 55 dB and that, with the exception of one scenario for the longer term operation of the airport in 2063, all predicted daytime levels at sensitive receivers are below 50 dB. No quantitative assessment of annoyance has been conducted in this HRA.

6.1.2 Sleep Disturbance

Possible effects of noise on sleep are generally grouped into three categories:

1. The immediate effects of noise on sleep (sleep disturbance and physiological effects)
2. The secondary effects of sleep disturbances (morning after effects)
3. Long term health effects.

Sleep disturbance is defined as any deviation, measurable or subjectively perceived, from an individual's habitual or desired sleep behaviour. This may include awakenings, sleep quality, medication use to control sleep, total sleep time, time spent in slow wave sleep (see Table 1), arousals and time spent in rapid eye movement sleep (WHO, 2009).

The WHO estimated sleep disturbance to be the most adverse non-auditory effect of environmental noise exposure (Basner et al., 2014; WHO, 2011). Undisturbed sleep of a sufficient number of hours is needed for alertness and performance during the day, for quality of life, and for health (Basner et al., 2014). Humans exposed to sound whilst asleep still have physiological reactions to the noise which do not adapt over time including changes in breathing, body movements, heart rate, as well as awakenings (Basner et al., 2014). The elderly, shift-workers, children and those with poor health are thought to be at risk for sleep disturbance by noise (Muzet, 2007).

The effect of night-time aircraft noise exposure has been explored for a range of sleep outcomes ranging from subjective self-reported sleep disturbance and perceived sleep quality, to more objective measures of interference with ability to fall asleep, shortened sleep duration, awakenings, and increased bodily movements as assessed by polysomnography (Michaud et al., 2007). Most evidence comes from studies of self-reported sleep disturbance. However, self-reported sleep disturbance outcomes are vulnerable to bias, as such measures are likely to be influenced by noise annoyance and other demographic factors (Clark and Stansfeld, 2011).

Reviews have concluded that there is evidence for an effect of night-time aircraft noise exposure on sleep disturbance from community based studies (Hume et al., 2012; Miedema & Vos, 2007). However, some reviews have concluded that the evidence is contradictory and inconclusive (Jones, 2009; Michaud et al., 2007), which might be explained by methodological differences between studies of noise effects on sleep disturbance. A meta-analysis of 24 studies, including nearly 23,000 individuals

exposed to night-time noise levels ranging from 45-65 dBA, found that aircraft noise was associated with greater self-reported sleep disturbance than road traffic noise (Miedema and Vos, 2007). However, another study, whilst confirming that aircraft noise was associated with greater self-reported sleep disturbance than road traffic noise, found that when [1]polysomnography measures of sleep disturbance were analysed, that road traffic noise was associated with greater disturbance than aircraft noise (Basner et al., 2011).

Polysomnography enables the assessment of noise effects on different stages of the sleep cycle. The average sleep cycle lasts between 90 to 110 minutes, and an individual experiences between four to six sleep cycles per night (Michaud et al., 2007). Table 27 summarises the duration and characteristics of each stage of the sleep cycle (Clark and Stansfeld, 2011) from wake, through non-rapid eye movement (NREM) stages 1 to 4, and rapid eye movement (REM) sleep. It is usual for people to move between NREM sleep stages several times before undergoing REM sleep. Slow-wave sleep (NREM stages 3 and 4) occurs more frequently in the first half of the night, and REM sleep propensity is greater in the second half of the night. Sleep disturbance is indicated by less stage 3, stage 4 and REM sleep, and by more wake and stage 1 sleep, as well as more frequent changes in sleep stage (Basner and Siebert, 2010).

Table 27: Stages of Sleep (taken from Clark and Stansfeld 2012)

Wake	
Non-rapid Eye Movement (NREM)	
Stage 1	Light stage of sleep Lasts 5-10 minutes Bridge between wakefulness and sleep
Stage 2	Light stage of sleep Lasts around 20 minutes Brain waves of increased frequency Increased heart rate variability
Stage 3	Transition to deeper stages of sleep Increased amount of delta waves of lower frequency
Stage 4	Deepest stage of sleep Characterised by a greater number of delta waves
Rapid Eye Movement (REM) sleep	Typically starts 70-90 minutes after falling asleep Characterised by rapid eye movements Increases in brain activity Greater variability in respiration rate, blood pressure

[1] Polysomnography records biophysiological changes that occur during sleep, including brain waves using electroencephalography (EEG), eye movements using electroculography (EOG), muscle activity using electromyography (EMG), and heart rhythm using electrocardiography (ECG).

	and heart rate

There is evidence that aircraft noise influences the time spent in different sleep stages, with aircraft noise reducing slow-wave sleep (NREM Stage 4) and REM sleep and increasing NREM Stages 1, 2 & 3 (Basner et al., 2008; Swift, 2010). This evidence, taken with the increase in REM sleep in the later stages of the night might have implications for early morning (04.00-06.30 hours) flight operations at airports.

A laboratory study compared the potential effects of changes in the night-time curfew at Frankfurt airport on sleep disruption (Basner and Siebert, 2010), using polysomnography on 128 subjects over 13 nights. Three different operational scenarios were compared: scenario 1 was based on 2005 air traffic at Frankfurt airport which included night flights; scenario 2 was as scenario 1 but cancelled flights between 23.00-05.00 hours; scenario 3 was as scenario 1 but with flights between 23.00-05.00 hours rescheduled to the day-time and evening periods. The study found that compared to the night without a curfew on night flights (scenario 1), small improvements were observed in sleep structure for the nights with curfew, even when the flights were rescheduled to periods before and after the curfew period. However, the change in the amount of time spent in the different sleep stages for the different scenarios was small, which might be explained by the small number of night-flights (on average 4 take-offs per hour) in the Frankfurt airport scenarios examined: larger effects may be observed for airports with a greater number of night-flights. The authors concluded that the benefits for sleep seen in the scenario involving rescheduling of flights rather than cancellation may be offset by the expected increase in air traffic during the late evening and early morning hours for those who go to bed before 22.30 or after 01.00 hours.

The WHO Europe Night Noise Guidelines (WHO, 2009) were based on expert-consensus that there was sufficient evidence that nocturnal environmental noise exposure was related to self-reported sleep disturbance and medication use, and that there was some evidence for effects of nocturnal noise exposure on high blood pressure (hypertension) and heart attacks. The WHO Europe Night Noise Guidelines state that the target for nocturnal noise exposure should be 40 dB Lnight, outside, which should protect the public as well as vulnerable groups such as the elderly, children, and the chronically ill from the effects of nocturnal noise exposure on health. The Night Noise Guidelines also recommend the level of 55 dB Lnight, outside, as an interim target for countries wishing to adopt a step-wise approach to the guidelines. It is worth noting that the 40 dB Lnight, outside guideline represents a very low level of noise exposure (equivalent to the noise level expected in a library).

There have been fewer studies on aircraft noise exposure and sleep in children (Stansfeld and Clark, 2015), even though children are a group thought to be vulnerable to the effects of sleep disturbance (Pirrera et al., 2010). Children sleep outside the typical hours used to denote night-time noise exposure around airports (e.g. Lnight is typically 23.00 hours to 07.00 hours), so exposures during the hours of the evening and morning, which would fall within day-time exposure metrics may also be relevant when considering sleep disturbance effects for children.

6.1.3 Cardiovascular Disease

In recent years, evidence that aircraft noise exposure leads to increased risk for poorer cardiovascular health has increased considerably. A recent review, suggested that risk for cardiovascular outcomes such as high blood pressure (hypertension), heart attack, and stroke, increases by 7 to 17% for a 10 dB increase in aircraft or road traffic noise exposure (Basner et al., 2014). A review of the evidence for children concluded that there were associations between aircraft noise and high blood pressure (Paunović et al., 2011), which may have implications for adult health (Stansfeld and Clark, 2015).

The HYENA study (HYpertension and Exposure to Noise near Airports) examined noise effects on the blood pressure (hypertension) of 4,861 people, aged 45-70 years, who had lived for over five years near seven major European airports including London Heathrow; Amsterdam Schiphol; Stockholm Arlanda

and Bromma; Berlin Tegel, Milan Malpensa; and Athens Eleftherios Venizelos (Jarup et al., 2008). High blood pressure was assessed via measurements and medication use. The HYENA study found that a 10 dB increase in aircraft noise at night (Lnight) was associated with a 14% increase in risk for high blood pressure but day-time aircraft noise (LAeq 16 hour) did not increase the risk for high blood pressure (Jarup et al., 2008). The HYENA study did not find an association between day-time aircraft noise and high blood pressure which might be because many residents work away from home during the day-time, leading to potential mis-classification of their day-time aircraft noise exposure. The HYENA study also found that a 10 dB increase in night-time aircraft noise was associated with a 34% increase in the use of medication for high blood pressure in the UK (Floud et al., 2011). The HYENA study is a high quality large-scale study of aircraft noise exposure effects on blood pressure, which includes a population sample around London Heathrow airport.

A further study conducted as part of the HYENA project demonstrated an association between noise and cardiovascular disease risk factors (Floud et al., 2013). The results are consistent with the hypothesis that noise exposure provokes a stress response causing a release of stress hormones, which in turn affect factors such as blood pressure and heart rate and thus cardiovascular disease risk. Night-time aircraft noise was statistically significantly associated with self-reported heart disease and stroke but was reduced and became non-significant after adjustment for confounders. However, there was a significant association for those who had lived for 20 years or more at their current address and aircraft noise. A statistically significant association (25 % increase in risk) was found between exposure to night-time aircraft noise and heart disease and stroke in people who had lived in the same home for 20 years or more, and this association was robust to adjustment for exposure to NO_2 air pollution.

A recent study around London Heathrow airport examined risks for hospital admission and mortality for stroke, coronary heart disease and cardiovascular disease for around 3.6 million people living near the airport (Hansell et al., 2013). Both day-time (LAeq 16 hour) and night-time (Lnight) aircraft noise exposure were related to increased risk for a cardiovascular hospital admission. Compared to those exposed to aircraft noise levels below 51 dB in the day-time LAeq, 16 hour, those exposed to aircraft noise levels over 63 dB LAeq, 16hour in the day-time had a 24% higher chance of a hospital admission for stroke; a 21% higher chance of a hospital admission for coronary heart disease; and a 14% higher chance of a hospital admission for cardiovascular disease. These estimates took into account age, sex, ethnicity, deprivation and lung cancer mortality as a proxy for smoking. These results were also not accounted for by air pollution, which was adjusted for in the analyses. Similar effects were also found between aircraft noise exposure and mortality for stroke, coronary heart disease, and cardiovascular disease. The study concluded that high levels of aircraft noise were associated with increased risks of stroke, coronary heart disease, and cardiovascular disease for both hospital admissions and mortality in areas near Heathrow airport.

Further longitudinal evidence for an association between aircraft noise exposure and mortality from heart attacks comes from a large-scale Swiss study of 4.6 million residents over 30 years of age (Huss et al., 2010). This study found that mortality from heart attacks increased with increasing level and duration of aircraft noise exposure (over 15 years), but there were no associations between aircraft noise exposure and other cardiovascular outcomes including stroke or circulatory disease. The lack of association between aircraft noise and stroke differs from the findings of the similar study conducted by Hansell et al., (2013) around Heathrow airport, which did find an association of aircraft noise on stroke mortality.

A multi-airport retrospective study of approximately 6 million older people residing near airports in the United States (Correia et al., 2013) found that averaged across all airports and using the 90th centile noise exposure metric, a zip code with 10 dB higher noise exposure had a 3.5% higher (95% confidence interval 0.2% to 7.0%) cardiovascular hospital admission rate, after controlling for covariates. Despite limitations related to potential misclassification of exposure, a statistically significant association between exposure to aircraft noise and risk of hospitalization for cardiovascular diseases among older

people living near airports was observed. The most recent meta-analysis of the field (Babisch, 2014) concluded that aircraft noise exposure was associated with increased risk for cardiovascular outcomes such as high blood pressure, heart attack and stroke.

It is biologically plausible that long-term exposure to environmental noise might influence cardiovascular health (Babisch, 2014). The proposed pathways between environmental noise exposure and cardiovascular diseases (Babisch, 2014) include increased stress associated with noise exposure that might cause physiological stress reactions in an individual, which in turn can lead to increases in established cardiovascular disease risk factors such as blood pressure, blood glucose concentrations, and blood lipids (blood fats). These risk factors lead to increased risk of high blood pressure (hypertension) and arteriosclerosis (e.g. narrowing of arteries due to fat deposits) and are related to serious events such as heart attacks and strokes (Babisch, 2014; Basner et al., 2014). The stress that triggers this pathway can operate directly via sleep disturbance or indirectly via interference with activities and annoyance.

To date, few studies have examined whether aircraft noise exposure influences metabolic risk factors for cardiovascular health, such as Type II diabetes, body mass index, and waist circumference. Such factors would lie on the proposed pathway between aircraft noise exposure and cardiovascular diseases. A recent study of long-term exposure to aircraft noise in Sweden found that exposure was associated with a larger waist circumference but less clearly with Type II diabetes and body mass index (Eriksson et al., 2014). Further studies are required to investigate these associations.

6.1.4 Children's Learning and Cognitive Development

Children may be particularly vulnerable to the effects of noise because they may have less cognitive capacity to understand environmental issues and anticipate stressors and they may lack appropriate coping strategies to deal with noise. Additionally, noise may interfere with learning at a critical developmental stage.

The impact of environmental noise on children's learning and memory has been known for many years. Epidemiological studies show effects of chronic noise exposure on tasks involving central processing and language, such as reading, comprehension, memory and attention. Experimental studies investigating acute (short-term) exposures have found similar effects. Exposure during critical periods of learning at school could potentially impair development and have a lifelong effect on educational attainment.

There are several ways in which aircraft noise could influence children's cognition: lost teaching time - as a teacher may have to stop teaching whilst noise events occur; teacher and pupil frustration; annoyance and stress responses; reduced morale; impaired attention; children might tune out the aircraft noise and over-generalise this response to other sounds in their environment missing out on information; and sleep disturbance from home exposure which might cause performance effects the next day (Stansfeld and Clark, 2015).

Many studies have found effects of aircraft noise exposure at school or at home on children's reading comprehension or memory skills (Evans and Hygge, 2007). The RANCH study (Road traffic and Aircraft Noise and children's Cognition and Health) of 2844 9-10 year old children from 89 schools around London Heathrow, Amsterdam Schiphol, and Madrid Barajas airports found that aircraft noise was associated with poorer reading comprehension and poorer recognition memory, after taking socioeconomic factors and road traffic noise into account (Stansfeld et al., 2005).

The exposure-response relationship between aircraft noise at school and reading comprehension from the RANCH study (Clark et al., 2006), showed that as aircraft noise exposure increased, performance on the reading test decreased. Reading began to fall below average at around 55 dB LAeq 16 hour at school. The development of cognitive skills such as reading and memory is important not only in terms

of educational achievement but also for subsequent life chances and adult health (Kuh and Ben-Shlomo, 2004). In the UK, reading age was delayed by up to 2 months for a 5 dB increase in aircraft noise exposure (Clark et al., 2006). The UK primary schools in the RANCH study ranged in aircraft noise exposure from 34 dB LAeq 16 hour to 68 dB LAeq 16 hour. The study found that a 20 dB difference in aircraft noise exposure between schools would result in an 8-month difference in reading age.

In the RANCH study, for primary school children, aircraft noise exposure at school and at home were very highly correlated: in the RANCH UK sample, this correlation was r=0.91 (Clark et al., 2006). Such a high correlation makes estimating the impact of aircraft noise exposure in both environments difficult. The RANCH study found that night-time aircraft noise at the child's home was also associated with impaired reading comprehension and recognition memory, but night-noise was not having an additional effect to that of day-time noise exposure on reading comprehension or recognition memory (Clark et al., 2006; Stansfeld et al., 2010). These findings suggest that indices of aircraft noise exposure in the day-time in the school environment should be sufficient to capture effects. Further analyses of the UK RANCH sample found that these associations for aircraft noise exposure remained after controlling for air pollution effects (Clark et al., 2012).

A further study investigating the effects of aircraft noise around Heathrow Airport in the home environments on children's cognition found a significant dose-response relationship between aircraft noise at home and performance on memory tests of immediate and/or delayed recall (Matsui et al., 2004). The study found no associations with other cognitive outcomes.

Two studies of interventions to reduce or remove aircraft noise exposure at school have been conducted. The longitudinal Munich Airport study (Hygge et al., 2002) found that prior to the relocation of the airport in Munich, high noise exposure was associated with poorer long-term memory and reading comprehension in children aged 10 years. Two years after the airport closed these cognitive impairments were no longer present, suggesting that the effects of aircraft noise on cognitive performance may be reversible if the noise stops. In the cohort of children living near the newly opened Munich airport impairments in memory and reading developed over the following two years.

A recent study of 6,000 schools exposed between the years 2000-2009 at the top 46 United States airports, (exposed to Day-Night-Average Sound Level of 55 dB or higher) found significant associations between aircraft noise and standardised tests of mathematics and reading, after taking demographic and school factors into account (Sharp et al., 2014). In a sub-sample of 119 schools, they found that the effect of aircraft noise on children's learning disappeared once the school had sound insulation installed.

Schools located near airports often also experience high levels of road traffic noise but it is important to note that aircraft noise exposure still influences children's learning, even if road traffic noise exposure is high. The results presented for the RANCH study are the association for aircraft noise exposure, after taking road traffic noise into account (Clark et al., 2006).

A study conducted by Haines et al.. (2002) studied a sample of approximately 11,000 11 year old children from 123 schools surrounding Heathrow Airport. The results of the study showed that chronic exposure to aircraft noise was significantly related to poorer reading and mathematics performance. However, after control for socioeconomic factors these associations were no longer statistically significant.

Children spend a considerable amount of time at school in the playground. Play is thought to be important for children's social, cognitive, emotional and physical development, as well as enabling relaxation between more formal teaching activities. The WHO (1999) established a community noise guideline of 55 dB for school playgrounds, during play, to protect against these effects. The WHO community noise guidelines that apply to schools and preschools are summarised in Table 28.

Table 28: WHO Community Noise Guidelines School Environments (WHO, 1999)

School Environment	Critical Health Effects	L_{Aeq} (dB(A))	Time base (hours)	L_{Amax} fast (dB)
School class rooms and preschools indoors	Speech intelligibility, disturbance of information extraction, message communication	35	During class	-
Preschool bedrooms indoors	Sleep disturbance	30	Sleeping time	45
School playground, outdoors	Annoyance (external source)	55	During play	-

6.1.5 Psychological health

It has been suggested that long-term noise exposure might influence psychological health. However, overall the evidence for aircraft noise exposure being linked to poorer well-being, lower quality of life, and psychological ill-health is not as strong or consistent as for other health outcomes, such as cardiovascular disease. A recent study of 2300 residents near Frankfurt airport found that annoyance but not aircraft noise levels per se (LAeq16 hour, Lnight, Lden) was associated with self-reported lower quality of life (Schreckenberg et al., 2010).

Several studies of children around London Heathrow airport have shown no effect of aircraft noise at school on children's psychological health or cortisol levels (Haines et al., 2001a; Haines et al., 2001b; Stansfeld et al., 2009): cortisol levels are known to be raised in children with depression. However, there may be a small effect of aircraft noise on hyperactivity symptoms. The West London Schools Study of 451 children around Heathrow airport, aged 8-11 years found higher rates of hyperactivity symptoms for children attending schools exposed to aircraft noise levels >63 dB LAeq 16 hour compared with <57 dB LAeq 16 hour (Haines et al., 2001a). A similar effect was observed in the RANCH study where a 10 dB LAeq 16 hour increase in aircraft noise exposure at school was associated with 0.13% increase in hyperactivity symptoms (Stansfeld et al., 2009). However, these increases in hyperactivity symptoms, whilst statistically significant, are extremely small and most likely not of clinical relevance. Aircraft noise exposure does not appear to be causing children to develop hyperactivity problems.

There have been fewer studies of aircraft noise effects on adult psychological health. The HYENA study, found that a 10 dB increase in day-time (LAeq 16 hour) noise exposure was associated with a 28% increase in anxiety medication use: similarly, a 10 dB increase in night-time (Lnight) aircraft noise was associated with a 27% increase in anxiety medication use. However, day-time and night-time aircraft noise exposure were not associated with sleep medication or anti-depressant medication use (Floud et al., 2011). Anxiety medication is prescribed for individuals experiencing levels of anxiety and worry that interfere with their ability to function effectively: they can also be prescribed for sleeping problems. A sub-study of the HYENA study found that salivary cortisol (a stress hormone which is higher in people with depression) was 34% higher for women exposed to aircraft noise > 60 dB LAeq 24 hour, compared to women exposed to less than 50 dB LAeq 24 hour (Selander et al., 2009). However, no association between aircraft noise and salivary cortisol was found for men.

6.2 Exposure Assessment

As part of the technical studies being completed for the EIS, an assessment of potential noise and vibration effects has been undertaken (Wilkinson-Murray, 2015 a and b). The exposure data for the noise HRA have been taken from these reports which include aircraft as well as ground operations noise sources.

A number of sensitive receptors were identified for use in the HRA. These are summarised in Table 29.

Table 29: Representative Sensitive Receptors

RECEPTOR	Receptor Number
RESIDENTIAL LOCATIONS	
Bringelly	1
Kemps Creek	4
Erskine Park	9
Kemps Creek 2	22
St Marys	26
Greendale	27
Silverdale	29
Rossmore	30
Horsley Park	32
Rooty Hill	150
Prospect	152
EDUCATIONAL	
Warragamba Preschool	43
Emmaus Catholic College, Kemps Creek	65
Horsley Park Public School	70
Luddenham Public School	73
Bringelly Public School	76
Mount Druitt Public School	142
St Marys South Public School	144
Bennett Road Public School, Colyton	145
Colyton High School	146
St Clair High School	147
Banks Public School, St Clair	148
Blackwell Public School, St Clair	149
Plumpton High School	151

The locations of these receptors are shown in Figure 15. It should be noted that although the schools have been identified primarily for assessment of the impacts of noise on child learning and cognitive development, they are also located in residential areas. Therefore the noise levels predicted at these locations may also be representative of the exposure to noise for the local community. As such, these locations have also been used in the assessment of sleep disturbance. Background noise levels that have been measured as part of the Noise and Vibration Assessment (Wilkinson-Murray, 2015 a and b) are shown in Table 30:

Table 30: Measured Background Noise Levels around Western Sydney Airport (source Wilkinson-Murray, 2015b)

Location	Measurement Duration	Rating Background Level (dBA)		
		Day (7am-6pm)	Evening (6pm-10pm)	Night (10pm-7am)
9 Harold Bentley Way, Glenmore Park	Monday 23/3/15 – Thursday 2/4/15	39	42	38
16 Park Avenue, Springwood	Wednesday 25/3/15 – Thursday 2/4/15	29	32	24
17 Blue Ridge Place, Orchard Hills	Monday 23/3/15 – Tuesday 31/3/15	34	38	36
25 Peter Pan Avenue, Wallacia	Monday 23/3/15 – Thursday 2/4/15	37	34	28
27 Dwyer Road, Bringelly	Monday 23/3/15 – Thursday 2/4/15	33	38	35
35 Ramsay Road, Rossmore	Friday 27/3/15 – Thursday 2/4/15	35	37	35
54 Ridgehaven Road, Silverdale	Thursday 26/3/15 – Thursday 2/4/15	36	36	31
114 Mount Vernon Road, Mount Vernon	Monday 23/3/15 – Thursday 2/4/15	34	35	33
120 Vincent Avenue, Mulgoa	Monday 23/3/15 – Tuesday 31/3/15	38	42	35
Twin Creeks Golf & Country Club (2 Twin Creeks Drive, Luddenham)	Thursday 26/3/15 – Thursday 2/4/15	34	38	33

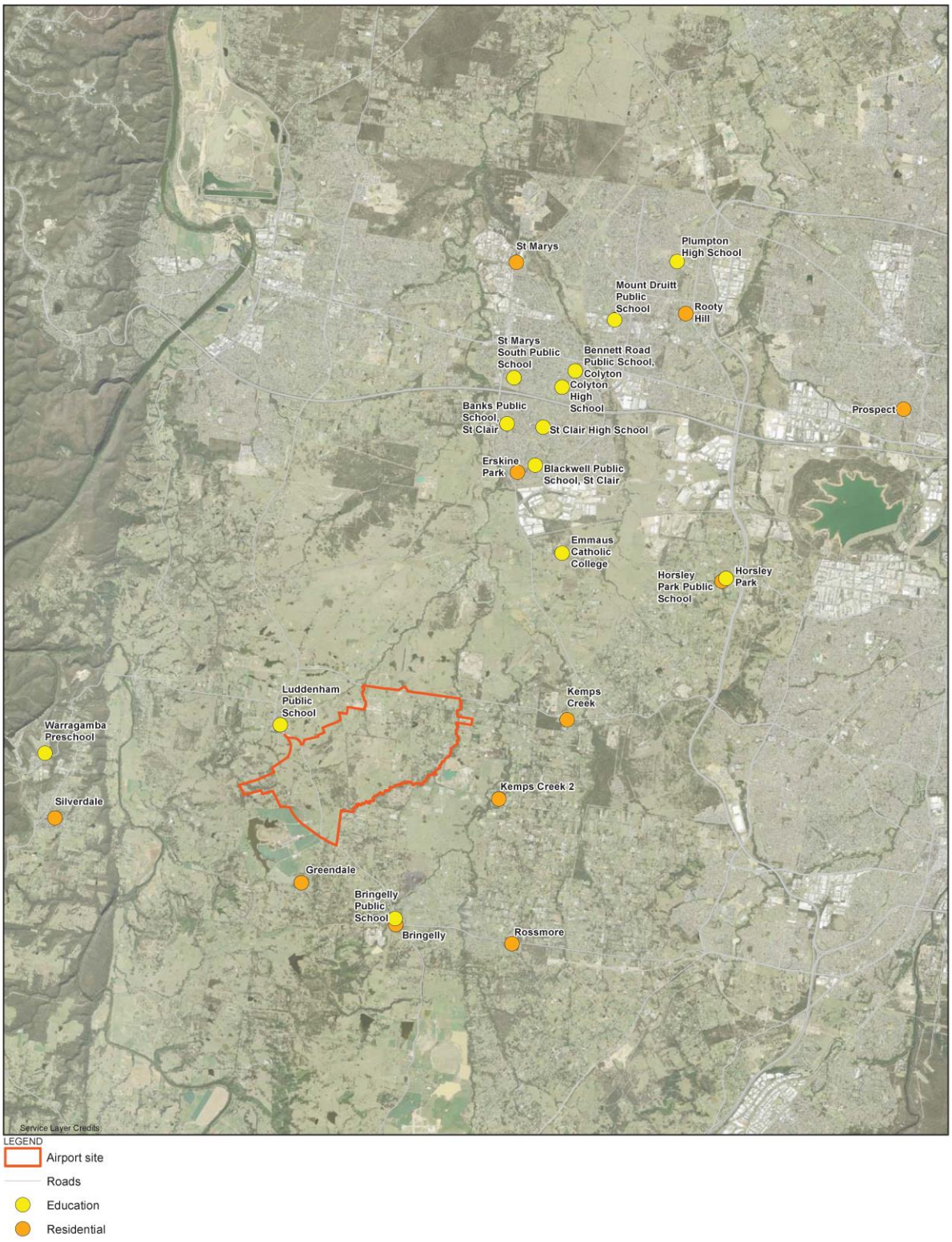
To enable assessment of the potential impacts of aircraft noise, Wilkinson Murray has provided measures of predicted noise exposure in terms of descriptors that are consistent with those used in health studies. The relevant units are:

- $L_{night,outside}$: This unit is used to describe night-time aircraft noise in documents produced by the WHO, and to estimate the risk of chronic health impacts associated with the noise. It represents the equivalent-continuous noise level due to aircraft noise over the period 11pm-7am, calculated on an annual basis as recommended by WHO.
- $L_{Aeq,9am-3pm}$: This unit is used to describe the impact of noise on school students and teachers. It represents the equivalent-continuous noise level due to aircraft noise over the period 9am-3pm, and is once again calculated on an annual basis.

Note that in all cases, these noise levels are calculated at an external point – the noise level within a building will be significantly lower, depending on the building fabric and whether windows and doors are open.

These units were calculated at specific nominated locations, using assumptions and procedures that are described in detail in the noise assessment reports (Wilkinson Murray, 2015 a and b).

Figure 15: Locations of Sensitive Receptors for Noise HRA



Three runway operating modes have been considered for the initial airport development, being "05", "23" and "Head to Head" modes as follows:

- Mode 05: Aircraft arrive from the South West and depart to the North East.
- Mode 23: Aircraft arrive from the North East and depart to the South West.
- Head to Head Mode: Aircraft arrive from the South West and depart to the South West.

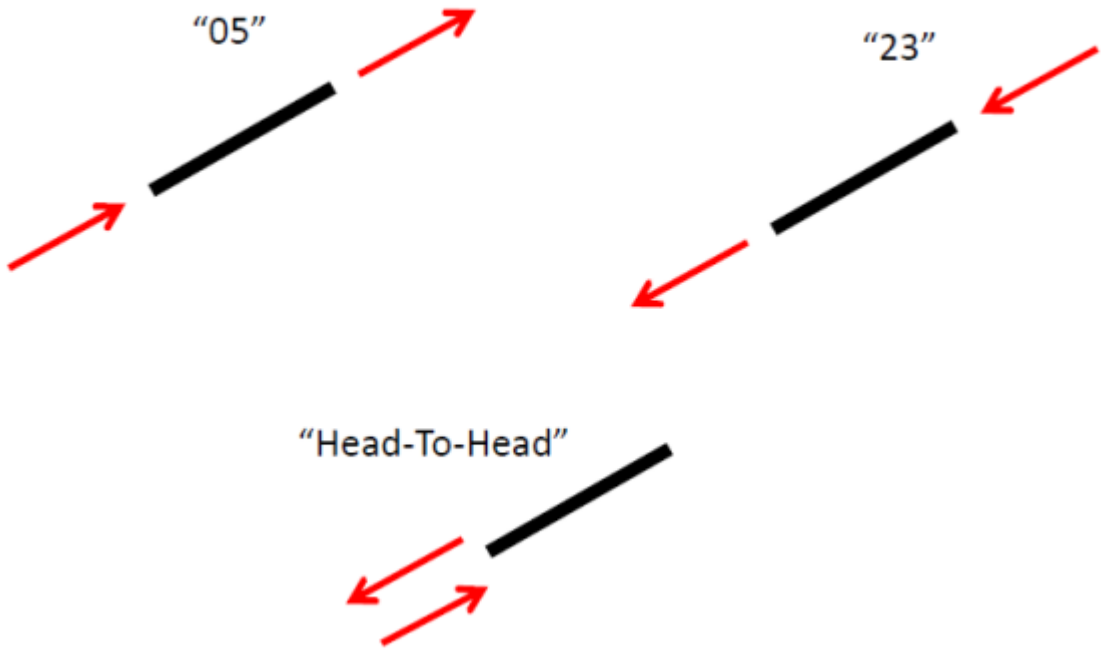
Figure 16 illustrates these modes. Each of these modes may or may not be available at a given time and more than one mode will be used each day, depending on meteorological conditions, particularly wind, number of presenting aircraft, and time of day. However, the assumed order for selection of the modes has an effect on the overall noise impact from the airport.

For daytime operations, two scenarios were considered, in which either the "Prefer 05" or the "Prefer 23" direction is adopted. For night-time operations, the possibility of "head-to-head" operations was also considered, in conjunction with either of the other two modes.

As outlined in Wilkinson Murray's noise assessment report, impacts of this development are considered for two nominal years, namely 2030 and 2050.

Potential impacts are also considered for the long-term case, with dual runways, in nominal year 2063. In this case, only the "Prefer 05" and "Prefer 23" modes are considered.

Figure 16: Potential Airport Operating Mode Options for WSA (Taken from Wilkinson Murray, 2015)



The predicted noise data used in the HRA are summarised in Tables 31 – 32 for aircraft noise and in Table 33 for ground operations noise sources.

Table 31: Daytime L_{Aeq} values 9am-3pm (dB) – aircraft noise (WHO Guideline 55 dB)

Receptor Number	Receptor Name	2030		2050		2063 (two-runway)	
		Prefer 05	Prefer 23	Prefer 05	Prefer 23	Prefer 05	Prefer 23
RESIDENTIAL LOCATIONS							
1	Bringelly	38	35	40	36	37	36
4	Kemps Creek	28	26	32	31	46	43
9	Erskine Park	39	35	45	41	38	35
22	Kemps Creek 2	34	32	37	34	44	41
26	St Marys	37	36	43	41	36	33
27	Greendale	34	36	38	39	48	52
29	Silverdale	32	35	37	40	43	46
30	Rossmore	26	24	28	26	39	35
32	Horsley Park	23	26	28	31	46	48
150	Rooty Hill	30	33	35	38	40	37
152	Prospect	19	23	24	28	42	44
EDUCATIONAL							
43	Warragamba Preschool	25	27	30	32	35	36
65	Emmaus Catholic College Kemps Creek	37	38	42	43	43	43
70	Horsley Park Public School	23	26	28	31	46	48
73	Luddenham Public School	44	46	48	49	49	51
76	Bringelly Public School	39	35	40	36	37	37
142	Mount Druitt Public School	32	34	37	39	43	39
144	St Marys South Public School	38	34	44	40	35	32

145	**Bennett Road Public School**	34	33	39	38	38	35
146	**Colyton High School**	33	34	38	39	40	36
147	**St Clair High School**	36	32	41	37	36	33
148	**Banks Public School**	39	35	45	41	36	32
149	**Blackwell Public School**	37	33	43	38	37	34
151	**Plumpton High School**	30	33	35	38	40	36

Bold indicates exceedance of the adopted criteria

Table 32: L_{Night} outside (equivalent to Leq 11pm-7am)– aircraft noise (WHO Guidelines – night 40 dB, interim target of 55 dB)

Receptor Number	Receptor Name	2030				2050				2063 (two-runway)	
		Prefer 05	Prefer 23	Prefer 05 + H2H	Prefer 23 + H2H	Prefer 05	Prefer 23	Prefer 05 + H2H	Prefer 23 + H2H	Prefer 05	Prefer 23
RESIDENTIAL											
1	**Bringelly**	34	24	24	24	34	27	33	27	33	31
4	**Kemps Creek**	26	24	22	22	30	28	28	27	**42**	37
9	**Erskine Park**	39	26	25	24	**44**	31	39	30	35	28
22	**Kemps Creek 2**	31	26	26	26	33	29	32	29	**40**	34
26	**St Marys**	37	35	30	29	**42**	**40**	38	37	34	26
27	**Greendale**	31	33	33	33	34	36	35	36	**43**	**47**
29	**Silverdale**	30	35	35	35	35	39	39	**40**	39	**44**
30	**Rossmore**	22	17	17	17	24	20	23	20	33	24
32	**Horsley Park**	22	27	22	22	26	32	26	29	**42**	**45**
150	**Rooty Hill**	29	34	28	28	34	39	33	36	38	27
152	**Prospect**	18	24	18	18	23	29	23	26	37	**43**
EDUCATIONAL											

43	**Warragamba Preschool**	24	28	28	28	28	32	32	32	32	34
65	**Emmaus Catholic College, Kemps Creek**	36	39	33	33	**41**	**42**	39	**41**	**41**	**41**
70	**Horsley Park Public School**	22	27	21	22	26	32	26	29	**42**	**46**
73	**Luddenham Public School**	**42**	**44**	**44**	**44**	**46**	**48**	**48**	**48**	**45**	**49**
76	**Bringelly Public School**	34	24	24	24	35	27	34	27	33	32
142	**Mount Druitt Public School**	31	35	29	29	35	39	34	37	**41**	28
144	**St Marys Sth Public School**	38	29	25	25	**43**	34	38	32	32	27
145	**Bennett Road Public School**	34	32	27	27	38	37	34	34	36	27
146	**Colyton High School**	33	34	28	28	37	38	34	35	38	28
147	**St Clair High School**	35	27	23	23	**40**	32	35	29	34	27
148	**Banks Public School**	39	26	25	24	**44**	31	39	30	33	27

149	**Blackwell Public School**	37	26	23	23	**42**	30	36	29	34	28
151	**Plumpton High School**	29	34	28	28	33	39	33	36	38	26

Bold indicates exceedance of the adopted criteria
(Note H2H refers to Head to Head mode)

Table 33: Predicted noise levels for day and night from ground operations noise (WHO Guidelines – night 40 dB, interim target 55 dB; daytime 55 dB)

Receptor	L_{night} dB			L_{Aeq} day (9am-3pm) dB		
	2030	2050	2063	2030	2050	2063
RESIDENTIAL						
Bringelly	36	38	**43**	39	40	45
Kemps Creek	32	35	39	35	37	41
Erskine Park	26	28	32	28	30	34
Kemps Creek 2	36	39	**45**	39	41	47
St Marys	17	20	22	20	21	24
Greendale	**42**	**43**	**47**	45	46	48
Silverdale	29	30	34	32	33	35
Rossmore	30	32	37	32	34	39
Horsley Park	21	24	27	23	25	29
Rooty Hill	15	18	21	18	19	23
Prospect	11	14	18	14	16	20
EDUCATIONAL						
Luddenham Public School	**51**	**53**	**55**	54	**55**	**58**
Warragamba Preschool	28	30	33	31	32	34
Bringelly Public School	37	38	**44**	39	41	46
Emmaus Catholic College, Kemps Creek	27	28	32	30	32	36
Blackwell Public School	25	27	31	27	29	33
Banks Public School	24	26	29	26	28	31
St Clair High School	23	25	29	25	27	31
St Marys South Public School	23	25	29	24	25	28
Horsley Park Public School	21	23	27	23	25	29
Bennett Road Public School	21	23	27	23	25	29

Colyton High School	20	22	26	22	24	28
Mount Druitt Public School	17	20	23	20	21	25
Plumpton High School	14	17	20	17	18	22

Bold indicates exceedance of the adopted criteria

The data shown in Tables 31 and 32 have been used to characterise the health risk associated with exposure to noise from aircraft. The data in Table 33 has been used to calculate the potential health risks associated with ground based operations for the proposed airport. The details of the noise modelling are contained within the EIS noise assessment reports (Wilkinson Murray, 2015 a and b).

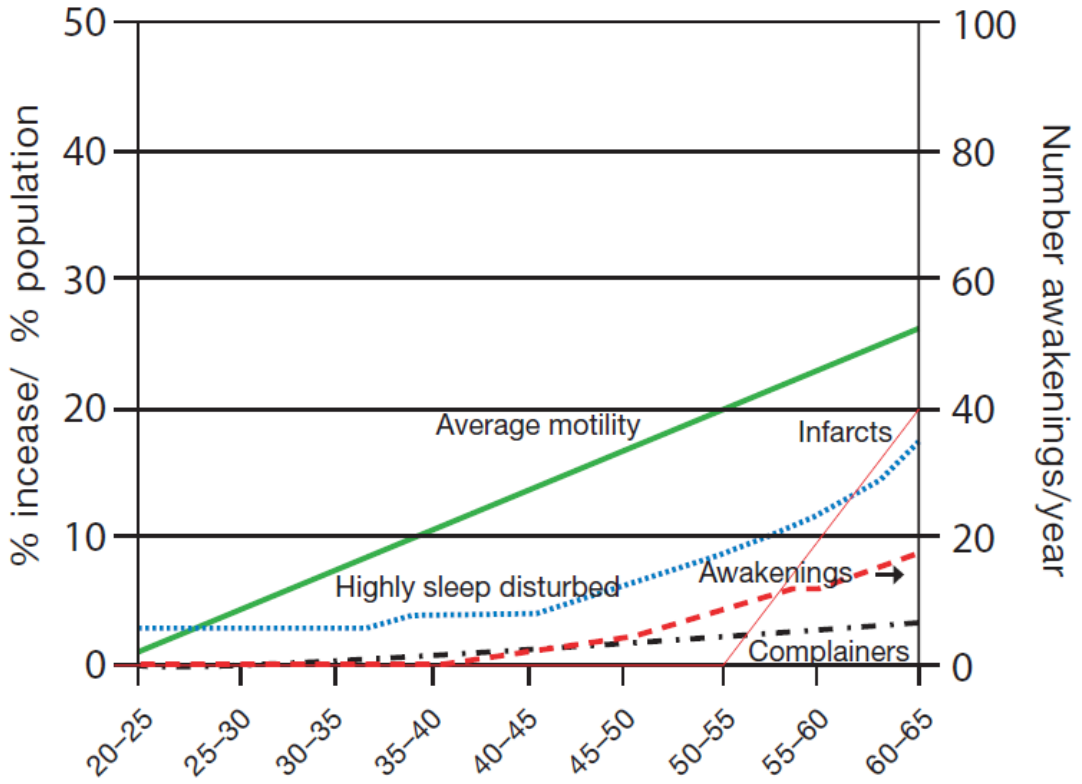
6.3 Risk Characterisation

To characterise the risk to aircraft noise from the proposed airport, three health outcomes have been assessed:

1. Sleep Disturbance assessed as awakenings
2. Increase in Myocardial Infarction
3. Impacts on learning and cognitive development in children

The dose-response relationships from WHO (2009) have been used in the risk calculations for myocardial infarctions and induced awakenings. The WHO dose-response relationships are shown in Figure 17:

Figure 17: Dose Response Relationships for Aircraft Noise Related Health Effects (Reproduced from WHO, 2009; original source European Commission, 2002). The noise metric used is $L_{night, outside}$.



In Figure 17, average motility and infarcts are expressed in percent increase (compared to the baseline number); the number of highly sleep disturbed people is expressed as percent of the population: complainers are expressed as a percent of the neighbourhood population; awakenings are expressed in number of additional awakenings per year.

WHO (2009) identified the health effects that are associated with noise (including aircraft noise) and these are summarised in Table 34:

Table 34: Effects of Different Levels of Night Noise on Population Health (WHO, 2009).

Average night noise level over a year $L_{night\ outside}$	Health effects observed in the population
Up to 30 dB	Although individual sensitivities and circumstances may differ, up to this level no substantial biological effects are observed. $L_{night\ outside}$ of 30 dB is equivalent to the no observed effects level (NOEL) for night noise
30 to 40 dB	A number of effects on sleep are observed in this range: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effects depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst case the effects are modest. $L_{night\ outside}$ of 40 dB is equivalent to the lowest observed adverse effects level (LOAEL) for night noise.
40 to 55 dB	Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with noise at night. Vulnerable groups are more severely affected.
Above 55 dB	The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a sizeable portion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases.

Below the level of 30 dB $L_{night,\ outside}$, no effects on sleep are observed except for a slight increase in the frequency of body movements during sleep due to night noise. There is insufficient evidence that the biological effects observed below 40 dB $L_{night,\ outside}$ are harmful to health (WHO, 2009). The WHO (2009) however concluded that adverse health effects are observed above 40 dB $L_{night,\ outside}$, such as self-reported sleep disturbance, environmental insomnia and increased use of sleeping pills and sedatives. Above 55 dB the cardiovascular effects become a major public health concern (WHO, 2009). These effects are likely to be less dependent on the nature of the noise. The WHO recommended that for the prevention of subclinical adverse health effects associated with night noise in the population, that the population should not be exposed to night noise levels greater than 40 dB $L_{night,\ outside}$. The WHO (2009) adopted 40 dB as the night noise guideline necessary to protect public health including the most vulnerable groups – children, the chronically ill and the elderly. An interim target of 55 dB was recommended in situations where the night noise guideline was not feasible in the short term but WHO emphasized that this value is not a health-based limit. Vulnerable groups cannot be protected at this level (WHO, 2009).

The purpose of the risk characterization is to estimate potential risks associated with exposure to noise from the proposed airport operations. For the assessment of health effects where there is a known threshold for effect, the predicted noise level for each averaging period is compared to the health

based guideline values as set by WHO (1999: 2009). The ratio of the predicted level to the guideline is termed the hazard quotient (HQ):

HQ = predicted noise level / health based guideline

The hazard quotients are estimated for each of the averaging periods relevant to the guidelines for a given health outcome. The hazard quotient approach has been used to assess the potential impact on children's learning and cognitive development. This applies to daytime noise only.

Where dose-response data are available, quantification of the increase in adverse health effects has been undertaken. This approach has been used for the assessment of awakenings and increases in myocardial infarction. This has been done fro night-time noise.

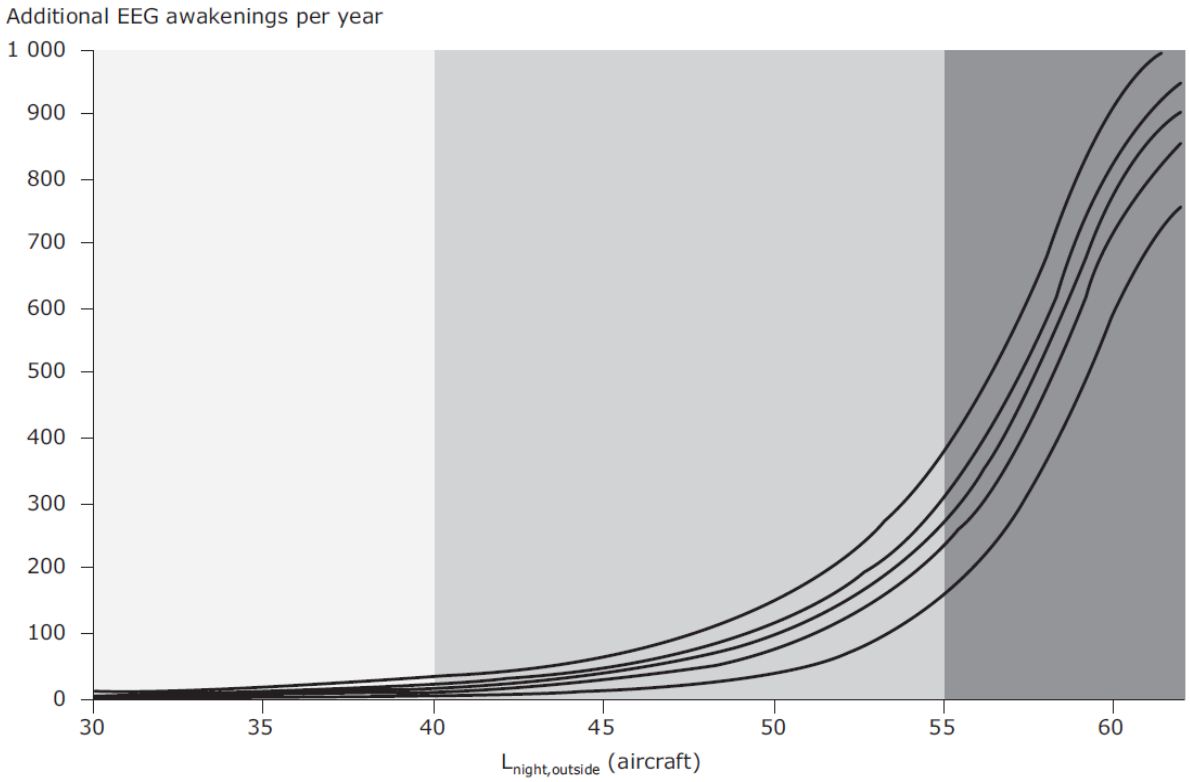
6.3.1 Awakenings

For night-time noise, the Wilkinson Murray (2015) report prepared as part of the EIS found that the extent of night time noise impact depends on the airport operating strategy, and in particular, the adoption of a "Head-to-Head" operating mode where practicable.

In terms of total population affected, the mode option with least impact is "Prefer 23 with Head-to-Head". In assessment year 2030, a "Prefer 05" operating mode option at night would result in an estimated 48,000 people experiencing more than 5 events above 60 dBA at night. This is reduced to approximately 6,000 with a "Prefer 23" operating mode option, or 4,000 if a "Head to Head" mode is included. Under a Prefer 23 with Head-to-Head mode option, an estimated 41,000 residents would experience an average of more than 5 aircraft noise events per night above 60 dBA in 2050. An external noise level of 60 dBA corresponds to an internal level of approximately 50 dBA if windows are open to a normal extent, which is the design criterion for aircraft noise in sleeping areas under Australian Standard 2021. Under the above scenario, the affected residents would be largely in areas to the north-east of the airport, including Horsley Park and parts of Blacktown. However some residents to the south-west of the airport would be more severely affected. Alternative airport operating modes are predicted to result in substantially greater numbers of residents impacted by night time noise, and in particular, a "Prefer 05" mode would result in large parts of St Marys experiencing more than 20 aircraft noise events per night above 60 dBA in 2050.

Two approaches have been taken to assessing awakenings. The first is to estimate the number of EEG awakenings that may be associated with aircraft noise and the second is to assess full awakenings. An EEG awakening is not a fully awakened state but is a measure of disturbed sleep. The dose response curves shown in the EEA *Good Practice Guide on Noise Exposure and Potential Health Effects* (EEA, 2010) have been used to estimate the number of EEG awakenings due to both aircraft and ground operational sources. The EEA identify that 33 dB $L_{night,outside}$ appears to be a threshold value for awakenings related to aircraft noise and below this, sleep disturbance is unlikely to occur. The dose response curves are shown in Figure 18:

Figure 18: Dose Response Curves for EEG Awakenings due to Aircraft Noise (reproduced from EEA, 2010)



The vertical axis in Figure 18 indicates the average number of additional EEG awakenings across a population per year. The shaded areas show the WHO guideline values for night-time noise L_{night} ranges 30-40dB, 40-55dB, >55dB

The data shown in Tables 31 and 32 have been used together with the dose-response data in Figure 18 to estimate the additional number of EEG awakenings per year an individual might experience due to the noise from airport operations. To put these results into context, the EEA (2010) noted that per person, there are usually 24 EEG awakenings per night even during undisturbed 8-hour night sleep. The results for aircraft noise are shown in Table 35 and for ground operations noise in Table 36.

Table 35: Predicted Number of Additional EEG Awakenings Per Person Per Year due to aircraft noise

RECEPTOR	Receptor Number	Lnight									
		2030				2050				2063	
		Prefer 05	Prefer 23	Prefer 05 + H2H	Prefer 23 + H2H	Prefer 05	Prefer 23	Prefer 05 + H2H	Prefer 23 + H2H	Prefer 05	Prefer 23
Bringelly I	1	5	0	0	0	5	0	0	0	0	0
Kemps Creek	4	0	0	0	0	0	0	0	0	40	25
Erskine Park	9	40	0	0	0	40	0	40	0	10	0
Kemps Creek 2	22	0	0	0	0	0	0	0	0	30	5
St Marys	26	25	10	0	0	40	30	40	0	5	0
Greendale	27	0	0	0	0	0	25	10	1	40	100
Silverdale	29	0	10	10	10	10	40	40	30	40	40
Rossmore	30	0	0	0	0	0	0	0	0	0	0
Horsley Park	32	0	0	0	0	0	0	0	0	40	50
Rooty Hill	150	0	5	0	0	5	40	0	10	40	0
Prospect	152	0	0	0	0	0	0	0	0	25	40
SCHOOL LOCATIONS REPRESENTATIVE OF LOCAL COMMUNITY EXPOSURES											

Warragamba Preschool	**43**	0	0	0	0	0	0	0	0	0	5
Emmaus Catholic College, Kemps Creek	**65**	25	40	0	0	30	40	40	30	30	30
Horsley Park Public School	**70**	0	0	0	0	0	0	0	0	40	50
Luddenham Public School	**73**	40	40	40	40	50	100	100	100	50	110
Bringelly Public School	**76**	5	0	0	0	10	0	5	0	0	0
Mount Druitt Public School	**142**	0	10	0	0	10	40	5	25	40	0
St Marys South Public School	**144**	40	0	0	0	40	5	40	0	0	0
Bennett Road Public School	**145**	5	0	0	0	40	25	5	5	25	0
Colyton High School	**146**	0	5	0	0	25	40	5	10	40	0
St Clair High School	**147**	10	0	0	0	30	0	10	0	5	0
Banks Public School	**148**	40	0	0	0	40	0	40	0	0	0

Blackwell Public School	**149**	25	0	0	0	40	0	25	0	5	0
Plumpton High School	**151**	0	5	0	0	0	40	0	10	40	0

The results for EEG awakenings for ground operations noise are shown in Table 36:

Table 36: Predicted Number of additional EEG Awakenings Per Person Per Year due to Ground Operations Noise

Name	Lnight			Awakenings		
	2030	2050	2063	2030	2050	2063
Residential locations						
Bringelly	36	38	43	30	40	60
Kemps Creek	32	35	39	15	25	42
Erskine Park	26	28	32	0	0	15
Kemps Creek 2	36	39	45	30	45	75
St Marys	17	20	22	0	0	0
Greendale	42	43	47	50	60	100
Silverdale	29	30	34	0	0	25
Rossmore	30	32	37	0	15	35
Horsley Park	21	24	27	0	0	0
Rooty Hill	15	18	21	0	0	0
Prospect	11	14	18	0	0	0
Educational locations representative of community exposures						
Luddenham Public School	51	53	55	190	240	400
Warragamba Preschool	28	30	33	0	00	20
Bringelly Public School	37	38	44	35	40	70
Emmaus Catholic College, Kemps Creek	27	28	32	0	0	15
Blackwell Public School, St Clair	25	27	31	0	0	10
Banks Public School, St Clair	24	26	29	0	0	0
St Clair High School	23	25	29	0	0	0
St Marys Sth Public School	23	25	29	0	0	0
Horsley Park Public School	21	23	27	0	0	0
Bennett Road Public School, Colyton	21	23	27	0	0	0
Colyton High School	20	22	26	0	0	0
Mount Druitt Public School	17	20	23	0	0	0
Plumpton High School	14	17	20	0	0	0

The results shown in Tables 35 and 36 indicate that there are several areas where there would be a significant increase in the number of awakenings from both aircraft and ground operations noise. The most affected area is Luddenham where in 2030, there are predicted to be up to 40 additional EEG awakenings per year due to aircraft noise and up to 190 additional EEG awakenings per year due to ground operations noise. In 2063, an additional 110 and 400 EEG awakenings are predicted for Luddenham from aircraft and ground operations noise respectively, The 2011 population of Luddenham was 1496 people. It should be noted that a significant proportion of the Luddenham and Badgerys Creek populations will be relocated as a consequence of the airport construction. This means that the number of people living in the affected areas will be substantially lower than the 2011

population figures. Other affected areas would include Bringelly, Greendale, Warragamba and Rossmore.

As discussed previously, EEG awakenings are not considered a health effect in itself, however they are considered to be early warning signals for other health effects when the values rise above the background levels of around 24 EEG awakenings per night (EEA, 2010).

It should also be noted that the dose-response curves shown in Figure 18 are derived from European studies where outdoor noise levels have been associated with sleep disturbance. In general, European buildings are better insulated than Australian buildings due to climatic conditions. Therefore, the attenuation achieved from outdoors to indoors is likely to be greater than in Australia, meaning that the indoor noise levels associated with EEG awakenings in Australia may be associated with lower outdoor noise levels than in Europe. This would mean that the number of predicted additional awakenings may be underestimated in the areas surrounding the Western Sydney airport site.

For full awakenings, the WHO dose-response curves shown in Figure 17 have been used to estimate the potential increases in awakenings for each of the runway operating modes assessed. The results shown in Table 37 are presented for aircraft noise and Table 38 for ground operations noise and show the number of additional awakenings per persone per year:

Table 37: Predicted **Number of Additional Awakenings per person per Year due to Aircraft Noise under each Operating Scenario**

RECEPTOR	Receptor Number	Lnight									
		2030				2050				2063	
		Prefer 05	Prefer 23	Prefer 05 + H2H	Prefer 23 + H2H	Prefer 05	Prefer 23	Prefer 05 + H2H	Prefer 23 + H2H	Prefer 05	Prefer 23
Bringelly	1	0	0	0	0	1	0	0	0	0	0
Kemps Creek	4	0	0	0	0	0	0	0	0	3	1
Erskine Park	9	1	0	0	0	5	0	1	0	0	0
Kemps Creek 2	22	0	0	0	0	0	0	0	0	3	1
St Marys	26	1	1	0	0	3	1	1	1	0	0
Greendale	27	0	0	0	0	0	1	1	1	3	10
Silverdale	29	0	1	1	1	1	1	1	1	3	5
Rossmore	30	0	0	0	0	0	0	0	0	0	0
Horsley Park	32	0	0	0	0	0	0	0	0	3	10
Rooty Hill	150	0	1	0	0	0	1	0	1	1	0
Prospect	152	0	0	0	0	0	0	0	0	1	3

SCHOOL LOCATIONS REPRESENTATIVE OF LOCAL COMMUNITY EXPOSURES											
Warragamba Preschool	**43**	0	0	0	0	0	0	0	0	0	0
Emmaus Catholic College, Kemps Creek	**65**	1	1	0	0	0	3	1	1	3	5
Horsley Park Public School	**70**	0	0	0	0	0	0	0	0	3	10
Luddenham Public School	**73**	3	3	5	5	10	10	10	10	5	10
Bringelly Public School	**76**	0	0	0	0	1	0	0	0	0	0
Mount Druitt Public School	**142**	0	1	0	0	1	1	0	1	3	0
St Marys Sth Public School	**144**	1	0	0	0	3	0	1	1	0	0
Bennett Road Public School	**145**	0	0	0	0	1	1	1	1	1	0
Colyton High School	**146**	0	0	0	0	1	1	1	1	1	0
St Clair High	**147**	1	0	0	0	3	0	1	0	0	0

School											
Banks Public School	**148**	1	0	0	0	3	0	1	0	0	0
Blackwell Public School	**149**	1	0	0	0	3	0	1	0	1	0
Plumpton High School	**151**	0	1	0	0	0	1	0	1	1	0

The results shown in Table 37 indicate that based on the $L_{night\ outside}$ noise levels, the predicted number of additional awakenings per person per year due to aircraft noise alone for all three scenarios is between 0-5 in 2030 and between 0-10 per person in 2063. The highest predicted number of awakenings is for 2063 with the most affected areas including Luddenham, Greendale and Horsley Park. For most areas assessed, aircraft noise would be unlikely to lead to any additional full awakenings. As with the EEG awakenings, the dose-response curves have been derived from European studies and may underestimate the impact in the area surrounding the Western Sydney airport site.

The results for ground operations are shown in Table 38.

Table 38: Predicted Number of Full Awakenings Per Person Per Year from Ground Operations

Name	Lnight			Awakenings		
	2030	2050	2063	2030	2050	2063
Residential locations						
Bringelly	36	38	43	1	2	2
Kemps Creek	32	35	39	0	0	2
Erskine Park	26	28	32	0	0	0
Kemps Creek 2	36	39	45	1	2	5
St Marys	17	20	22	0	0	0
Greendale	42	43	47	1	2	8
Silverdale	29	30	34	0	0	0
Rossmore	30	32	37	0	0	1
Horsley Park	21	24	27	0	0	0
Rooty Hill	15	18	21	0	0	0
Prospect	11	14	18	0	0	0
Educational locations representative of community exposures						
Warragamba Preschool	28	30	33	0	0	0
Emmaus Catholic College, Kemps Creek	27	28	32	0	0	0
Horsley Park Public School	21	23	27	0	0	0
Luddenham Public School	51	53	55	10	12	15
Bringelly Public School	37	38	44	1	2	3
Mount Druitt Public School	17	20	23	0	0	0
St Marys Sth Public School	23	25	29	0	0	0
Bennett Road Public School, Colyton	21	23	27	0	0	0
Colyton High School	20	22	26	0	0	0
Banks Public School, St Clair	24	26	29	0	0	0
St Clair High School	23	25	29	0	0	0
Blackwell Public School, St Clair	25	27	31	0	0	0
Plumpton High School	14	17	20	0	0	0

As can be seen from Table 38, the predicted noise from ground operations has a greater impact in the suburbs closest to the proposed airport, in particular Luddenham. In 2030, the number of additional awakenings is calculated to be between 0-10 and in 2063 between 0-15. The combined effects of aircraft and ground operations noise is predicted to lead to an additional 25 full awakenings per person per year in Luddenham in 2063. Other affected areas include Greendale, Kemps Creek, Rossmore and Bringelly.

6.3.2 Cardiovascular Effects

The WHO has identified that the NOAEL for increases for myocardial infarction (heart attacks) is 55 dB $L_{night, outside}$. For all receptors assessed for overflight noise, the $L_{night, outside}$ predicted levels were below 55 dB (see Table 28). This was observed for all years assessed and all operating modes. On the basis of these results, it can be concluded that the aircraft noise would not lead to any increased risk in myocardial infarction in nearby communities.

Based on the WHO exposure response curve presented in Figure 17, the ground operations noise levels predicted for Luddenham may result in an increase in myocardial infarction (an indicator of ischaemic heart disease) of approximately 2% in 2030. In 2063, the increase is predicted to be about 10%. Mitigation measures should be considered to reduce this impact. This assessment has assumed that the total population of Luddenham is exposed to the noise levels predicted by Wilkinson-Murray. The 2011 total population of Luddenham is 1496 people but would be substantially lower now following the relocation of the airport residents in 2015.

6.3.3 Learning and Cognitive Development in Children

The aircraft noise report found that the noise impact around the airport would depend primarily on the airport operating mode that was adopted by Air Traffic Control. The two basic operating scenarios that have been assessed are – "Prefer 05" in which aircraft approach and depart the airport in a south-west to north-east direction (unless this is not possible due to wind or other conditions), and "Prefer 23" in which the opposite direction is preferred. A "Head-to-Head" mode of operation, in which aircraft both approach and depart to the south-west, is also considered for night time operations.

In assessment year 2030, a "Prefer 05" operating scenario at night would result in an estimated 48,000 people experiencing more than 5 events above 60 dBA at night. This is reduced to approximately 6,000 with a "Prefer 23" operating scenario, or 4,000 if a "Head to Head" mode is included. However, as for daytime noise, "Prefer 23" or "Head to Head" result in slightly more people experiencing higher noise impacts. These will be residents in rural residential areas to the south and west of the airport (Wilkinson-Murray, 2015a).

The potential risk arising from aircraft noise on children's learning and cognitive development is related to daytime noise and has been undertaken using the hazard quotient approach. For this assessment, the WHO Community Noise Guidelines (1999) have been used.

Two approaches have been taken:

1. Assessment based on outside predicted levels
2. Assessment using the indoor guideline assuming a 10 dB reduction in noise levels due to noise attenuation by buildings.

The relevant WHO guidelines are shown in Table 27. The predicted daytime noise levels for each of the school locations identified as sensitive receivers are shown in Table 28. The resulting hazard quotients (HQ) are shown in Table 39 for outdoors and Table 40 for indoors for aircraft noise.

Table 39: Hazard Quotients for Learning and Cognitive Development in Children – outside for aircraft noise (WHO Guideline 55dB)

	2030						2050						2063 (two-runway)					
Receptor	**Prefer 05**			**Prefer 23**			**Prefer 05**			**Prefer 23**			**Prefer 05**			**Prefer 23**		
	L_{Aeq} 9am – 3pm (dB)	dB above or below guideline	HQ	L_{Aeq} 9am – 3pm (dB)	dB above /below guideline	HQ	L_{Aeq} 9am – 3pm (dB)	dB above /below guideline	HQ	L_{Aeq} 9am – 3pm (dB)	dB above /below guideline	HQ	L_{Aeq} 9am – 3pm (dB)	dB above /below guideline	HQ	L_{Aeq} 9am – 3pm (dB)	dB above /below guideline	HQ
Warragamba Preschool	25	-30	0.5	27	-28	0.5	30	-25	0.5	32	-23	0.6	35	-20	0.6	36	-19	0.7
Emmaus Catholic College, Kemps Creek	37	-18	0.7	38	-17	0.7	42	-13	0.8	43	-12	0.8	43	-12	0.8	43	-12	0.8
Horsley Park Public School	23	-32	0.4	26	-29	0.5	28	-27	0.5	31	-24	0.6	46	-9	0.8	48	-7	0.9
Luddenham Public School	44	-11	0.8	46	-9	0.8	48	-7	0.9	49	-6	0.9	49	-6	0.9	51	-4	0.9
Bringelly Public School	39	-16	0.7	35	-20	0.6	40	-15	0.7	36	-19	0.7	37	-18	0.7	37	-18	0.7
Mount Druitt Public	32	-23	0.6	34	-21	0.6	37	-18	0.7	39	-16	0.7	43	-12	0.8	39	-16	0.7

School																		
St Marys Sth Public School	38	-17	0.7	34	-21	0.6	44	-11	0.8	40	-15	0.7	35	-20	0.6	32	-23	0.6
Bennett Road Public School	34	-21	0.6	33	-22	0.6	39	-16	0.7	38	-17	0.7	38	-18	0.7	35	-20	0.6
Colyton High School	33	-22	0.6	34	-21	0.6	38	-17	0.7	39	-16	0.7	40	-15	0.7	36	-19	0.6
St Clair High School	36	-19	0.7	32	-23	0.6	41	-14	0.7	37	-18	0.7	36	-19	0.6	33	-22	0.6
Banks Public School	39	-16	0.7	35	-20	0.6	45	-10	0.8	41	-14	0.8	36	-19	0.6	32	-23	0.6
Blackwell Primary School	37	-18	0.7	33	-22	0.6	43	-12	0.8	38	-17	0.7	37	-18	0.7	34	-21	0.6
Plumpton High School	30	-25	0.6	33	-22	0.6	35	-20	0.6	38	-17	0.7	40	-15	0.7	36	-19	0.6

Table 40: Hazard Quotients for Learning and Cognitive Development in Children – inside assuming 10 dB attenuation (WHO Guideline 35dB)

	2030				2050				2063 (two-runway)			
Receptor	**Prefer 05**	**HQ**	**Prefer 23**	**HQ**	**Prefer 05**	**HQ**	**Prefer 23**	**HQ**	**Prefer 05**	**HQ**	**Prefer 23**	**HQ**
Warragamba Preschool	15	0.4	17	0.5	20	0.6	22	0.6	25	0.7	27	0.8
Emmaus Catholic College, Kemps Creek	27	0.8	28	0.8	32	0.9	33	**1**	33	**1**	33	**1**
Horsley Park Public School	13	0.4	16	0.5	18	0.5	21	0.6	36	**1**	38	**1.1**
Luddenham Public School	34	**1**	36	**1.0**	38	**1.1**	39	**1.1**	39	**1.1**	41	**1.2**
Bringelly Public School	29	0.8	25	0.7	30	0.9	26	0.8	27	0.8	27	0.8
Mount Druitt Public School	22	0.6	24	0.7	27	0.8	29	0.8	33	0.9	29	0.8
St Marys Sth Public School	28	0.8	24	0.7	34	**1**	30	0.9	25	0.7	22	0.6
Bennett Road Public School	24	0.7	23	0.7	29	0.8	28	0.8	28	0.8	25	0.7
Colyton High School	23	0.7	24	0.7	28	0.8	29	0.8	30	0.9	26	0.7

St Clair High School	26	0.7	22	0.6	31	0.9	27	0.8	26	0.8	23	0.7
Banks Public School	29	0.8	25	0.7	35	**1**	31	0.9	26	0.7	22	0.6
Blackwell Primary School	27	0.8	23	0.7	33	0.9	28	0.8	27	0.8	24	0.7
Plumpton High School	20	0.6	23	0.7	23	0.7	28	0.8	30	0.88	26	0.7

Note: 10 dB has been subtracted from outdoor noise levels in Table 40 to provide an estimate of indoor noise levels.
Number in bold indicate hazard quotient graeter than or equal to 1

As can be seen from Tables 39 and 40, most hazard quotients are less than 1 indicating that the risk from the aircraft noise from each of the proposed modes of operation generally does not pose an unacceptable risk with respect to children's learning and cognitive development. For outdoor noise, the actual predicted L_{day} values are between 6 dB and 25 dB below the relevant WHO guideline. Hazard quotients less than 1 are considered to be an acceptable level of risk (enHealth, 2012).

In some cases, there are marginal exceedances of 1. This does not mean that there will be an impact on children's learning and cognitive development but that there is an increased risk albeit very low. The main impact is at Luddenham where the predicted noise levels are between 4 and 6 dB below the indoor guidelines in 2063. According to enHealth (2004) and WHO (1999), a 10 dB increase in noise is associated with a doubling of the loudness and is noticeable. Noise mitigation measures recommended as part of the noise technical report will lead to a reduction in this potential risk.

For ground operations noise, the HQ results are shown in Tables 41 and 42:

Table 41: Hazard Quotients for Learning and Cognitive Development in Children – inside for ground-based noise assuming 10 dB attenuation (WHO guideline 35 dB)

Receptor	Lday 2030 dB	Hazard Quotient – indoors	Lday 2050 dB	Hazard Quotient – indoors	Lday 2063 dB	Hazard Quotient – indoors
Warragamba Preschool	31	0.6	32	0.6	34	0.7
Emmaus Catholic College, Kemps Creek	30	0.6	32	0.6	36	0.7
Horsley Park Public School	23	0.4	25	0.4	29	0.5
Luddenham Public School	54	**1.3**	55	**1.3**	58	**1.4**
Bringelly Public School	39	0.8	41	0.9	46	**1.0**
Mount Druitt Public School	20	0.3	21	0.3	25	0.4
St Marys Sth Public School	24	0.4	25	0.4	28	0.5
Bennett Road Public School	23	0.4	25	0.4	29	0.5
Colyton High School	22	0.3	24	0.4	28	0.5
St Clair High School	25	0.4	27	0.5	31	0.6
Banks Public School	26	0.5	28	0.5	31	0.6
Blackwell Public School	27	0.5	29	0.5	33	0.7
Plumpton High School	17	0.2	18	0.2	22	0.3

As can be seen from Table 41, the greatest impact from ground operations noise indoors is at Luddenham. The hazard quotients experienced at Luddenham exceed 1 suggesting that noise mitigation measures should be implemented. The hazard quotients above 1 correspond to an increase in noise levels above the guideline value of between 19 and 23 dB indicating a significant increase in

noise levels. The data shown in Table 42 show a similar pattern for outside noise with the hazard quotients exceeding 1 at Luddenham in 2063.

Table 42: Hazard Quotients for Learning and Cognitive Development in Children – outside (WHO Guideline 55 dB)

Receptor	2030	Hazard Quotient outdoors	2050	Hazard Quotient outdoors	2063	Hazard Quotient outdoors
Warragamba Preschool	31	0.6	32	0.6	34	0.6
Emmaus Catholic College	30	0.5	32	0.6	36	0.7
Horsley Park Public School	23	0.4	25	0.5	29	0.5
Luddenham Public School	54	1.0	55	**1.0**	58	**1.1**
Bringelly Public School	39	0.7	41	0.7	46	0.8
Mount Druitt Public School	20	0.4	21	0.4	25	0.5
St Marys Sth Public School	24	0.4	25	0.5	28	0.5
Bennett Road Public School	23	0.4	25	0.5	29	0.5
Colyton High School	22	0.4	24	0.4	28	0.5
St Clair High School	25	0.5	27	0.5	31	0.6
Banks Public School	26	0.5	28	0.5	31	0.6
Blackwell Public School	27	0.5	29	0.5	33	0.6
Plumpton High School	17	0.3	18	0.3	22	0.4

Bold numbers indicate hazard quotient greater than or equal to 1 indicating exceedance of guideline value..

6.4 Summary

The HRA has been conducted for noise impacts from aircraft and ground operations noise sources. Based on the results of the noise assessment, the risk posed to the health of the exposed communities is generally low. No increase in cardiovascular outcomes is likely from aircraft noise as the predicted night noise levels are below the threshold for adverse effects. However, ground operations noise is predicted to be above the threshold value of 55 dB Lnight and may lead to a 10% increase in myocardial infarctions in Luddenham in 2063 if not mitigated.

A significant increase in EEG awakenings is predicted especially in Luddenham. In 2030, it is predicted that there would be 190 additional EEG awakenings per person per year and an additional 400 EEG awakenings per person per year with ground-based noise in 2063. For full awakenings, the number is lower but still highest in Luddenham. There is a greater predicted impact from ground- operations noise than aircraft noise. Mitigation measures in the noise assessment report should be implemented and would reduce this impact.

Impacts on children's learning and cognitive development are predicted to be within acceptable risk levels for most locations for aircraft noise. The impact of ground operations noise is more substantial. In Luddenham, increases of up to 3 dB above the WHO guideline are predicted for outdoor noise levels in 2063. Mitigation measures should be implemented at these locations to reduce this risk to within acceptable levels. For the indoor assessment, assuming a 10 dB attenuation from predicted outdoor

levels, the hazard quotients above 1 correspond to an increase in noise levels above the guideline value of between 19 and 23 dB in 2030 and 2063 respectively at Luddenham indicating a significant increase in noise levels. Mitigation measures should be implemented to reduce this risk to within acceptable levels.

According to the Wilkinson-Murray reports there are practical limits on the mitigation measures that can be applied to reduce the impact of ground operations noise sources. Although in theory it is possible to locate buildings and construct earth mounds in positions that may shield affected receivers from noise sources, in practice this is difficult to achieve. Space is required around the runway for safety and other reasons and access to the runway is required. Also, to facilitate mitigation of aircraft noise would essentially comprise a wall almost the full length of the runway, which is unlikely to be feasible. Even if feasible, only small reductions of 5-8dBA may be achievable using 10m mounds, and significant residual impacts would still result.

Engine run-up on high power would normally be carried out during daytime and night time. High power run-up should be restricted to special circumstances where high power testing is required after maintenance activity prior to an aircraft taking off. Restricting the amount of high power run-up at night time will substantially reduce the impact of run-up noise. It may also be practical to construct buildings or mounds or barriers near the run-up area to provide greater noise shielding. It is possible that reductions of around 10dBA may be able to be achieved with mounds or buildings at least 10m high, but moderate residual impacts would still occur.

In relation to the high levels of exceedance predicted and on the assumption that the noise mound along the edge of the runway or airport boundary is not feasible, there would seem to be few practical options to avoid the need for acquisition in the most affected areas.

In any event, many of the localities affected by ground noise will also be affected by aircraft noise, but to a greater degree. Luddenham is one such locality. This means that, even if ground noise sources is reduced substantially, this locality will still be significantly affected by airport noise. This raises the possibility of at-receiver treatment to reduce internal noise levels, because this type of treatment will reduce both ground and aircraft noise.

7 HEALTH RISK ASSESSMENT – GROUNDWATER AND SURFACE WATER

7.1 Existing Groundwater Conditions

The following information provides an overview of the groundwater conditions beneath the proposed airport site. Information has been sourced primarily from the Groundwater Assessment prepared by GHD (2015) which provides a review of previous investigations conducted to inform the environmental impact statement (EIS) prepared in 1997 as well as a reanalysis of additional, more recent information. However, it is noted that groundwater has not been sampled since completion of the 1997 EIS, thus the following information may not be representative of current groundwater conditions in the area.

7.1.1 Local Hydrogeology

According to GHD, there are two main aquifers present beneath the airport site:

- A shallow alluvial aquifer which is considered to be localised around the main creeks which drain the site, and is generally encountered at depths of approximately 0.7 – 4.7 m below ground level (bgl).
- A confined regional aquifer within the Bringelly Shale which is present at approximately 20 m bgl.

The 1997 EIS notes that perched groundwater was intermittently encountered within the weathered shale profile, however it is not considered to be a continuous aquifer. GHD also report the presence of a deep regional aquifer interpreted to be present at depths of greater than 100 m bgl within the Hawkesbury Sandstone.

GHD indicate that it is unlikely the aquifers are interconnected based on geological information, water strike observations and groundwater elevation data. Details of the aquifer parameters are presented in GHD and have not been re-iterated herein, the following summary of information from GHD is provided for the purpose of the current assessment:

- Both aquifers present beneath the site are reported to have low hydraulic conductivity (0.0027 – 0.14 m/day).
- Storage parameters of the aquifers present beneath the site have not been assessed.
- Standing water level elevations (in surrounding registered bores) suggest that there is a strong downward head gradient between the Bringelly Shale aquifer and the underlying Hawkesbury Sandstone aquifer, which suggests that there is limited hydraulic connectivity between the aquifers.
- The Luddenham Dyke (which runs south-east to north-west in the south west area of the site) is observed to create a divide in the Bringelly Shale aquifer with flow on the eastern side towards Badgerys Creek and on the western side toward Duncan Creek.

7.1.2 Use of Groundwater in Study Area

According to GHD, there are 42 registered groundwater bores within a five (5) km radius of the centre of the site. Twelve (12) of these bores are registered as being used for domestic, stock, industrial, farming and irrigation purposes, these wells range in depth from 61 - 337 m bgl (GHD, 2015). The depth of registered extraction bores indicates that the majority of groundwater users extract water from the Bringelly Shale and Hawkesbury Sandstone aquifers.

Water quality within the aquifers beneath the site and potential environmental values considered relevant are discussed further below in **Section 7.1.3**.

7.1.3 Groundwater Environmental Values

The National Water Quality Management Strategy (NWQMS; Australian Government, 2013) defines 'Environmental Value' as:

'*the term applied to a particular category of value or use of groundwater that is important for a healthy ecosystems or for public benefit, welfare, safety or health*.'

The Environmental Values (EV) of an aquifer require protection from the effects of contamination, waste discharge and deposits. The NWQMS defines the following environmental values of groundwater aquifers which have been adopted in the NSW Groundwater Quality Protection Policy (NSW GQPP; Department of Land & Water Conservation [DLWC], 1998):

- Ecosystem protection;
- Recreation and aesthetics;
- Raw water for drinking water supply;
- Agricultural water; and
- Industrial water.

The NSW GQPP (DLWC, 1998) states that:

'*All groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained*.'

'*Groundwater pollution should be prevented so that future remediation is not required*.'

'*For new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource*.'

The NSW GQPP (DLWC, 1998) outlines various levels of groundwater quality based on availability of groundwater and salinity as follows:

- 0-1,000 mg/l total salts (low yield): Good quality – usually potable and suitable for most uses.
- 0-1,000 mg/l total salts (high yield): Good quality – usually potable and yields may be sufficient for irrigation.
- 1,000-3,000 mg/l total salts: Suitable for all livestock, some domestic and limited industrial uses
- 3,000-14,000 mg/l total salts: Fair to poor stock quality

Based on the above groundwater classifications and the reported conductivity of groundwater sampled in 1995 and 1998 the following EV are considered to apply to the aquifers beneath the site:

- Ecosystem protection;
- Recreation and aesthetics;
- Agricultural water

Raw water for drinking water supplies is not considered to be an EV for the Alluvial aquifer or the Bringelly Shale aquifer. This is based on the salinity in the Alluvial and Bringelly Shale aquifers which is reported to be >1,000 mg/l (based on 1995-1998 data), and thus is unsuitable for potable water uses.

Industrial water use has not been considered further because the level of protection and chemicals of concern are considered likely to vary depending upon the type of industrial water use.

Consideration of potential risks to the relevant ecological values, as listed above, will be included in the assessment of risks to groundwater.

7.1.4 Source of Potential Groundwater Contamination

CURRENT

Table 43 summarises the findings of a review of current land use conditions at and in the vicinity of the site including potentially contaminating activities.

Table 43: Potentially Contaminating Activities - Current

Potentially Contaminating Activity	Associated Potential Contaminants (c)
Farming activities (use and storage of associated chemical products; and historical land filling practice on rural properties)	- Pesticide and herbicides - Fertilisers - Petroleum hydrocarbons - Polycyclic aromatic hydrocarbons (PAH) - Heavy metals - Chlorinated hydrocarbons (from de-greasing activities) - Asbestos - Paint and paint thinner associated compounds
Landfill operation (a)	- Petroleum Hydrocarbons - Heavy metals - PAH - Perfluorinated compounds (PFC) - Asbestos - Chlorinated hydrocarbons - Other household and industrial chemicals
Brickworks	- Asbestos - Fluoride - Petroleum hydrocarbons - PAH - Heavy metals
Landscape suppliers	- Fertilisers - Herbicides and pesticides - PAH - Heavy metals
Defence and Air Force base operations (b)	- Petroleum hydrocarbons - PAH - Heavy metals - Asbestos - PFC
Petrol Station operation (former and current)	- Petroleum hydrocarbons - Chlorinated hydrocarbons (from de-greasing activities) - Heavy metals - Asbestos

(a) The Elizabeth Drive Landfill Facility is noted to be present to the north of the site. There is potential for other historical land filling activities to have been conducted in the area.

(b) Defence Establishment Orchard Hills is located to the north-west of the site, and an Air Force Telecommunications facility (decommissioned) is located to the south-east of the site.

(c) This is not an exhaustive list of potential contaminants, but is intended to provide an indication of the types of contaminants which may be present at the site and in surrounding areas (thus posing a potential groundwater contamination issue).

AIRPORT CONSTRUCTION and OPERATION

During the construction and operation of the proposed airport, there would be potential for a number of activities which may result in environmental contamination if not properly managed. **Table 44** provides a list of potentially contaminating activities which may occur during airport construction and operation.

Table 44: Potentially Contaminating Activities – Airport Construction and Operation

Potentially Contaminating Activity	Associated Potential Contaminants (a)
Chemical and fuel storage	- Petroleum Hydrocarbons - Heavy metals - PAH - PFC (b)
Equipment Operation	- Petroleum Hydrocarbons - Heavy metals - PAH - PFC (b)
Equipment maintenance	- Petroleum Hydrocarbons - Heavy metals - PAH - Chlorinated Hydrocarbons - PFC (b)
Fire Fighting	- PFC (c) - Petroleum Hydrocarbons - Heavy metals - PAH

(a) This is not an exhaustive list of potential contaminants, but is intended to provide an indication of the types of contaminants which may be present at the site and in surrounding areas (thus posing a potential groundwater contamination issue).

(b) PFCs have been identified to be present in some hydraulic fluids used in the aviation industry.

(c) It is understood that Airservices Australia transitioned to 'fluorine-free' aqueous film forming foams (AFFF) for fire-fighting at airports across Australia from 2010. However there are some compounds in the fluorine-free foams which may break down to perfluorooctanoic acid (PFOA; one of the main PFCs in previously used AFFF). There is also potential for small amounts of PFCs to be present in these foams as a result of contamination which may occur during the production of the products.

Based on the activities and identified potential contaminants which may be associated with construction and operation of the proposed airport, there is likely to be considerable overlap of contaminants potentially present as a result of current activities at the site and in surrounding areas. It is therefore considered important that baseline groundwater data for these identified potential contaminants be collected to enable appropriate monitoring to be conducted during construction and operation phases of the proposed airport. This would enable any impacts from the airport construction and operation to be detected early and mitigation measures put in place to minimise any risk.

7.1.5 Hazard Identification

Contaminants of potential concern (CoPC) are considered to be those contaminants which are known or suspected to be present at concentrations which may warrant inclusion in the risk assessment. A CoPC is selected based on its reported presence in environmental media at concentrations above

adopted relevant screening criteria which have been derived to be protective of identified environmental values for the groundwater aquifer.

The ASC NEPM (NEPC, 2013) states that '*site assessment should consider the risks from contaminated groundwater to all potential receptors on and off the site of origin and potential effects on groundwater resources*.' Groundwater investigation levels (GIL) are adopted from the following sources (which have been individually referenced in **Table 45**:

- Australian Water Quality Guidelines 2000 (AWQG) (ANZECC, 2000)
- Australian Drinking Water Guidelines 2011 (ADWG) (NHMRC, 2011) and
- Guidelines for Managing Risk in Recreational Waters 2008 (GMRRW) (NHMRC, 2008)

Where guideline values could not be obtained from the above sources, additional sources were referenced as per the hierarchy listed in enHealth (2012).

Table 45 outlines the guidelines adopted for groundwater for each identified EV as per the guidance set out in the ASC NEPM (NEPC, 2013) and enHealth (2012).

In the absence of groundwater specific guidelines, surface water guidelines have been adopted for screening of groundwater. This approach is considered conservative as surface water guidelines only apply to groundwater at the point of discharge, however all available groundwater data have been collected from within the aquifer and not at the point of discharge to surface water.

Table 45: Adopted Groundwater Guidelines

Environmental Value	Guideline Hierarchy
Ecosystem protection	- ANZECC (2000) Freshwater Quality Criteria (95% Protection) (e) - ANZECC (2000) Freshwater Quality Criteria (Medium to Low Reliability) - USEPA (2013) Ambient Water Quality Criteria (Chronic – Freshwater) - USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria - USEPA (2003) Region 5 RCRA Ecological Screening Levels (water) - RIVM (2001) Dutch Groundwater Intervention Value
Recreation (a) and aesthetics	- NHMRC (2011) Drinking Water Guidelines (as amended 2013) - WHO (2011) Drinking Water Guidelines - WHO (2008) Petroleum Products in Drinking Water - USEPA (2015) Regional Screening Level – Tap Water
Agricultural water (b) (d)	- ANZECC (2000) Stock Water Screening Criteria - ANZECC (2000) Irrigation – Long Term Value (LTV) (c) - NHMRC (2011) Drinking Water Guidelines (as amended 2013) - WHO (2011) Drinking Water Guidelines - WHO (2008) Petroleum Products in Drinking Water - USEPA (2015) Regional Screening Level – Tap Water

(a) As per NHMRC (2008) Guidelines for managing risk in recreational waters, all drinking water guidelines have been multiplied by a factor of 10x based on the assumption that recreational exposure would result in a lower incidental intake (0.2L) of water than direct ingestion of drinking water (assumed to be 2 L/day).

(b) Agricultural water is considered to consist of stock water and irrigation uses.

(c) The long term value for irrigation has been selected as a conservative approach as it is unclear how long irrigation activities using groundwater have been conducted for.

(d) Drinking water guidelines have been selected where no ANZECC Stock Watering guideline is available, as per ANZECC (2000).

(e) A 95% species protection value has been selected as the area is considered to be moderately disturbed, and thus 95% is likely to provide a suitable level of protection for current and proposed future land uses.

ANZECC – Australia New Zealand Environment Conservation Council

NHMRC – National Health and Medical Research Council

RIVM – Dutch National Institute for Public Health and the Environment

USEPA – United States Environment Protection Agency

WHO – World Health Organisation

7.1.6 Identification of Contaminants of Potential Concern

Groundwater data from samples collected in 1995 and 1998 were compared to GIL (as per the ASC NEPM [NEPC, 2013]) from guideline sources listed in **Table 45**. The analytical data screening is presented in **Table A1** in **Appendix A**. **Table 46** provides a summary of CoPC which were reported at concentrations which exceeded the adopted GILs.

Table 46: Groundwater Chemicals of Potential Concern

Environmental Value	Chemicals of Potential Concern
Ecosystem protection	- Aluminium - Copper - Lead - Zinc - Calcium - Chloride - Magnesium - Potassium - Sodium - Nitrogen - Phosphorus Reported electrical conductivity in groundwater (in both the Alluvial aquifer and the Bringelly Shale aquifer) was generally above the range identified for lowland river systems (ANZECC,2000). Therefore where groundwater has the potential to discharge to surface water it may result in increased salinity loading to the surface water environment.
Recreation and aesthetics (a)	- Phosphorus
Agricultural water (irrigation and stock watering)	- Iron (irrigation criteria only) - Nitrogen - Phosphorus
(a) Analytical data have been compared to health based screening values for primary contact recreation exposures via incidental ingestion. Further consideration of potential aesthetic impacts (as per NHMRC, 2008) should be made where groundwater is discharged to surface water bodies.	

The CoPCs listed in **Table 45** provide an indication of chemicals which may pose a risk to surface water at the point of discharge. The reported exceedances of screening criteria do not indicate that there is an actual risk to surface water environments from groundwater contaminants. It should be noted that there was only a limited number of contaminants analysed in the groundwater samples. Not all potential chemical contaminants which may be associated with current land uses at the site were assessed (**Section 7.1.4**). Given that there are sources of these pollutants identified, further investigation and baseline monitoring is required to identify conditions such that:

- risks to construction workers can be assessed;
- if required, remediation can be conducted prior to construction of the proposed airport; and
- monitoring can be conducted during airport construction and operation to assess the effectiveness of environmental management and mitigation measures.

7.1.7 Potential Exposure Pathways

A fundamental concept of risk assessment is the identification of an exposure pathway between the source of contamination and the identified receptors. An exposure pathway linkage is generally considered to include the following elements:

- **Contaminant Source**: A source of contamination and/or a mechanism for release of the chemical or physical agent;
- **Retention or Transport Medium**: Where the exposure point differs from the source (e.g. where soil contamination at the source has resulted in groundwater contamination at the point of

exposure) a transport/exposure medium or media (where chemicals are transferred between media) via which the chemical or physical agent is transported.

- **Exposure Point**: A location of potential contact between the organism and the chemical or physical agent;
- **Exposure Route**: A mechanism via which the chemical or physical agent comes in contact with the exposed receptors (e.g. inhalation, ingestion, dermal contact).

Where one or more of the above linkage elements is missing, the exposure pathway is considered to be incomplete and there is therefore no risk to the receptor. Where the exposure pathway linkage is identified to be complete, further assessment should be undertaken of the potential risks arising from exposure.

For the purpose of the current assessment, it is assumed that there is potential for contaminants to be present in groundwater, and thus the potential exposure points and exposure routes for groundwater have been considered further and are listed in **Table 47** below. If exposure occurs via the pathways identified in Table 46, there is a potential for health impacts in the exposed community.

Table 47: Groundwater Exposure Pathway Linkages

Receptor	Exposure Point	Exposure Route
Human users of extracted groundwater (e.g. farmers, residents etc.) (a)	Groundwater extraction point	- Incidental ingestion of groundwater during irrigation and other domestic activities - Dermal contact with groundwater during irrigation and other domestic activities - Inhalation of groundwater derived vapours at the point of extraction (c)
Human users of surface water bodies where groundwater discharges to surface water (e.g. recreational receptors)	Surface water body	- Incidental ingestion of groundwater derived contaminants in surface water - Dermal contact with groundwater derived contaminants in surface water - Inhalation of groundwater derived vapours at the point of discharge to surface water
Groundwater dependent ecosystems	Within the groundwater aquifer	- Uptake and accumulation of groundwater derived contaminants via plant root systems - Direct exposure to contaminants in groundwater
Aquatic organisms that inhabit surface water bodies where groundwater discharges	Surface water body where groundwater is discharging	- Ingestion of groundwater derived contaminants in surface water - Direct contact with groundwater derived contaminants in surface water - Ingestion of accumulated groundwater derived contaminants in the food chain (b)

(a) The drinking water exposure pathway has not been considered for these receptors as reported electrical conductivity in the Alluvial and Bringelly Shale aquifers is considered to exceed concentrations which would enable use of extracted groundwater for drinking water purposes.

(b) This exposure route may have wider implications where groundwater derived contaminants have the potential to bioaccumulate within the food chain. Bioaccumulation of contaminants in aquatic organisms may also result in biomagnification in higher order organisms (e.g. birds which consume aquatic organisms).

(c) Groundwater has not been analysed for the presence of volatile contaminants to date, however there is potential that they may be present as a result of current and proposed future activities at the site.

7.1.8 Risk Characterisation

The final step in the risk assessment process is to characterise the risks to identified receptors as a result of potential exposures to CoPC. This step involves integration of the information collected during the previous steps and qualitative (or where possible quantitative) assessment of the potential for unacceptable risks to occur.

For this assessment, only a qualitative evaluation of the potential for risks to identified receptors has been conducted. This is due to the limited data available which can be used to assess existing risks and risks under proposed future (construction and operation of the airport) conditions at the site. The following sections provide an assessment of the additional information required to further evaluate potential risks to environmental values of groundwater under proposed future conditions, and management and mitigation measures which can be implemented to reduce the potential for risks.

CURRENT POTENTIAL RISKS

Screening of available groundwater data against adopted GIL (as per the ASC NEPM [NEPC, 2013]) indicates that there are potential risks to the following EVs where groundwater is extracted or discharging to the surface:

- Ecosystem protection
- Recreation
- Agricultural water (irrigation and stock watering)

The following limitations and data gaps have been identified during the current assessment, and thus no further assessment or refinement of the risk assessment process could be completed:

- Groundwater hasn't been sampled since 1998 and thus current groundwater conditions at the site are uncertain.
- The potential for groundwater contamination to be present as a result of current land uses at and surrounding the site has not been assessed. Therefore it is unable to be determined what additional risks may be posed to groundwater from construction and operation of the airport(outside of identified CoPC).
- Groundwater samples have not been analysed for all contaminants which may be present as a result of proposed airport construction or operation. The absence of these data will make it difficult to analyse monitoring data to assess whether contamination is occurring and the effectiveness of any management and mitigation measures being implemented.
- No consideration of the potential for current PFC impacts has been included in the assessments conducted to date. It is understood that fire-fighting foams containing PFCs are unlikely to be employed during construction and operation of the airport. However there are a number of other products (e.g. hydraulic fluids) which may be used during airport operation which may contain PFCs and thus a robust understanding of baseline conditions will assist in future monitoring of these compounds.

POTENTIAL RISKS ASSOCIATED WITH CONSTRUCTION AND OPERATION

As outlined in **Section 7.1.3**, there is potential for groundwater contamination to occur as a result of a range of activities which would be undertaken during construction and operation of the proposed airport. Appropriate management and mitigation measures should be implemented to reduce the potential for these risks to be realised. It is therefore important to obtain a robust baseline groundwater dataset for the following reasons:

- to inform management and mitigation measures, to prevent exposure of construction and operation workers to existing groundwater contaminants, if present;

- to enable appropriate monitoring of groundwater quality during construction and operation to determine whether management and mitigation measures are appropriate; and
- to inform future decisions with regard to airport operations.

7.2 Existing Surface Water Conditions

The following information provides an overview of the surface water conditions in waterways within and surrounding the proposed airport site. Information has been sourced primarily from the Surface Water Quality Report prepared by GHD (2015) which provides a review of previous groundwater and surface water investigations conducted to inform the environmental impact statement (EIS) prepared in 1997. Additional surface water sampling has been conducted in 2014 and 2015, however this information was not available for this risk assessment.

7.2.1 Identification of Existing Water Bodies

Two main catchments have been identified by GHD to drain the site: South Creek Catchment and Nepean River Catchment. The following is a summary of the waterways which intersect the proposed airport site:

- Duncans Creek (located to the south-west of the site) drains to the Nepean River (west of the site);
- Oaky Creek (drains the central and northern area of the site) drains to Cosgroves Creek;
- Cosgroves creek (flows along to the north-west/north of the site) drains to South Creek to north-east of the site;
- Badgerys Creek (flows along the southern and south-eastern boundary of the site) drains to South Creek to the north-east of the site; and
- Thompsons Creek (located to the south-east of the site) drains to South Creek to the south-east of the site.

Each of the above listed creeks and rivers have a number of small tributaries which drain the site and areas immediately surrounding the site. GHD indicate that previous investigations have determined that the creeks which drain the site and surrounding area may not flow continuously, and that during dry periods only intermittent pools of water may remain along the creek beds.

There are a number of major water supply catchments located in the area surrounding the site. Warragamba Dam is located approximately 14 km west of the site and is one of Sydney's major drinking water supply dams. Prospect Reservoir is located approximately 8 km north-east of the site. Prospect Reservoir is a potable water supply dam which is used during periods of high demand (NSW SCA, 2015).

The rural setting of the site is currently such that GHD have noted that there are numerous farm storage dams present at and surrounding the site. GHD also noted the presence of a very large storage dam, located to the south-west of the site at the head waters of Duncans Creek. It is assumed this dam is used for agricultural purposes including irrigation as it is located adjacent a large agricultural facility.

7.2.2 Use of Surface Water in the Study Area

Review of the land uses in the area at and surrounding the site has identified the following uses of surface water (note these are the main identified surface water uses, however there may be other uses of surface water in the area):

- Agriculture (stock water and irrigation) – mostly farm dams
- Ecological habitat
- Potable domestic supply (Warragamba Dam and Prospect Reservoir)
- Non-potable domestic uses
- Collection of rain water for drinking and other purposes in surrounding rural residential areas
- Industrial use (a few large scale industrial operations in the area are observed to have large dams adjacent their facilities which indicates that this water may be used for industrial purposes)

Surface water quality must be protected during construction and operation of the airport to ensure that the above listed beneficial uses of surface water are not impacted.

7.2.3 Surface Water Environmental Values

According to the NSW DEC (2006) '*Environmental values are those values or uses of water that the community believes are important for a healthy ecosystem – for public benefit, welfare, safety or health.*'

The NSW DEC (2006) (now NSW EPA) define the following 'water quality objectives' (WQOs) which should be considered when assessing the potential impacts of activities on waterways:

- Aquatic ecosystems
- Aquatic foods (cook before eating)
- Drinking water at the point of supply
- Homestead water supply
- Irrigation water supply
- Livestock water supply
- Primary contact recreation
- Secondary contact recreation
- Visual amenity.

The above WQOs are intended to provide goals which will assist in selecting the most appropriate management options. The guiding principles of the WQOs are (NSW DEC, 2006):

- Where the environmental values are being achieved in a waterway, they should be protected, and
- Where the environmental values are not being achieved in a waterway, all activities should work towards their achievement over time.

Based on available information, the following WQOs (herein referred to as EVs) are considered to be relevant to waterways at the site:

- Aquatic ecosystems
- Aquatic foods (cook before eating)
- Irrigation water supply
- Livestock water supply
- Primary contact recreation
- Secondary contact recreation
- Visual amenity.

Drinking water at the point of supply is not considered a relevant environmental value of most waterways at and surrounding the site, however as noted in **Section 7.2.3** there are two waterways in the area surrounding the site which are currently used for drinking water supply purposes (e.g. Warragamba Dam and Prospect Reservoir). The potential for the proposed airport activities to impact on nearby municipal water supplies sourced from these storages has been assessed as there is potential for air emissions to impact these waterways.

7.2.4 Sources of Potential Surface Water Contamination

The potentially contaminating activities identified to be currently occurring at the site and which may occur during construction and operation of the site are considered to also have the potential to result in surface water contamination (**Section 7.1.4**).

In addition there is the potential for increased loading of suspended particles to surface water during construction activities. Air modelling of dust as PM_{10}, $PM_{2.5}$ and TSP conducted for construction and operation of the airport has shown that the impact on both Warragamba Dam and Prospect Reservoir is very low with an annual average increase at Warragamba for PM_{10} of 0.02 µg/m^3. This would not have any impact on surface water quality.

On rare occasions, aircraft may be required to jettison fuel to enable a safe landing in an emergency situation. Such incidents are managed under the direction of air traffic control and would be expected to occur at a considerable distance from the airport site and at high altitude to avoid the risk of fuel reaching the ground.

Aircraft movements at the site and during operation would also result in increased potential for deposition of particulates and aircraft emissions in surrounding waterways. Further qualitative discussion is provided in **Section 7.2.8**.

Through consultation on the EIS there have been concerns raised by the community about the potential for aircraft emissions to impact on the quality of tank water in the area close to the airport. Air dispersion modelling has been conducted and predicted ground level concentrations of VOCs and PM_{10} in areas close to the airport site. This is discussed further in the Local Air Quality Report (Pacific Environment, 2015). The predicted ground level concentrations of benzene and other VOC are very low. The maximum predicted concentration of benzene within 5 km of the airport site is 0.1 µg/m^3 and diesel particles 0.8 ng/m^3. These concentrations are very low and would not impact of the quality of tank water.

7.2.5 Hazard Identification

The ANZECC (2000) guidelines set out key 'indicators' which can be used to measure whether there is a potential risk to each environmental value. Indicators (or guidelines) have been selected based on the appropriate level of protection for the waterways at and surrounding the site, and provide a risk-based approach to assessing the potential for risks to environmental values. **Table 48** outlines the hierarchy of guideline sources from which indicator values have been selected as per ANZECC (2000), NEPC (2013) and enHealth (2012).

Surface water samples collected to date have not been compared to drinking water screening criteria as the waterways which have been sampled are not currently used for drinking water purposes. Qualitative consideration of the potential for airport construction and operation to result in impacts to potable water sources has been undertaken in **Section 7.2.8**.

Table 48: Adopted Surface Water Guidelines

Environmental Value	Guideline Hierarchy
Aquatic ecosystems	- ANZECC (2000) Freshwater Quality Criteria (95% Protection) (e) - ANZECC (2000) Freshwater Quality Criteria (Medium to Low Reliability) - USEPA (2013) Ambient Water Quality Criteria (Chronic – Freshwater) - USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria - USEPA (2003) Region 5 RCRA Ecological Screening Levels (water) - RIVM (2001) Dutch Groundwater Intervention Value
Aquatic foods	As per the ANZECC (2000) guidance, where surface waters are used for aquaculture purposes, contaminant concentrations in the tissue of the organisms must meet Australia New Zealand Food Standards. As such no surface water screening criteria have been adopted as part of the current assessment.
Primary and secondary contact recreation (a)	- NHMRC (2011) Drinking Water Guidelines (as amended 2013) - WHO (2011) Drinking Water Guidelines - WHO (2008) Petroleum Products in Drinking Water - USEPA (2015) Regional Screening Level – Tap Water
Agricultural water (b) (d)	- ANZECC (2000) Stock Water Screening Criteria - ANZECC (2000) Irrigation – Long Term Value (LTV) (c) - NHMRC (2011) Drinking Water Guidelines (as amended 2013) - WHO (2011) Drinking Water Guidelines - WHO (2008) Petroleum Products in Drinking Water - USEPA (2015) Regional Screening Level – Tap Water

(a) As per NHMRC (2008) Guidelines for managing risk in recreational waters, all drinking water guidelines have been multiplied by a factor of 10x based on the assumption that recreational exposure would result in a lower incidental intake (0.2 L) of water than direct ingestion of drinking water (assumed to be 2 L/day).

(b) Agricultural water is considered to consist of livestock water and irrigation uses.

(c) The long term value for irrigation has been selected as a conservative approach as it is unclear how long irrigation activities using groundwater have been conducted for.

(d) Drinking water guidelines have been selected where no ANZECC Stock Watering guideline is available, as per ANZECC (2000).

(e) A 95% species protection value has been selected as the area is considered to be moderately disturbed, and thus 95% is likely to provide a suitable level of protection for current and proposed future land uses.

7.2.6 Identification of Contaminants of Potential Concern

Surface water data from samples collected in 1996, 1998, 2014 and 2015 were compared to selected screening criteria (as per NSW DEC (2006) and ANZECC (2000)) from guideline sources as listed in **Table 45**. The analytical data screening is presented in **Table A2 and Table A3** in **Appendix A**. **Table 49** below provides a summary of CoPC (from all sampled waterways) which were reported at concentrations which exceeded the adopted screening criteria.

Table 49: Surface Water Chemicals of Potential Concern

Environmental Value	Chemicals of Potential Concern
Aquatic ecosystems	- Cadmium - Copper - Iron - Mercury (one sample only) - Zinc - Phosphorus - Anionic surfactants as MBAs (see discussion below) Reported electrical conductivity (EC) in samples from Badgerys Creek, Oaky Creek (one sample) and Cosgroves Creek were generally above the range identified for lowland river systems (ANZECC, 2000). According to GHD (2015) the elevated EC is expected to be due to the influence of the surrounding shale geology.
Primary and secondary contact recreation	- Phosphorus
Agricultural water	- Iron (irrigation only) - Mercury (stock watering only) - Phosphorus - TPH C15-C28/C16-C34 - TPH C29-C36
MBA = Methylene blue activated substances (considered, by ANZECC (2000), to include linear alkylbenzene sulfonates [LAS]) TPH = Total Petroleum Hydrocarbons	

Anionic surfactants as methylene blue activated substances were analysed in surface water samples collected in 1996, 1998, 2014 and 2015. In 1996, concentrations ranged between 12 mg/L (Duncans Creek) and 16 mg/L (Cosgroves Creek and Thompsons Creek), in 1998, concentrations ranged between <0.05 – 0.21 mg/L. At locations which were sampled during both 1996 and 1998 sampling events, reported concentrations of anionic surfactants as MBAs were between one and three orders of magnitude lower in samples collected in 1998 compared to results from 1996. Samples collected in 2015 correlated more closely with results obtained in 1998. The EIS conducted in 1997 states that

> 'No substantial rain had fallen for four months and western Sydney was officially declared "in drought". In April 1998, the drought ended with substantial rainfall over the following winter.'

The drought conditions may have caused the marked difference between anionic surfactants (as MBAs) concentrations in 1996 compared to other years. However, no other analytes were reported to have been affected to such an extent.

7.2.7 Potential Exposure Pathways

For the purpose of the current assessment, it is assumed that there is potential for contaminants to be present in surface water, and thus the potential exposure points and exposure routes for surface water have been considered further and are listed in **Table 50** below.

Table 50: Surface Water Exposure Pathway Linkages

Receptor	Exposure Point	Exposure Route
Human users of extracted surface water (e.g. farmers, residents etc.)	Tap or hose	- Ingestion of surface water as a potable water supply (c) - Incidental ingestion of contaminants in surface water during irrigation and other domestic activities - Dermal contact with contaminants in surface water during irrigation and other domestic activities - Inhalation of surface water derived vapours at the point of extraction (b) - Ingestion of contaminants accumulated in food crops irrigated with impacted surface water
Human users of surface water bodies (e.g. recreational receptors)	Surface water body	- Incidental ingestion of contaminants in surface water - Dermal contact with contaminants in surface water - Inhalation of surface water derived vapours
Aquatic and terrestrial (e.g. birds) organisms	Surface water body	- Ingestion of contaminants in surface water - Direct contact with contaminants in surface water - Ingestion of accumulated contaminants in the food chain (a)

(a) This exposure route may have wider implications where contaminants in surface water have the potential to bioaccumulate within the food chain. Bioaccumulation of contaminants in aquatic organisms may also result in biomagnification in higher order organisms (e.g. birds which consume aquatic organisms).

(b) Volatile contaminants have not been detected in surface water during sampling undertaken to date, however this exposure pathway should be considered where there is potential for surface water impacts from volatile contaminants during construction and operation of the airport.

(c) This exposure pathway is considered to be less common than the use of private tank water storages for potable water. However, consideration of the potential for current residents to be extracting water from farm dams for potable uses should be made.

7.2.8 Risk Characterisation

For the purposes of this assessment, a qualitative evaluation of the potential for risks to identified receptors under current conditions at the site and in surrounding areas has been conducted. There are limited surface water data available which can be used to assess risks under proposed future (construction and operation of the airport) conditions at the site. However, based on available information there is potential for the construction and operation of the airport to impact the environmental values of surface water. These potential risks are discussed further below.

CURRENT POTENTIAL RISKS

The currently available information indicates that there is potential risk to the following environmental values of surface water at the site and in the surrounding area:

- Aquatic ecosystems
- Primary and secondary contact recreation
- Agricultural water

There is no information available which can be used to determine whether the identified CoPC are a result of naturally elevated background concentrations in the area or as a result of a current contamination source. Further investigation is required to assess the potential risk to surface water bodies at and surrounding the site under current conditions. This will provide a baseline to assess any impacts from the airport operation and construction and identify key mitigation measures to minimise these risks.

POTENTIAL RISKS ASSOCIATED WITH CONSTRUCTION AND OPERATION

The proposed activities during construction and operation of the proposed airport that have the potential to impact surface water are as follows:

- increased loading of suspended particulates in surface run-off as a result of earthmoving activities and/or increased vegetation clearing
- increased potential for accidental spill of stored chemicals or fuels from construction or operation vehicles which may be released to nearby surface water environments;
- potential for release of stored groundwater which has not been adequately characterised (with regard to contamination concentrations) to surface water bodies;
- potential for fuel jettisoning to occur in emergency situations; and
- potential for vehicle and aircraft emissions to deposit in nearby surface water bodies which may result in increased contaminant loading to waterways.

Modelling of air toxics and particles from vehicles, ground based operations and aircraft overflights indicates that the levels of these pollutants near surface waters is low and therefore the resultant risk will also be very low.

Based on currently available information with regard to construction and operation of the proposed airport, there is a potential risk to surface waters from the other sources outlined above. However the implementation of management and mitigation measures through the construction environmental management and the airport environmental management plan once the airport is in operation will minimise these risks.

POTENTIAL FOR IMPACTS TO POTABLE WATER SUPPLIES

Although the proposed airport is not located within the catchment area for Warragamba Dam and Prospect Reservoir, there is the potential for aircraft flights over these areas. These waterways are major potable water storages which supply water to Sydney's municipal reticulated water system. The following activities could potentially result in impacts to these water storages:

- **Increased dust emissions** during construction activities which have the potential to result in increased deposition of particulates to the surrounding area. Dust management strategies implemented as part of the environmental management plan for construction will minimise this risk. Results for air dispersion modelling for PM_{10} conducted as part of this EIS show that the annual average concentrations at Warragamba are predicted to be 0.02 µg/m^3 which would have no impact on water quality at the Warragamba Dam. The Prospect Reservoir is approximately 8 km from the site. PM_{10} modelling for receptors close to the reservoir show that there is predicted to be a maximum annual average increase of 0.09 µg/m^3 during construction activities which would not affect water quality.
- **Surface water discharges**: The distance from the site, the topography of the area, and the number of waterways present between the site and the water supply storages would reduce the potential for overland flow of impacted surface run-off from the site. These factors are also considered likely to limit the potential for discharge of site-derived groundwater impacts to these water bodies. However, the management and mitigation measures contained in the construction environmental management plan will ensure that site-derived contaminants are not able to discharge to these waterways. Implementation of these measures will minimise any risk to surface waters and subsequently to people who may come in contact with these waters.
- **Fuel Jettisoning**: Instances of fuel jettisoning for commercial aircraft are very rare and only occur in emergency situations where an unscheduled landing is required. Where fuel jettisoning is considered necessary, the pilot is required to contact air traffic control to alert them of the need to undertake fuel jettisoning and is required to take any reasonable precautions to

ensure the safety of people and property on the ground and in the air, and where possible, jettison fuel at a minimum altitude of 6,000 ft. Most fuel is considered to evaporate within 100 metres with only a small amount of fuel likely to reach ground level (if at all). There are no recorded instances in Australia of fuel reaching the ground after a fuel jettison event.

- Most aircraft which fly shorter haul domestic routes do not have the capacity to jettison fuel as they can land fully fuelled, however larger aircraft used on longer domestic routes and international long haul flights do have the capacity to jettison fuel.
- Based on existing protocols and the available information, it is considered unlikely that fuel jettisoning would result in impacts to surface water bodies surrounding the proposed airport site including Warragamba Dam, Prospect Reservoir and private water storages (e.g. tanks).
- **Aircraft emissions**: There is potential that emissions from increased aircraft traffic during operation of the proposed airport may impact on water quality in Warragamba Dam and Prospect Reservoir (as well as other waterways in the area) as well as private tank water supplies. Consideration should be given to a pre-construction and post construction/operation monitoring program to test the quality of local tank water and monitor any changes to the quality of the water over time. This would enable informed decisions to be made about implementation of any mitigation measures in a timely manner.

7.3 Conclusions and Recommended Mitigation Measures

The groundwater and surface water risk assessment has been undertaken in accordance with the ASC NEPM (NEPC, 2013) and provides a preliminary assessment of the potential risks posed by the construction and operation of the proposed airport to groundwater and surface water receptors.

The 1997 EIS identified the following potential risks to groundwater and surface water as a result of the construction and operation of the proposed airport:

- 'Airport development would result in a lowering of groundwater levels due to reduced infiltration in paved areas. This effect may be locally counteracted by rising levels beneath proposed detention dams.'
- 'There is a possibility of groundwater contamination from a number of sources; however properly engineered surface water drainage facilities and fuel storage and delivery systems would protect it from obvious sources of pollution.'
- A range of potential impacts to local surface water bodies as a result of construction and operation of the proposed airport were also identified.

These risks are still valid and are consistent with the outcomes of the current risk assessment. Based on available data, with regard to existing groundwater and surface water conditions at the site, there is potential for risks to current users of groundwater without mitigation measures in place. The following management and mitigations measures are proposed in the surface and groundwater studies of this EIS:

- Any storage of material such as chemicals, fuel or concrete components should be bunded to contain any spills. Procedures should also be established to clean up spills as quickly as possible to reduce the potential for groundwater or surface water impacts.
- Dust control should be managed through the use of water sprays and stabilising or covering of stockpiles.
- Implementation of sediment and erosion control measures to reduce the potential for surface run-off to reach surface water bodies.
- Construction of suitable drainage and detention ponds (with gravel filter beds at discharge points) to prevent direct surface water run-off to waterways and thus prevent deposition of silt and increased turbidity.
- Monitoring of discharge from retention ponds to mitigate the potential for impacts to surface water quality in the receiving environment.

- Dosing of detention ponds with flocculants when monitoring detects excessive nutrients being discharged from the system, this will increase the sediment and nutrient removal from stormwater prior to release.
- Installation of gross pollutant traps to intercept and retain coarse sediment, rubbish and debris in storm water.
- Installation of flame traps to limit the release of oils and fuels in stormwater.
- Installation and maintenance of a waste water treatment system which incorporates: tertiary processes, includes disinfection and a high level of nutrient removal. It is noted that where reverse osmosis is proposed as a filtration system in the waste water treatment, monitoring for perfluorinated compounds should be conducted as these compounds are of a size which can reduce the efficiency of reverse osmosis filters.
- Ongoing monitoring of waste water discharges and the adequacy of chemical storage bunding as well as other management measures should be undertaken throughout construction and operation phases at the proposed airport.

With the implementation of mitigation measures described in the related technical reports (surface water, water quality and groundwater), the potential risks would be minimised.

7.4 Limitations of the Groundwater and Surface Water Assessment

The current risk assessment is based on limited data and provides a high level assessment of the potential for risks to groundwater and surface water receptors at and surrounding the site. The outcomes of the risk assessment indicate the need for further investigation into the current status of groundwater and surface water, especially with regard to spatial and temporal trends to ensure that a well-defined baseline is established to enable any changes in environmental quality due to airport construction and operation to be detected and mitigated.

8 CONCLUSIONS

A health risk assessment (HRA) has been undertaken to assess the potential risks associated with air and noise emissions and potential surface and groundwater contamination that may arise from the construction and operation of the proposed Western Sydney Airport at Badgerys Creek. Overall, the analysis has found that the health impacts of the proposed airport would be in line with national and international standards of acceptability.

Air Quality

The HRA has examined the increase in risk resulting from air pollution generated by the construction and operation of the proposed airport. The pollutants considered were particulate matter, NO_2, SO_2, CO, benzene and diesel. The prediction of changes in local air quality were derived from the local air quality assessment (Pacific Environment 2015) which is included elsewhere in the EIS. A limited assessment was also conducted for ozone as a regional air pollutant. Based on existing evidence, the health impacts associated with the emissions from the airport are expected to represent a small increase in current rates of health impacts associated with existing air pollution in the Sydney basin.The highest risk during construction is associated with PM_{10} during terminal construction. The highest risk could result in an additional 2 deaths per hundred years from all causes (non-accidental). The most affected areas would be Luddenham, Bringelly, Kemps Creek and Badgerys Creek.

For the 2030 and 2063 scenarios the results of the HRA show that the highest risk is associated with NO_2 with increases in mortality and hospital admissions predicted. The most affected areas are likely to be Luddenham, Bringelly, Kemps Creek, Mulgoa, Wallacia and Rossmore. The risks from PM_{10} and $PM_{2.5}$ are also at the high end of acceptable risk criteria established by international agencies. The risks from all other pollutants assessed is low and within acceptable risk criteria.

For regional air quality, the increase in risk of mortality and hospital admissions related to changes in ozone are small and within acceptable risk criteria. There are limitations to this assessment as the analysis, due to availability of air quality data, is limited to days when exceedances of the ozone standards are predicted. The assessment does not evaluate the full risk that may be experienced by changes in ozone levels due to airport operations.

Mitigation measures to reduce NO_2 and PM are included in the local air quality technical report and when implemented, would have an effect of reducing NO_2 emissions generated. It is also worth noting that particularly for the 2063 scenario assessment, the modelling assumed no future reductions in emissions technology either for aircraft or for vehicular traffic more generally. On the basis that emissions reduction has occurred over the past several decades and is expected to occur again in the future, the results of the HRA are likely to overestimate the actual level of risk that would be realised.

Noise

The noise HRA was conducted for the two categories of noise generated by: aircraft overflights and ground-based noise sources. The prediction of changes in the noise environment were derived from the noise assessments by Wilkinson Murray included in the EIS and additional data provided specifically for the HRA.

Three health outcomes were assessed – sleep disturbance (as awakenings), increases in ischaemic heart disease and impacts on cognitive development and learning in children. The results for the HRA for noise shows that ground based operations may lead to an increase in sleep disturbance (assessed as awakenings), increases in risk of cardiovascular disease and delays in childhood learning and cognitive development. These effects are predicted for suburbs close to the airport site, in particular Luddenham. The impact of aircraft overflights is lower than that for ground based operations. The risk of sleep disturbance and impacts on cognitive development are predicted to be higher for 2063 than 2030.

Based on the results of the noise assessment, the risk posed to the health of the exposed communities is generally low. No increase in cardiovascular outcomes is likely from aircraft noise as the predicted night noise levels are below the threshold for adverse effects. However, ground operations noise is predicted to be above the threshold value of 55 dB Lnight and may lead to a 10% increase in myocardial infarctions in Luddenham in 2063 if not mitigated.

A significant increase in EEG awakenings is predicted especially in Luddenham. In 2030, it is predicted that there would be 190 additional EEG awakenings per person per year and an additional 400 EEG awakenings per person per year with ground-based noise in 2063. For full awakenings, the number is lower but still highest in Luddenham. There is a greater predicted impact from ground- operations noise than aircraft noise. Mitigation measures in the noise assessment report should be implemented and would reduce this impact.

Impacts on children's learning and cognitive development are predicted to be within acceptable risk levels for most locations for aircraft noise. The impact of ground operations noise is more substantial. Mitigation measures should be implemented at these locations to reduce this risk to within acceptable levels.

The EIS noise assessments include mitigation and management measures which will reduce the potential impacts which have been assessed by the HRA. Particularly important, the Department will in future stages of assessment, consider the results of the EIS – both the noise technical study as well as the health risks identified in this report and incorporate the findings into the further analysis of airport operating mode options before determining the preferred flight tracks. Additionally, the Department would develop a noise amelioration strategy considering both overflight and ground-based noise sources with a range of mitigation options included for the most affected areas in accordance with AS2021.

Surface and groundwater

There are 42 registered groundwater bores within a five kilometre radius of the centre of the site. Twelve of these bores are registered as being used for domestic, stock, industrial, farming and irrigation purposes. The depth of registered extraction bores indicates that the majority of groundwater users extract water from the Bringelly Shale and Hawkesbury Sandstone aquifers. The salinity in the Alluvial and Bringelly Shale aquifers is reported to be >1,000 mg/l (based on 1995-1998 data) and thus is considered unsuitable for potable uses.

The site has historically been used for a wide range of agricultural, industrial, commercial and rural-residential activities from generate a range of potential contaminants in soil and groundwater. Based on these historical site activities and the potential contaminants which may be associated in future with construction and operation of the airport, there is likely to be considerable overlap of contaminants potentially present. It is therefore important that baseline groundwater data is collected including all potential contaminants that may be already present to enable identification of the current baseline conditions and from which to monitor future performance of the airport.

The contaminating activities which may occur during construction and operation of the airport may also have the potential to result in surface water contamination. Aircraft movements at the site during operation may result in increased deposition of particulates in surrounding waterways. Results of air dispersion modelling has shown that these impacts are predicted to be low. In addition, it is unlikely that fuel jettisoning would have an impact on surface water bodies around the airport site given the rarerity of fuel jettisoning, existing protocols in place, and the evaporative nature of aviation fuel.

Based on currently available information with regard to construction of the proposed airport, there is considered to be risks to environmental values of surface water. However these risks are not unique or unusual to the proposed airport and are common for other major infrastructure projects where standard construction measures are typically effective in reducing risks. Implementation of mitigation

measures through the construction environmental management plan and the site EMP during operation will minimise these risks.

The outcomes of the risk assessment suggest that there is a need to collect additional data to fill identified data gaps and enable a more robust assessment of current and potential future risks to groundwater and surface water receptors. Consideration should be given to a pre-construction and post construction/operation monitoring program to test the quality of local tank water and monitor any changes to the quality of the water over time. This would enable informed decisions to be made about implementation of any mitigation measures in a timely manner.

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Appendix A DATA TABLES

Table A1 - Selected Groundwater Screening Criteria

Chemical Name	Units	Primary Contact Recreation	Reference	Stock Watering	Reference	Irrigation	Reference	Freshwater Ecosystem	Reference
Alkalinity (Carbonate as CaCO3)	mg/L	-	-	-	-	-	-	-	-
Bicarbonate as CaCO3	mg/L	-	-	-	-	-	-	-	-
Electrical Conductivity (lab)	uS/cm	-	-	-	-	-	-	125-2200	ANZECC (2000) Lowland River Trigger Values
pH (Lab)	pH Units	-	-	-	-	-	-	6.0-8.0	ANZECC (2000) Lowland River Trigger Values
Aluminium	mg/L	200	USEPA (2015) Tap Water x 10	5	ANZECC (2000) Stock Watering	5	ANZECC (2000) Irrigation LTV	0.055	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Cadmium	mg/L	0.02	NHMRC (2011) Drinking Water Guidelines x 10	0.01	ANZECC (2000) Stock Watering	0.01	ANZECC (2000) Irrigation LTV	0.0002	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Copper	mg/L	20	NHMRC (2011) Drinking Water Guidelines x 10	0.4	ANZECC (2000) Stock Watering	0.2	ANZECC (2000) Irrigation LTV	0.0014	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Iron	mg/L	140	USEPA (2015) Tap Water x 10	14	USEPA (2015) Tap Water Guidelines	0.2	ANZECC (2000) Irrigation LTV	0.3	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Lead	mg/L	0.1	NHMRC (2011) Drinking Water Guidelines x 10	0.1	ANZECC (2000) Stock Watering	2	ANZECC (2000) Irrigation LTV	0.0034	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Zinc	mg/L	60	USEPA (2015) Tap Water x 10	20	ANZECC (2000) Stock Watering	2	ANZECC (2000) Irrigation LTV	0.008	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Calcium	mg/L	-	-	1000	ANZECC (2000) Stock Watering	-	-	116	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Chloride	mg/L	-	-	-	-	-	-	230	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Magnesium	mg/L	-	-	-	-	-	-	82	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Potassium	mg/L	-	-	-	-	-	-	53	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Sodium	mg/L	-	-	-	-	-	-	680	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Sulphate	mg/L	5000	NHMRC (2011) Drinking Water Guidelines x 10	2000	ANZECC (2000) Stock Watering	-	-	-	-
Total Kjeldahl Nitrogen	mg/L	-	-	-	-	-	-	-	-
Nitrate (as N)	mg/L	-	-	-	-	-	-	-	-
Nitrogen (Total)	mg/L	-	-	-	-	5	ANZECC (2000) Irrigation LTV	0.2-0.3	ANZECC (2000) Lowland River Trigger Values
Nitrate + Nitrate as N	mg/L	-	-	-	-	-	-	-	-
Phosphorus	µg/L	0.004	USEPA (2015) Tap Water x 10	0.0004	USEPA (2015) Tap Water Guidelines	0.05	ANZECC (2000) Irrigation LTV	0.01	ANZECC (2000) Lowland River Trigger Values

Table A2 - Historical Groundwater Analytical Data

Adopted Screening Criteria	Compounds / Units	Alkalinity (Carbonate as CaCO3) mg/L	Bicarbonate as CaCO3 mg/L	Electrical Conductivity (lab) µS/cm	pH (Lab) pH Units	Aluminium mg/L	Cadmium mg/L	Copper mg/L	Iron mg/L	Lead mg/L	Zinc mg/L	Calcium mg/L	Chloride mg/L	Magnesium mg/L	Potassium mg/L	Sodium mg/L	Sulphate mg/L
Primary Contact Recreation		-	-	-	-	200	0.02	20	140	0.1	60	-	-	-	-	-	5000
Stock Watering		-	-	-	-	5	0.01	0.4	14	0.1	20	1000	-	-	-	-	2000
Irrigation		-	-	-	-	5	0.01	0.2	0.2	2	2	-	-	-	-	-	-
Freshwater Ecosystem Protection		**-**	**-**	***125-2200***	***6.0-8.0***	***0.055***	***0.0002***	***0.0014***	***0.3***	***0.0034***	***0.008***	***116***	***230***	***82***	***53***	***680***	**-**
Location Code	**Well Depth (m)**	**Date Sampled**															
GW A	27.3	29/09/1998	<1	188	***29,700***	7.43	<0.01	<0.001	***0.013***	<1	***0.004***	***0.039***	***518***	***9660***	***186***	56	***5440***	4
GW B	38.5	29/09/1998	<1	921	***28,500***	6.72	<0.01	<0.001	***0.02***	<1	***0.005***	***0.042***	***650***	***9450***	***573***	***96***	***4600***	4
GW C	26	29/09/1998	<1	866	***5,520***	7.65	***0.06***	<0.001	***0.002***	<0.1	***0.022***	***0.014***	42	***1120***	51	15	***935***	9
GW E	Deep (11.3)	29/09/1998	<1	1140	***7,900***	7.42	<0.01	<0.001	***0.002***	<0.1	***0.006***	***0.012***	62	***1670***	***163***	11	***1260***	152
GW E	Shallow (5.0)	29/09/1998	<1	777	***3,990***	7.21	0.04	<0.001	***0.002***	<0.1	0.001	0.008	106	***648***	***113***	7	488	93
GW F	Deep (30.3)	29/09/1998	<1	621	***20,970***	7.08	<0.001	<0.001	***0.003***	<0.1	0.003	***0.009***	***291***	***6560***	***516***	36	***3260***	85
GW F	Shallow (6.0)	29/09/1998	<1	1060	***40,800***	7.02	0.01	<0.001	***0.004***	<0.1	0.003	***0.017***	***181***	***13,800***	***1500***	13	***6560***	390
GW G	Deep (24.3)	29/09/1998	<1	687	***23,900***	6.94	<0.01	<0.001	***0.008***	<1	***0.004***	***0.018***	***446***	***7740***	***464***	53	***3970***	1
GW G	Shallow (5.0)	29/09/1998	<1	630	***14,390***	7.5	0.02	<0.001	***0.003***	<0.1	0.001	0.006	***145***	***4070***	***364***	6	***2160***	249
GW Well G1a		15/06/1995	-	-	***17,700***	-	-	-	-	-	-	-	-	-	-	-	-	-
GW Well G3a		15/06/1995	-	-	***22,190***	-	-	-	-	-	-	-	-	-	-	-	-	-
GW G4a	-	15/06/1995	-	-	***36,600***	-	-	-	-	-	-	-	-	-	-	-	-	-
GW G5	-	15/06/1995	-	-	***31,200***	-	-	-	-	-	-	-	-	-	-	-	-	-
GW G6	-	15/06/1995	-	-	***28,000***	-	-	-	-	-	-	-	-	-	-	-	-	-
GW G7	-	15/06/1995	-	-	***28,800***	-	-	-	-	-	-	-	-	-	-	-	-	-
GW H	Deep (12.3)	29/09/1998	<1	862	***33,600***	6.98	<0.01	<0.001	***0.006***	<1	***0.007***	***0.014***	***237***	***10,600***	***1080***	31	***5370***	1080
GW H	Duplicate (4.5)	29/09/1998	<1	157	-	-	0.04	<0.001	***0.004***	<1	<0.001	***0.025***	23	***8410***	***799***	12	***4280***	677
GW H	Shallow (4.5)	29/09/1998	<1	155	***26,450***	7.07	0.04	<0.001	***0.004***	<1	<0.001	***0.024***	25	***8380***	***812***	12	***4270***	657
GW J	Deep (42.3)	29/09/1998	<1	549	***26,300***	6.72	<0.01	<0.001	***0.014***	***1.8***	0.002	***0.037***	***605***	***8300***	***217***	***62***	***4560***	1
GW J	Shallow (4.5)	29/09/1998	<1	255	***28,000***	7.51	0.03	<0.001	***0.004***	<1	<0.001	***0.009***	54	***8810***	***744***	13	***4580***	494
GW K	32.3	29/09/1998	<1	939	***27,400***	7.03	<0.01	<0.001	***0.005***	<1	***0.015***	***0.018***	***282***	***8160***	***825***	***59***	***4180***	977
GW Well D11	10.05	13/06/1995	-	-	***14,810***	-	-	-	-	-	-	-	-	-	-	-	-	-
GW Well D13	10.35	13/06/1995	-	-	1350	-	-	-	-	-	-	-	-	-	-	-	-	-
GW Well D8	10.05	13/06/1995	-	-	***3010***	-	-	-	-	-	-	-	-	-	-	-	-	-
GW Well D9	10.25	13/06/1995	-	-	***14,290***	-	-	-	-	-	-	-	-	-	-	-	-	-
MW2D	-	29/09/1998	<1	907	-	-	<0.01	<0.001	***0.019***	<1	***0.005***	***0.038***	***633***	***9290***	***574***	***91***	***4530***	3
MW2D Duplicate	-	29/09/1998	<1	893	-	-	<0.01	<0.001	***0.019***	<1	***0.005***	***0.041***	***675***	***9290***	***611***	***92***	***4400***	3

Table A2 - Historical Groundwater Analytical Data

Adopted Screening Criteria	Compounds	Total Kjeldahl Nitrogen	Nitrate (as N)	Nitrogen (Total)	Nitrate + Nitrate as N	Phosphorus
	Units	mg/L	mg/L	mg/L	mg/L	mg/L
Primary Contact Recreation		-	-	-	-	0.004
Stock Watering		-	-	-	-	0.0004
Irrigation		-	-	5	-	0.05
Freshwater Ecosystem Protection		**-**	**-**	***0.2-0.3***	**-**	***0.01***

Location Code	Well Depth (m)	Date Sampled					
GW A	27.3	29/09/1998	11.9	0.06	***12***	0.06	***0.06***
GW B	38.5	29/09/1998	12.4	0.03	***12.4***	0.03	***0.02***
GW C	26	29/09/1998	2.5	0.03	***2.5***	0.03	***0.42***
GW E	Deep (11.3)	29/09/1998	0.5	0.06	***0.6***	0.06	***0.08***
GW E	Shallow (5.0)	29/09/1998	3.9	9.75	***13.7***	9.78	***1.2***
GW F	Deep (30.3)	29/09/1998	5	0.03	***5***	0.03	***0.08***
GW F	Shallow (6.0)	29/09/1998	0.8	0.03	***0.8***	0.03	***0.53***
GW G	Deep (24.3)	29/09/1998	6.6	0.02	***6.6***	0.02	***0.04***
GW G	Shallow (5.0)	29/09/1998	1	0.02	***1***	0.02	***0.11***
GW Well G1a		15/06/1995	-	-	-	-	-
GW Well G3a		15/06/1995	-	-	-	-	-
GW G4a	-	15/06/1995	-	-	-	-	-
GW G5	-	15/06/1995	-	-	-	-	-
GW G6	-	15/06/1995	-	-	-	-	-
GW G7	-	15/06/1995	-	-	-	-	-
GW H	Deep (12.3)	29/09/1998	1.8	0.02	***1.8***	0.02	***0.09***
GW H	Duplicate (4.5)	29/09/1998	1	0.06	***1.1***	0.06	***0.46***
GW H	Shallow (4.5)	29/09/1998	1	0.06	***1.1***	0.06	***0.47***
GW J	Deep (42.3)	29/09/1998	11.7	0.05	***11.8***	0.05	***0.07***
GW J	Shallow (4.5)	29/09/1998	1.3	0.4	***1.7***	0.4	***0.54***
GW K	32.3	29/09/1998	4.5	0.03	***4.5***	0.03	***0.06***
GW Well D11	10.05	13/06/1995	-	-	-	-	-
GW Well D13	10.35	13/06/1995	-	-	-	-	-
GW Well D8	10.05	13/06/1995	-	-	-	-	-
GW Well D9	10.25	13/06/1995	-	-	-	-	-
MW2D	-	29/09/1998	13.7	0.04	***13.7***	0.04	***0.11***
MW2D Duplicate	-	29/09/1998	13.3	0.03	***13.3***	0.03	***0.06***

Table A3 - Selected Surface Water Screening Criteria

Chemical Name	Units	Primary Contact Recreation	Reference	Stock Watering	Reference	Irrigation	Reference	Freshwater Ecosystem	Reference
Anionic Surfactants as MBAs	mg/L	-	-	-	-	-	-	0.28	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Electrical Conductivity (lab)	uS/cm	-	-	-	-	-	-	125-2200	ANZECC (2000) Lowland River Trigger Values
pH (Lab)	pH Units	-	-	-	-	-	-	6.0-8.0	ANZECC (2000) Lowland River Trigger Values
Cadmium	mg/L	0.02	NHMRC (2011) Drinking Water Guidelines x 10	0.01	ANZECC (2000) Stock Watering	0.01	ANZECC (2000) Irrigation LTV	0.0002	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Chromium (III+VI)	mg/L	0.5	WHO (2011) Drinking Water Guidelines x 10	1	ANZECC (2000) Stock Watering	0.1	ANZECC (2000) Irrigation LTV	0.085	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Copper	mg/L	20	NHMRC (2011) Drinking Water Guidelines x 10	0.4	ANZECC (2000) Stock Watering	0.2	ANZECC (2000) Irrigation LTV	0.0014	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Iron	mg/L	140	USEPA (2015) Tap Water x 10	14	USEPA (2015) Tap Water Guidelines	0.2	ANZECC (2000) Irrigation LTV	0.3	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Lead	mg/L	0.1	NHMRC (2011) Drinking Water Guidelines x 10	0.1	ANZECC (2000) Stock Watering	2	ANZECC (2000) Irrigation LTV	0.0034	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Mercury	mg/L	0.01	NHMRC (2011) Drinking Water Guidelines x 10	0.002	ANZECC (2000) Stock Watering	0.002	ANZECC (2000) Irrigation LTV	0.0006	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Nickel	mg/L	0.2	NHMRC (2011) Drinking Water Guidelines x 10	1	ANZECC (2000) Stock Watering	0.2	ANZECC (2000) Irrigation LTV	0.011	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Zinc	mg/L	60	USEPA (2015) Tap Water x 10	20	ANZECC (2000) Stock Watering	2	ANZECC (2000) Irrigation LTV	0.008	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
C6 - C 9 Fraction	mg/L	150	WHO (2008) Petroleum Products in Drinking Water x 10	15	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
C10 - C14 Fraction	mg/L	0.9	WHO (2008) Petroleum Products in Drinking Water x 10	0.09	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
C15 - C28 Fraction	mg/L	0.9	WHO (2008) Petroleum Products in Drinking Water x 10	0.09	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
C29 - C36 Fraction	mg/L	0.9	WHO (2008) Petroleum Products in Drinking Water x 10	0.09	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
Benzene	mg/L	0.01	NHMRC (2011) Drinking Water Guidelines x 10	0.001	NHMRC (2011) Drinking Water Guidelines	-	-	0.95	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Toluene	mg/L	8	NHMRC (2011) Drinking Water Guidelines x 10	0.8	NHMRC (2011) Drinking Water Guidelines	-	-	0.18	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Ethylbenzene	mg/L	3	NHMRC (2011) Drinking Water Guidelines x 10	0.3	NHMRC (2011) Drinking Water Guidelines	-	-	0.08	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Xylene Total	mg/L	6	NHMRC (2011) Drinking Water Guidelines x 10	0.6	NHMRC (2011) Drinking Water Guidelines	-	-	0.013	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
PAHs (Sum of total) - Lab calc	mg/L	-	-	-	-	-	-	-	-
Phenols (a)	mg/L	58	USEPA (2015) Tap Water x 10	5.8	USEPA (2015) Tap Water Guidelines	-	-	0.32	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
1,2-dichlorobenzene	mg/L	15	NHMRC (2011) Drinking Water Guidelines x 10	1.5	NHMRC (2011) Drinking Water Guidelines	-	-	0.16	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Phosphorus	mg/L	0.004	USEPA (2015) Tap Water x 10	0.0004	USEPA (2015) Tap Water Guidelines	0.05	ANZECC (2000) Irrigation LTV	0.01	ANZECC (2000) Lowland River Trigger Values

(a) The value for phenol has been adopted as a conservative approach

Table A4 - Historical Surface Water Analytical Data

Adopted Screening Criteria	Compounds	Fraction Organic Carbon	Soxhlet Grease	MBAS	Dissolved Oxygen (% saturated) (Field) (Filtered)	Dissolved Oxygen (Lab) (Filtered)	Electrical conductivity (lab)	pH (Lab)	Total Suspended Solids	Turbidity	Cadmium	Chromium (III+VI)	Copper	Iron	Lead	Mercury	Nickel	Zinc	C6 - C 9 Fraction	C10 - C14 Fraction	C15 - C28 Fraction
	Units	%	mg/L	mg/L	%S	mg/L	µS/cm	pH Units	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L
Primary Contact Recreation		-	-	-	-	-	-	-	-	-	0.02	0.5	20	140	0.1	0.01	0.2	60	15,000	900	900
Stock Watering		-	-	-	-	-	-	-	-	-	0.01	1	0.4	14	0.1	0.002	1	20	1500	90	90
Irrigation		-	-	-	-	-	-	-	-	-	0.01	0.1	0.2	0.2	2	0.002	0.2	2	-	-	-
Freshwater Ecosystem Protection		-	-	***0.28***	-	-	***125-2200***	***6.0-8.0***	-	-	***0.0002***	***0.085***	***0.0014***	***0.3***	***0.0034***	***0.0006***	***0.011***	***0.008***	-	-	-
Location ID	**Date Sampled**																				
Badgerys Creek B1 (BCUS)	04-12-96	10	<5	<0.02	63	4.5	1170	6.9	2	1.1	<0.005	<0.005	***0.005***	0.22	<0.005	<0.001	<0.005	***0.013***	<20	<40	<200
Badgerys Creek B2	04-12-96	25	<5	0.22	150	12.2	2900	7.3	33	7	<0.005	0.01	<0.005	***1.8***	<0.005	<0.001	<0.005	<0.01	<20	<40	<200
Badgerys Creek B3 (BCDS)	04-12-96	<0.01	<5	**14**	24	2.2	1080	6.7	14	5.1	<0.001	<0.01	***0.005***	<0.005	<0.005	<0.02	<0.005	<0.005	<40	<200	<200
Badgerys Creek B3 (BCDS)	17-09-98	9	<5	0.13	107	11.3	1530	6.9	9	46	***0.001***	<0.005	<0.005	***1.93***	<0.005	<0.001	<0.005	<0.01	<20	<20	<100
Badgerys Creek B3 (BCDS)	08-10-98	11	<5	0.16	13	1.4	1895	7	15	19	<0.001	<0.005	<0.005	***1.51***	<0.005	<0.001	<0.005	***0.02***	<20	<20	<100
Badgerys Creek B3 (BCDS)	15-12-98	17	8	<0.05	35	2.9	2250	7.2	24	19	<0.0005	<0.005	<0.005	***3.02***	<0.002	<0.001	<0.005	<0.01	<20	<20	<100
Cosgroves Creek C1 (CCUS)	10-12-96	<0.01	<5	**16**	25	2.2	1500	6.7	5	2.9	<0.001	0.018	<0.005	<0.005	<0.005	<0.02	<0.005	<0.005	<40	<200	<200
Cosgroves Creek C3	10-12-96	<0.01	<5	**16**	25	2.2	1500	6.7	5	2.9	<0.001	0.018	<0.005	<0.005	<0.005	<0.02	<0.005	<0.005	<40	<200	<200
Cosgroves Creek C3	16-09-98	12	<5	0.19	65	6.6	1220	6.9	12	16	***0.001***	<0.005	<0.005	***1.76***	<0.005	<0.001	<0.005	<0.01	<20	<20	<100
Cosgroves Creek C3	07-10-98	15	<5	0.12	53	4.9	1820	7	8	10	<0.001	<0.005	<0.005	***2.28***	<0.005	<0.001	<0.005	<0.01	<20	<20	<100
Cosgroves Creek C3	14-12-98	18	9	0.1	2	0.2	2150	7.4	6	16	<0.0005	<0.005	<0.005	***3.17***	<0.002	<0.001	<0.005	<0.01	<20	<20	<100
Duncans Creek D1	10-12-96	<0.01	<5	**12**	15	1.3	1750	6.7	13	5.2	<0.001	0.01	<0.005	<0.005	<0.005	<0.02	<0.005	<0.005	<40	<200	<200
Duncans Creek D1	17-09-98	10	<5	0.17	28	2.7	1330	7	10	12	***0.001***	<0.005	<0.005	***1.26***	<0.005	<0.001	<0.005	<0.01	<20	<20	<100
Duncans Creek D1	08-10-98	8	<5	0.06	24	2.2	1950	7	8	10	***0.001***	<0.005	<0.005	***1.29***	0.003	<0.001	<0.005	***0.04***	<20	<20	<100
Duncans Creek D1	15-12-98	10	<5	0.09	50	4.1	2590	7.1	9	6.2	<0.0005	<0.005	<0.005	***0.58***	<0.002	<0.001	<0.005	<0.01	<20	<20	<100
South Creek S1	16-09-98	12	<5	0.09	105	10.1	673	7.2	12	65	0.001	<0.005	***0.006***	***1.5***	<0.005	<0.001	<0.005	***0.01***	<20	<20	<100
South Creek S1	07-10-98	10	<5	0.2	83	7.4	1000	7.1	8	15	<0.001	<0.005	<0.005	***1.41***	0.002	<0.001	<0.005	***0.03***	<20	<20	<100
South Creek S1	14-12-98	5	<5	0.05	100	7.7	1600	7	56	38	<0.0005	<0.005	<0.005	***0.81***	<0.002	<0.001	<0.005	<0.01	<20	<20	<100
South Creek S2	16-09-98	11	<5	0.12	66	6.6	727	6.9	11	82	***0.001***	<0.005	***0.006***	***1.81***	<0.005	<0.001	***0.012***	***0.01***	<20	<20	<100
South Creek S2	07-10-98	9	<5	0.16	60	5.5	989	7	19	32	<0.001	<0.005	<0.005	***1.5***	<0.005	<0.001	<0.005	***0.01***	<20	<20	<100
South Creek S2	14-12-98	7	<5	<0.05	87	6.8	1420	6.8	5	7	<0.0005	<0.005	<0.005	***0.35***	<0.002	<0.001	<0.005	***0.16***	<20	<20	<100
South Creek S3	16-09-98	12	<5	0.13	79	7.5	690	6.9	12	40	***0.001***	<0.005	<0.005	***2.03***	<0.005	<0.001	<0.005	<0.01	<20	<20	<100
South Creek S3	07-10-98	11	<5	0.21	44	4.1	645	6.9	14	23	***0.001***	<0.005	<0.005	***3.06***	0.003	<0.001	<0.005	***0.02***	<20	<20	<100
South Creek S3	14-12-98	12	<5	<0.05	39	3.1	850	7.4	4	12	<0.0005	<0.005	<0.005	***0.66***	<0.002	<0.001	<0.005	***0.03***	<20	<20	<100
Thompson Creek T1	10-12-96	<0.01	<5	**16**	23	2.2	4960	6.4	5	4.9	***0.01***	0.018	***0.005***	<0.005	<0.005	<0.02	<0.005	<0.005	<40	<200	<200
Thompson Creek T1	17-09-98	11	<5	0.14	50	5.5	2400	7	11	10	***0.001***	<0.005	<0.005	***1.21***	<0.005	<0.001	<0.005	<0.01	<20	<20	<100
Thompson Creek T1	09-10-98	13	<5	0.21	15	1.5	4240	7	8	11	<0.001	<0.005	<0.005	***1.39***	<0.005	***0.01***	<0.005	***0.03***	<20	<20	<100
Thompson Creek T1	15-12-98	18	<5	0.17	46	4.2	9550	7.3	11	14	<0.0005	<0.005	<0.005	***1.16***	<0.002	<0.001	0.006	<0.01	<20	<20	<100

Table A4 - Historical Surface Water Analytical Data

Adopted Screening Criteria	Compounds	C29 - C36 Fraction	Benzene	Toluene	Ethylbenzene	Xylene Total	PAHs (Sum of total) - Lab calc	Phenols	1,2-dichlorobenzene	Ammonia as N	Total Kjeldahl Nitrogen	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)	Phosphorus
	Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Primary Contact Recreation		900	10	8,000	3,000	6,000	-	58,000	15,000	-	-	-	-	-	0.004
Stock Watering		90	1	800	300	600	-	5,800	1,500	-	-	-	-	-	0.0004
Irrigation		-	-	-	-	-	-		-	-	-	-	-	-	0.05
Freshwater Ecosystem Protection		**-**	***950***	***180***	***80***	***13***	**-**	**-**	***160***	**-**	**-**	**-**	**-**	**-**	***0.01***
Location ID	**Date Sampled**														
Badgerys Creek B1 (BCUS)	04-12-96	<200	<1	<1	<1	<1	<1	<10	<1	0.054	5	<0.02	<0.02	-	<0.02
Badgerys Creek B2	04-12-96	<200	<1	<1	<1	<1	<1	<10	<1	0.38	2.9	<0.02	<0.02	-	***1.2***
Badgerys Creek B3 (BCDS)	04-12-96	<1	<1	<1	<1	<1	<1	1100	<1	0.21	0.7	<0.02	<0.02	0.12	***0.26***
Badgerys Creek B3 (BCDS)	17-09-98	<100	<1	<1	<1	<1	<1	<10	<1	0.14	1.1	1.16	0.03	2.3	***0.35***
Badgerys Creek B3 (BCDS)	08-10-98	<100	<1	<1	<1	<1	<1	<10	<1	0.16	1.3	0.01	<0.01	1.31	***0.47***
Badgerys Creek B3 (BCDS)	15-12-98	<100	<1	<1	<1	<1	<1	<10	<1	0.13	1.4	0.02	<0.01	1.42	***0.32***
Cosgroves Creek C1 (CCUS)	10-12-96	<1	<1	<1	<1	<1	<1	<50	<1	0.12	0.9	<0.02	<0.02	-	<0.02
Cosgroves Creek C3	10-12-96	<1	<1	<1	<1	<1	<1	<50	<1	0.12	0.9	<0.02	<0.02	<0.02	<0.02
Cosgroves Creek C3	16-09-98	<100	<1	<1	<1	<1	<1	30	<1	0.11	1.2	0.13	0.01	1.3	***0.07***
Cosgroves Creek C3	07-10-98	<100	<1	<1	<1	<1	<1	<10	<1	0.06	1.2	0.03	<0.01	1.23	***0.07***
Cosgroves Creek C3	14-12-98	<100	<1	<1	<1	<1	<1	<10	<1	0.7	1.7	<0.01	<0.01	1.7	***0.05***
Duncans Creek D1	10-12-96	<1	<1	<1	<1	<1	<1	530	<1	0.025	0.2	<0.02	<0.02	<0.02	<0.02
Duncans Creek D1	17-09-98	<100	<1	<1	<1	<1	<1	<10	<1	0.02	1.1	0.2	<0.01	1.3	***0.03***
Duncans Creek D1	08-10-98	<100	<1	<1	<1	<1	<1	<10	<1	<0.01	0.8	<0.01	<0.01	0.8	***0.04***
Duncans Creek D1	15-12-98	<100	<1	<1	<1	<1	<1	<10	<1	<0.01	0.5	<0.01	<0.01	0.5	***0.02***
South Creek S1	16-09-98	<100	<1	<1	<1	<1	<1	<10	<1	0.04	0.9	0.67	0.02	1.6	***0.14***
South Creek S1	07-10-98	<100	<1	<1	<1	<1	<1	<10	<1	0.08	1.2	0.14	<0.01	1.34	***0.12***
South Creek S1	14-12-98	<100	<1	<1	<1	<1	<1	<10	<1	0.24	0.3	0.19	<0.01	0.49	0.01
South Creek S2	16-09-98	<100	<1	<1	<1	<1	<1	<10	<1	0.04	1	0.5	0.02	1.5	***0.11***
South Creek S2	07-10-98	<100	<1	<1	<1	<1	<1	<10	<1	0.03	0.7	<0.01	<0.01	0.7	***0.07***
South Creek S2	14-12-98	<100	<1	<1	<1	<1	<1	<10	<1	<0.01	0.4	0.04	<0.01	0.44	0.01
South Creek S3	16-09-98	<100	<1	<1	<1	<1	<1	120	<1	0.09	1.1	0.24	0.02	1.4	***0.47***
South Creek S3	07-10-98	<100	<1	<1	<1	<1	<1	<10	<1	0.21	1.3	0.18	0.04	1.52	***0.5***
South Creek S3	14-12-98	<100	<1	<1	<1	<1	<1	<10	<1	0.03	0.8	<0.01	<0.01	0.8	***0.05***
Thompson Creek T1	10-12-96	<1	<1	<1	<1	<1	<1	4900	<1	0.13	0.5	<0.02	0.026	<0.02	<0.02
Thompson Creek T1	17-09-98	<100	<1	<1	<1	<1	<1	<10	<1	0.18	1	0.1	0.01	1.1	0.01
Thompson Creek T1	09-10-98	<100	<1	<1	<1	<1	<1	<10	<1	0.29	1.1	0.02	<0.01	1.12	***0.04***
Thompson Creek T1	15-12-98	<100	<1	<1	<1	<1	<1	<10	<1	0.04	1.1	0.04	<0.01	1.14	***0.04***

Table A5 - Selected Surface Water Screening Criteria

Chemical Name	Units	Primary Contact Recreation	Reference	Stock Watering	Reference	Irrigation	Reference	Freshwater Ecosystem	Reference
Anionic Surfactants as MBAs	mg/L	-	-	-	-	-	-	0.28	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Electrical Conductivity (lab)	uS/cm	-	-	-	-	-	-	125-2200	ANZECC (2000) Lowland River Trigger Values
pH (Lab)	pH Units	-	-	-	-	-	-	6.0-8.0	ANZECC (2000) Lowland River Trigger Values
Total Phosphorus as P	mg/L	0.004	USEPA (2015) Tap Water x 10	0.0004	USEPA (2015) Tap Water Guidelines	0.05	ANZECC (2000) Irrigation LTV	0.01	ANZECC (2000) Lowland River Trigger Values
Calcium	mg/L	-	-	1000	ANZECC (2000) Stock Watering	-	-	116	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Magnesium	mg/L	-	-	-	-	-	-	82	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Potassium	mg/L	-	-	-	-	-	-	53	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Arsenic	mg/L	0.1	NHMRC (2011) Drinking Water Guidelines x 10	0.5	ANZECC (2000) Stock Watering	0.1	ANZECC (2000) Irrigation LTV	0.15	USEPA (2013) Ambient Water Quality Criteria (Chronic - Freshwater)
Cadmium	mg/L	0.02	NHMRC (2011) Drinking Water Guidelines x 10	0.01	ANZECC (2000) Stock Watering	0.01	ANZECC (2000) Irrigation LTV	0.0002	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Chromium	mg/L	0.5	WHO (2011) Drinking Water Guidelines x 10	1	ANZECC (2000) Stock Watering	0.1	ANZECC (2000) Irrigation LTV	0.085	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Copper	mg/L	20	NHMRC (2011) Drinking Water Guidelines x 10	0.4	ANZECC (2000) Stock Watering	0.2	ANZECC (2000) Irrigation LTV	0.0014	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Iron	mg/L	140	USEPA (2015) Tap Water x 10	14	USEPA (2015) Tap Water Guidelines	0.2	ANZECC (2000) Irrigation LTV	0.3	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Lead	mg/L	0.1	NHMRC (2011) Drinking Water Guidelines x 10	0.1	ANZECC (2000) Stock Watering	2	ANZECC (2000) Irrigation LTV	0.0034	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Mercury	mg/L	0.01	NHMRC (2011) Drinking Water Guidelines x 10	0.002	ANZECC (2000) Stock Watering	0.002	ANZECC (2000) Irrigation LTV	0.0006	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Nickel	mg/L	0.2	NHMRC (2011) Drinking Water Guidelines x 10	1	ANZECC (2000) Stock Watering	0.2	ANZECC (2000) Irrigation LTV	0.011	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Zinc	mg/L	60	USEPA (2015) Tap Water x 10	20	ANZECC (2000) Stock Watering	2	ANZECC (2000) Irrigation LTV	0.008	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Benzene	mg/L	0.01	NHMRC (2011) Drinking Water Guidelines x 10	0.001	NHMRC (2011) Drinking Water Guidelines	-	-	0.95	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Ethylbenzene	mg/L	3	NHMRC (2011) Drinking Water Guidelines x 10	0.3	NHMRC (2011) Drinking Water Guidelines	-	-	0.08	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Toluene	mg/L	8	NHMRC (2011) Drinking Water Guidelines x 10	0.8	NHMRC (2011) Drinking Water Guidelines	-	-	0.18	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Total Xylenes	mg/L	6	NHMRC (2011) Drinking Water Guidelines x 10	0.6	NHMRC (2011) Drinking Water Guidelines	-	-	0.013	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
C6 - C9 Fraction	mg/L	150	WHO (2008) Petroleum Products in Drinking Water x 10	15	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
C6 - C10 Fraction	mg/L	150	WHO (2008) Petroleum Products in Drinking Water x 10	15	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
C6 - C10 Fraction minus BTEX (F1)	mg/L	150	WHO (2008) Petroleum Products in Drinking Water x 10	15	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
C10 - C14 Fraction	mg/L	0.9	WHO (2008) Petroleum Products in Drinking Water x 10	0.09	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
C15 - C28 Fraction	mg/L	0.9	WHO (2008) Petroleum Products in Drinking Water x 10	0.09	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
C29 - C36 Fraction	mg/L	0.9	WHO (2008) Petroleum Products in Drinking Water x 10	0.09	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
>C10 - C16 Fraction	mg/L	0.9	WHO (2008) Petroleum Products in Drinking Water x 10	0.09	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
>C10 - C16 Fraction minus Naphthalene (F2)	mg/L	0.9	WHO (2008) Petroleum Products in Drinking Water x 10	0.09	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
>C10 - C40 Fraction (sum)	mg/L	0.9	WHO (2008) Petroleum Products in Drinking Water x 10	0.09	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
>C16 - C34 Fraction	mg/L	0.9	WHO (2008) Petroleum Products in Drinking Water x 10	0.09	WHO (2008) Petroleum Products in Drinking Water	-	-	-	-
C10-C36 Fraction (sum)	mg/L	-	-	-		-	-	0.6	RIVM (2001) Dutch Groundwater Intervention Value
1,1-Dichloroethane	mg/L	0.027	USEPA (2015) Tap Water x 10	0.0027	USEPA (2015) Tap Water Guidelines	-	-	0.09	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
1,2-Dichloroethane	mg/L	0.03	NHMRC (2011) Drinking Water Guidelines x 10	0.003	NHMRC (2011) Drinking Water Guidelines	-	-	1.9	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
1,1-Dichloroethene	mg/L	0.3	NHMRC (2011) Drinking Water Guidelines x 10	0.03	NHMRC (2011) Drinking Water Guidelines	-	-	0.7	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
1,1,1-Trichloroethane	mg/L	80	USEPA (2015) Tap Water x 10	8	USEPA (2015) Tap Water Guidelines	-	-	0.27	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
1,1,2-Trichloroethane	mg/L	0.0028	USEPA (2015) Tap Water x 10	0.00028	USEPA (2015) Tap Water Guidelines	-	-	6.5	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
1,1,1,2-Tetrachloroethane	mg/L	0.0057	USEPA (2015) Tap Water x 10	0.00057	USEPA (2015) Tap Water Guidelines	-	-	-	-
1,1,2,2-Tetrachloroethane	mg/L	0.00076	USEPA (2015) Tap Water x 10	0.000076	USEPA (2015) Tap Water Guidelines	-	-	0.4	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
1,2,3-Trichlorobenzene	mg/L	0.07	USEPA (2015) Tap Water x 10	0.007	USEPA (2015) Tap Water Guidelines	-	-	0.01	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
1,2,4-Trichlorobenzene	mg/L	0.011	USEPA (2015) Tap Water x 10	0.0011	USEPA (2015) Tap Water Guidelines	-	-	0.17	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
1,2,3-Trichloropropane	mg/L	0.0000075	USEPA (2015) Tap Water x 10	0.00000075	USEPA (2015) Tap Water Guidelines	-	-	-	-
1,2-Dibromo-3-chloropropane	mg/L	0.01	WHO (2011) Drinking Water Guidelines x 10	0.001	WHO (2011) Drinking Water Guidelines	-	-	-	-
1,2-Dibromoethane	mg/L	0.01	NHMRC (2011) Drinking Water Guidelines x 10	0.001	NHMRC (2011) Drinking Water Guidelines	-	-	-	-
1,2-Dichlorobenzene	mg/L	15	NHMRC (2011) Drinking Water Guidelines x 10	1.5	NHMRC (2011) Drinking Water Guidelines	-	-	0.16	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
1,3-Dichlorobenzene	mg/L	-	-	-	-	-	-	0.26	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
1,4-Dichlorobenzene	mg/L	0.4	NHMRC (2011) Drinking Water Guidelines x 10	0.04	NHMRC (2011) Drinking Water Guidelines	-	-	0.06	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
1,2-Dichloropropane	mg/L	0.4	WHO (2011) Drinking Water Guidelines x 10	0.04	WHO (2011) Drinking Water Guidelines	-	-	0.9	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
1,3-Dichloropropane	mg/L	3.7	USEPA (2015) Tap Water x 10	0.37	USEPA (2015) Tap Water Guidelines	-	-	1.1	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
2-Chlorotoluene	mg/L	2.4	USEPA (2015) Tap Water x 10	0.24	USEPA (2015) Tap Water Guidelines	-	-	-	-
4-Chlorotoluene	mg/L	2.5	USEPA (2015) Tap Water x 10	0.25	USEPA (2015) Tap Water Guidelines	-	-	-	-
Bromobenzene	mg/L	0.62	USEPA (2015) Tap Water x 10	0.062	USEPA (2015) Tap Water Guidelines	-	-	-	-
Bromodichloromethane	mg/L	0.6	WHO (2011) Drinking Water Guidelines x 10	0.06	WHO (2011) Drinking Water Guidelines	-	-	-	-
Bromoform	mg/L	1	WHO (2011) Drinking Water Guidelines x 10	0.1	WHO (2011) Drinking Water Guidelines	-	-	0.32	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Bromomethane	mg/L	0.01	NHMRC (2011) Drinking Water Guidelines x 10	0.001	NHMRC (2011) Drinking Water Guidelines	-	-	0.016	USEPA (2003) Region 5 RCRA Ecological Screening Levels (Water)
Chloroethane	mg/L	210	USEPA (2015) Tap Water x 10	21	USEPA (2015) Tap Water Guidelines	-	-	-	-
Chloromethane	mg/L	1.9	USEPA (2015) Tap Water x 10	0.19	USEPA (2015) Tap Water Guidelines	-	-	-	-
cis-1,2-Dichloroethene	mg/L	0.36	USEPA (2015) Tap Water x 10	0.036	USEPA (2015) Tap Water Guidelines	-	-	-	-
cis-1,4-Dichloro-2-butene	mg/L	0.000013	USEPA (2015) Tap Water x 10	0.0000013	USEPA (2015) Tap Water Guidelines	-	-	-	-
Dibromochloromethane	mg/L	1	WHO (2011) Drinking Water Guidelines x 10	0.1	WHO (2011) Drinking Water Guidelines	-	-	-	-
Dibromomethane	mg/L	0.08	USEPA (2015) Tap Water x 10	0.008	USEPA (2015) Tap Water Guidelines	-	-	-	-
Dichlorodifluoromethane	mg/L	2	USEPA (2015) Tap Water x 10	0.2	USEPA (2015) Tap Water Guidelines	-	-	-	-
Hexachlorobutadiene	mg/L	0.007	NHMRC (2011) Drinking Water Guidelines x 10	0.0007	NHMRC (2011) Drinking Water Guidelines	-	-	0.00004	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Pentachloroethane	mg/L	0.0064	USEPA (2015) Tap Water x 10	0.00064	USEPA (2015) Tap Water Guidelines	-	-	0.08	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
trans-1,2-Dichloroethene	mg/L	3.6	USEPA (2015) Tap Water x 10	0.36	USEPA (2015) Tap Water Guidelines	-	-	0.97	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
trans-1,4-Dichloro-2-butene	mg/L	0.000013	USEPA (2015) Tap Water x 10	0.0000013	USEPA (2015) Tap Water Guidelines	-	-	-	-
Trichlorofluoromethane	mg/L	11	USEPA (2015) Tap Water x 10	1.1	USEPA (2015) Tap Water Guidelines	-	-	-	-
Acenaphthene	mg/L	5.3	USEPA (2015) Tap Water x 10	0.53	USEPA (2015) Tap Water Guidelines	-	-	0.0058	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Acenaphthylene	mg/L	-	-	-	-	-	-	4.84	USEPA (2003) Region 5 RCRA Ecological Screening Levels (Water)
Anthracene	mg/L	18	USEPA (2015) Tap Water x 10	1.8	USEPA (2015) Tap Water Guidelines	-	-	0.00001	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Benz(a)anthracene	mg/L	0.00034	USEPA (2015) Tap Water x 10	0.000034	USEPA (2015) Tap Water Guidelines	-	-	0.000018	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Benzo(a)pyrene	mg/L	0.0001	NHMRC (2011) Drinking Water Guidelines x 10	0.00001	NHMRC (2011) Drinking Water Guidelines	-	-	0.0001	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Benzo(g,h,i)perylene	mg/L	-	-	-	-	-	-	0.00764	USEPA (2003) Region 5 RCRA Ecological Screening Levels (Water)

Table A5 - Selected Surface Water Screening Criteria

Chemical Name	Units	Primary Contact Recreation	Reference	Stock Watering	Reference	Irrigation	Reference	Freshwater Ecosystem	Reference
Benzo(k)fluoranthene	mg/L	0.0034	USEPA (2015) Tap Water x 10	0.00034	USEPA (2015) Tap Water Guidelines	-	-	-	-
Chrysene	mg/L	0.034	USEPA (2015) Tap Water x 10	0.0034	USEPA (2015) Tap Water Guidelines	-	-	-	-
Dibenz(a,h)anthracene	mg/L	0.000034	USEPA (2015) Tap Water x 10	0.0000034	USEPA (2015) Tap Water Guidelines	-	-	-	-
Fluoranthene	mg/L	8	USEPA (2015) Tap Water x 10	0.8	USEPA (2015) Tap Water Guidelines	-	-	0.001	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Fluorene	mg/L	2.9	USEPA (2015) Tap Water x 10	0.29	USEPA (2015) Tap Water Guidelines	-	-	0.003	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Indeno(1,2,3-c,d)pyrene	mg/L	0.00034	USEPA (2015) Tap Water x 10	0.000034	USEPA (2015) Tap Water Guidelines	-	-	0.00431	USEPA (2003) Region 5 RCRA Ecological Screening Levels (Water)
Naphthalene	mg/L	0.0017	USEPA (2015) Tap Water x 10	0.00017	USEPA (2015) Tap Water Guidelines	-	-	0.016	ANZECC (2000) Fresh Water Quality Criteria (95% protection)
Phenanthrene	mg/L	-	-	-	-	-	-	0.0006	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Pyrene	mg/L	1.2	USEPA (2015) Tap Water x 10	0.12	USEPA (2015) Tap Water Guidelines	-	-	0.000025	USEPA (2006) Region 3 BTAG Fresh Water Quality Criteria
Carbon Tetrachloride	mg/L	0.03	NHMRC (2011) Drinking Water Guidelines x 10	0.003	NHMRC (2011) Drinking Water Guidelines	-	-	0.24	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Chlorobenzene	mg/L	3	NHMRC (2011) Drinking Water Guidelines x 10	0.3	NHMRC (2011) Drinking Water Guidelines	-	-	0.055	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Chloroform	mg/L	3	WHO (2011) Drinking Water Guidelines x 10	0.3	WHO (2011) Drinking Water Guidelines	-	-	0.37	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Tetrachloroethene	mg/L	0.5	NHMRC (2011) Drinking Water Guidelines x 10	0.05	NHMRC (2011) Drinking Water Guidelines	-	-	0.07	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Trichloroethene	mg/L	0.2	WHO (2011) Drinking Water Guidelines x 10	0.02	WHO (2011) Drinking Water Guidelines	-	-	0.33	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)
Vinyl chloride	mg/L	0.003	NHMRC (2011) Drinking Water Guidelines x 10	0.0003	NHMRC (2011) Drinking Water Guidelines	-	-	0.1	ANZECC (2000) Medium to Low Reliability Criteria (Freshwater)

Table A6 - Surface Water Analytical Data

						Location	Badgery's Creek - upstream	Badgery's Creek - upstream	Badgery's Creek - mid-catchment (a)	Badgery's Creek - mid-catchment (b)	Badgery's Creek - downstream	Badgery's Creek - downstream	Oaky Creek - downstream	Cosgrove Creek - upstream	Cosgrove Creek - upstream	Cosgrove Creek - downstream	Duncan's Creek - downstream
						Location ID	B1	BCUS (B1)	B2	BCMC	B3	BCDS (B3)	OCDS	C1	CCUS (C1)	CCDS	DN1
						Sample date:	22/09/2014	16/03/2015	22/09/2014	16/03/2015	22/09/2014	16/03/2015	16/03/2015	22/09/2014	16/03/2015	16/03/2015	22/09/2014
Analyte grouping/Analyte	**Units**	**LOR**	Primary Contact Recreation	Stock Watering	Irrigation	***Freshwater Ecosystem Protection***											
Electrical Conductivity @ 25°C	µS/cm	1	-	-	-	***125-2200***	-	**2710**	-	**3100**	-	**3050**	**4320**	-	**5020**	1050	-
Total Hardness as CaCO3	mg/L	1	-	-	-	-	-	550	-	521	-	535	604	-	806	160	-
Total Kjeldahl Nitrogen as N	mg/L	0.1	-	-	-	-	2.8	1.6	2.3	2.9	2.5	2.2	1.1	0.8	0.6	1.3	1.5
Total Nitrogen as N	mg/L	0.1	-	-	-	-	2.8	6.2	2.5	18.5	2.6	2.3	1.2	0.8	0.8	1.3	1.5
Ammonia as N	mg/L	0.01	-	-	-	-	0.01	0.17	0.013	0.28	0.006	0.22	0.22	<0.005	0.14	0.04	<0.005
Total Organic Carbon	mg/L	0.2	-	-	-	-	25	10.2	24	31.7	18	12.7	19.3	10	8.9	10.5	16
Anionic Surfactants as MBAS	mg/L	0.1	-	-	-	***0.28***	<0.1	0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	0.1	0.1	<0.1
Nitrate as N	mg/L	0.01	-	-	-	-	<0.005	4.56	0.13	15.5	0.078	0.1	0.06	<0.005	0.15	0.03	<0.005
Nitrite + Nitrate as N	mg/L	0.01	-	-	-	-	-	4.64	-	15.6	-	0.1	0.06	-	0.15	0.03	-
Nitrite as N	mg/L	0.01	-	-	-	-	<0.005	0.08	0.011	0.08	0.01	<0.01	<0.01	<0.005	<0.01	<0.01	<0.005
Oil & Grease	mg/L	5	-	-	-	-	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Suspended Solids (SS)	mg/L	5	-	-	-	-	10	23	17	<5	16	<5	19	32	<5	44	30
Total Phosphorus as P	mg/L	0.01	0.004	0.0004	0.05	***0.01***	***1.6***	***0.42***	***0.5***	***0.31***	***0.5***	***1***	***0.05***	***0.09***	***0.03***	***0.3***	***0.1***
Calcium	mg/L	1	-	1000	-	***116***	-	67	-	52	-	61	49	-	74	23	-
Magnesium	mg/L	1	-	-	-	***82***	-	***93***	-	***95***	-	***93***	***117***	-	***151***	25	-
Potassium	mg/L	1	-	-	-	***53***	-	13	-	***80***	-	***71***	19	-	8	9	-
Sodium	mg/L	1	-	-	-	***680***	-	430	-	497	-	449	***741***	-	***846***	162	-
Arsenic	mg/L		0.1	0.5	0.1	***0.15***	0.003	-	0.002	-	0.001	-	-	<0.001	-	-	0.001
Cadmium	mg/L	0.0001	0.02	0.01	0.01	***0.0002***	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	0.5	1	0.1	***0.085***	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	20	0.4	0.2	***0.0014***	***0.007***	***0.007***	***0.01***	***0.009***	***0.008***	0.003	***0.002***	***0.003***	0.001	<0.001	***0.004***
Iron	mg/L	0.05	140	14	0.2	***0.3***	-	***0.38***	-	***1.35***	-	***0.72***	***2.35***	-	0.18	***3.82***	-
Lead	mg/L	0.001	0.1	0.1	2	***0.0034***	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury	mg/L	0.0001	0.01	0.002	0.002	***0.0006***	<0.00005	<0.0001	<0.00005	<0.0001	<0.00005	<0.0001	<0.0001	<0.00005	<0.0001	<0.0001	<0.00005
Nickel	mg/L	0.001	0.2	1	0.2	***0.011***	0.004	0.001	0.005	0.01	0.003	0.005	0.003	0.001	0.002	0.001	0.003
Zinc	mg/L	0.005	60	20	2	***0.008***	***0.01***	0.008	***0.01***	***0.059***	0.007	0.008	0.008	0.003	<0.005	0.006	0.006
Benzene	µg/L	1	10	1	-	***950***	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	µg/L	2	3,000	300	-	***80***	<1	<2	<1	<2	<1	<2	<2	<1	<2	<2	<1
Toluene	µg/L	2	8,000	800	-	***180***	<1	<2	<1	<2	<1	<2	<2	<1	<2	<2	<1
meta- & para-Xylene	µg/L	2	-	-	-	-	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
ortho-Xylene	µg/L	2	-	-	-	-	<1	<2	<1	<2	<1	<2	<2	<1	<2	<2	<1
Total Xylenes	µg/L	2	6,000	600	-	***13***	-	<2	-	<2	-	<2	<2	-	<2	<2	-
Sum of BTEX	µg/L	1	-	-	-	-	-	<1	-	<1	-	<1	<1	-	<1	<1	-
C6 - C9 Fraction	µg/L	20	150,000	15,000	-	-	<10	<20	<10	<20	<10	<20	<20	<10	<20	<20	<10
C6 - C10 Fraction	µg/L	20	150,000	15,000	-	-	<10	<20	<10	<20	<10	<20	<20	<10	<20	<20	<10
C6 - C10 Fraction minus BTEX (F1)	µg/L	20	150,000	15,000	-	-	<10	<20	<10	<20	<10	<20	<20	<10	<20	<20	<10
C10 - C14 Fraction	µg/L	50	900	90	-	-	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	µg/L	100	900	90	-	-	<100	<100	150	<100	230	<100	<100	<100	<100	<100	120
C29 - C36 Fraction	µg/L	50	900	90	-	-	190	<50	500	<50	340	<50	<50	220	<50	<50	320
>C10 - C16 Fraction	µg/L	100	900	90	-	-	<50	<100	<50	<100	<50	<100	<100	<50	<100	<100	<50
>C10 - C16 Fraction minus Naphthalene (F2)	µg/L	100	900	90	-	-	<50	<100	<50	<100	<50	<100	<100	<50	<100	<100	<50
>C10 - C40 Fraction (sum)	µg/L	100	900	90	-	-	-	<100	-	<100	-	<100	<100	-	<100	<100	-
>C16 - C34 Fraction	µg/L	100	900	90	-	-	240	<100	540	<100	480	<100	<100	260	<100	<100	380
>C34 - C40 Fraction	µg/L	100	-	-	-	-	<100	<100	280	<100	180	<100	<100	<100	<100	<100	150
C10 - C36 Fraction (sum)	µg/L	50	-	-	-	***600***	-	<50	-	<50	-	<50	<50	-	<50	<50	-

Table A6 - Surface Water Analytical Data

						Location	Badgery's Creek - upstream	Badgery's Creek - upstream	Badgery's Creek - mid-catchment (a)	Badgery's Creek - mid-catchment (b)	Badgery's Creek - downstream	Badgery's Creek - downstream	Oaky Creek - downstream	Cosgrove Creek - upstream	Cosgrove Creek - upstream	Cosgrove Creek - downstream	Duncan's Creek - downstream
						Location ID	B1	BCUS (B1)	B2	BCMC	B3	BCDS (B3)	OCDS	C1	CCUS (C1)	CCDS	DN1
						Sample date:	22/09/2014	16/03/2015	22/09/2014	16/03/2015	22/09/2014	16/03/2015	16/03/2015	22/09/2014	16/03/2015	16/03/2015	22/09/2014
Analyte grouping/Analyte	**Units**	**LOR**	Primary Contact Recreation	Stock Watering	Irrigation	***Freshwater Ecosystem Protection***											
1.1-Dichloroethane	µg/L	5	27	2.7	-	***90***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.2-Dichloroethane	µg/L	5	30	3	-	***1900***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.1-Dichloroethene	µg/L	5	300	30	-	***700***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.1-Dichloropropylene	µg/L	5	-	-	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.1.1-Trichloroethane	µg/L	5	80,000	8,000	-	***270***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.1.2-Trichloroethane	µg/L	5	2.8	0.28	-	***6500***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.1.1.2-Tetrachloroethane	µg/L	5	5.7	0.57	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.1.2.2-Tetrachloroethane	µg/L	5	0.76	0.076	-	***400***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.2.3-Trichlorobenzene	µg/L	5	70	7	-	***10***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.2.4-Trichlorobenzene	µg/L	5	11	1.1	-	***170***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.2.3-Trichloropropane	µg/L	5	0.0075	0.00075	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.2-Dibromo-3-chloropropane	µg/L	5	10	1	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.2-Dibromoethane (EDB)	µg/L	5	10	1	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.2-Dichlorobenzene	µg/L	5	15,000	1,500	-	***160***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.3-Dichlorobenzene	µg/L	5	-	-	-	***260***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.4-Dichlorobenzene	µg/L	5	400	40	-	***60***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.2-Dichloropropane	µg/L	5	400	40	-	***900***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
1.3-Dichloropropane	µg/L	5	3700	370	-	***1100***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
2.2-Dichloropropane	µg/L	5	-	-	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
2-Chlorotoluene	µg/L	5	2400	240	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
4-Chlorotoluene	µg/L	5	2500	250	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Bromobenzene	µg/L	5	620	62	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Bromodichloromethane	µg/L	5	600	60	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Bromoform	µg/L	5	1000	100	-	***320***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Bromomethane	µg/L	50	10	1	-	***16***	<10	<50	<10	<50	<10	<50	<50	<10	<50	<50	<10
Chloroethane	µg/L	50	210,000	21,000	-	-	<10	<50	<10	<50	<10	<50	<50	<10	<50	<50	<10
Chloromethane	µg/L	50	1900	190	-	-	<10	<50	<10	<50	<10	<50	<50	<10	<50	<50	<10
cis-1.2-Dichloroethene	µg/L	5	360	36	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
cis-1.3-Dichloropropylene	µg/L	5	-	-	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
cis-1.4-Dichloro-2-butene	µg/L	5	0.013	0.0013	-	-	-	<5	-	<5	-	<5	<5	-	<5	<5	-
Dibromochloromethane	µg/L	5	1000	100	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Dibromomethane	µg/L	5	80	8	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Dichlorodifluoromethane	µg/L	50	2000	200	-	-	<10	<50	<10	<50	<10	<50	<50	<10	<50	<50	<10
Hexachlorobutadiene	µg/L	5	7	0.7	-	***0.04***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Iodomethane	µg/L	5	-	-	-	-	-	<5	-	<5	-	<5	<5	-	<5	<5	-
Pentachloroethane	µg/L	5	6.4	0.64	-	***80***	-	<5	-	<5	-	<5	<5	-	<5	<5	-
trans-1.2-Dichloroethene	µg/L	5	3600	360	-	***970***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
trans-1.3-Dichloropropylene	µg/L	5	-	-	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
trans-1.4-Dichloro-2-butene	µg/L	5	0.013	0.0013	-	-	-	<5	-	<5	-	<5	<5	-	<5	<5	-
Trichlorofluoromethane	µg/L	50	11,000	1,100	-	-	<10	<50	<10	<50	<10	<50	<50	<10	<50	<50	<10
Acenaphthene	µg/L	1	5300	530	-	***5.8***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Acenaphthylene	µg/L	1	-	-	-	***4840***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Anthracene	µg/L	1	18,000	1,800	-	***0.01***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Benz(a)anthracene	µg/L	1	0.34	0.034	-	***0.018***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Benzo(a)pyrene	µg/L	0.5	0.1	0.01	-	***0.1***	<0.1	<0.5	<0.1	<0.5	<0.1	<0.5	<0.5	<0.1	<0.5	<0.5	<0.1
Benzo(b+j)fluoranthene	µg/L	1	-	-	-	-	-	<1.0	-	<1.0	-	<1.0	<1.0	-	<1.0	<1.0	-
Benzo(g.h.i)perylene	µg/L	1	-	-	-	***7.64***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Benzo(k)fluoranthene	µg/L	1	3.4	0.34	-	-	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1

Table A6 - Surface Water Analytical Data

			Location	Badgery's Creek - upstream	Badgery's Creek - upstream	Badgery's Creek - mid-catchment (a)	Badgery's Creek - mid-catchment (b)	Badgery's Creek - downstream	Badgery's Creek - downstream	Oaky Creek - downstream	Cosgrove Creek - upstream	Cosgrove Creek - upstream	Cosgrove Creek - downstream	Duncan's Creek - downstream
			Location ID	B1	BCUS (B1)	B2	BCMC	B3	BCDS (B3)	OCDS	C1	CCUS (C1)	CCDS	DN1
			Sample date:	22/09/2014	16/03/2015	22/09/2014	16/03/2015	22/09/2014	16/03/2015	16/03/2015	22/09/2014	16/03/2015	16/03/2015	22/09/2014
Analyte grouping/Analyte	**Units**	**LOR**	Primary Contact Recreation	Stock Watering	Irrigation	***Freshwater Ecosystem Protection***										
Chrysene	µg/L	1	34	3.4	-	-	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Dibenz(a.h)anthracene	µg/L	1	0.034	0.0034	-	-	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Fluoranthene	µg/L	1	8,000	800	-	***1***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Fluorene	µg/L	1	2,900	290	-	***3***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Indeno(1.2.3.cd)pyrene	µg/L	1	0.34	0.034	-	***4.31***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Naphthalene	µg/L	1	1.7	0.17	-	***16***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Phenanthrene	µg/L	1	-	-	-	***0.6***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Pyrene	µg/L	1	1,200	120	-	***0.025***	<0.1	<1.0	<0.1	<1.0	<0.1	<1.0	<1.0	<0.1	<1.0	<1.0	<0.1
Sum of polycyclic aromatic hydrocarbons	µg/L	0.5	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ (zero)	µg/L	0.5	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon Tetrachloride	µg/L	5	30	3	-	***240***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Chlorobenzene	µg/L	5	3,000	300	-	***55***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Chloroform	µg/L	5	3,000	300	-	***370***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Tetrachloroethene	µg/L	5	500	50	-	***70***	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1
Trichloroethene	µg/L	5	-	-	-	-	<1	<5	<1	<5	<1	<5	<5	<1	<5	<5	<1

Table A6 - Surface Water Analytical

			Location	Duncan's Creek - downstream	South Creek - Upstream	South Creek - recovery	South Creek - downstream	Thompson Creek - upstream	Thomsons Creek - mid-catchment
			Location ID	DCDS (DN1)	SCUS	SCREC	SCDS	TCUS	T1
			Sample date:	16/03/2015	16/03/2015	16/03/2015	16/03/2015	16/03/2015	22/09/2014
Analyte grouping/Analyte	**Units**	**LOR**	Primary Contact Recreation	Stock Watering	Irrigation	***Freshwater Ecosystem Protection***						
Electrical Conductivity @ 25°C	µS/cm	1	-	-	-	***125-2200***	847	1680	1540	1900	1640	-
Total Hardness as CaCO3	mg/L	1	-	-	-	-	162	281	253	292	179	-
Total Kjeldahl Nitrogen as N	mg/L	0.1	-	-	-	-	0.7	1.1	0.9	1	1	0.7
Total Nitrogen as N	mg/L	0.1	-	-	-	-	0.9	1.2	1	1.1	1	0.7
Ammonia as N	mg/L	0.01	-	-	-	-	0.23	0.3	0.14	0.06	0.04	<0.005
Total Organic Carbon	mg/L	0.2	-	-	-	-	6.3	10.1	14.4	16.6	20.3	11
Anionic Surfactants as MBAS	mg/L	0.1	-	-	-	***0.28***	0.1	<0.1	0.1	0.1	0.1	<0.1
Nitrate as N	mg/L	0.01	-	-	-	-	0.19	0.08	0.12	0.1	0.01	<0.005
Nitrite + Nitrate as N	mg/L	0.01	-	-	-	-	0.2	0.1	0.12	0.1	0.01	-
Nitrite as N	mg/L	0.01	-	-	-	-	0.01	0.02	<0.01	<0.01	<0.01	<0.005
Oil & Grease	mg/L	5	-	-	-	-	<5	<5	<5	<5	<5	<5
Suspended Solids (SS)	mg/L	5	-	-	-	-	14	<5	10	19	<5	31
Total Phosphorus as P	mg/L	0.01	0.004	0.0004	0.05	***0.01***	***0.06***	***0.27***	***0.05***	***0.08***	***0.09***	***0.07***
Calcium	mg/L	1	-	1000	-	***116***	32	40	32	38	24	-
Magnesium	mg/L	1	-	-	-	***82***	20	44	42	48	29	-
Potassium	mg/L	1	-	-	-	***53***	4	44	22	33	6	-
Sodium	mg/L	1	-	-	-	***680***	111	235	228	279	272	-
Arsenic	mg/L		0.1	0.5	0.1	***0.15***	-	-	-	-	-	<0.001
Cadmium	mg/L	0.0001	0.02	0.01	0.01	***0.0002***	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	0.5	1	0.1	***0.085***	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper	mg/L	0.001	20	0.4	0.2	***0.0014***	***0.002***	***0.004***	***0.01***	***0.002***	***0.002***	***0.003***
Iron	mg/L	0.05	140	14	0.2	***0.3***	***1.31***	***0.36***	***1.01***	***1.11***	***0.85***	-
Lead	mg/L	0.001	0.1	0.1	2	***0.0034***	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury	mg/L	0.0001	0.01	0.002	0.002	***0.0006***	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.00005
Nickel	mg/L	0.001	0.2	1	0.2	***0.011***	0.001	0.003	0.002	0.004	0.003	0.002
Zinc	mg/L	0.005	60	20	2	***0.008***	0.008	<0.005	***0.013***	0.005	0.007	0.007
Benzene	µg/L	1	10	1	-	***950***	<1	<1	<1	<1	<1	<1
Ethylbenzene	µg/L	2	3,000	300	-	***80***	<2	<2	<2	<2	<2	<1
Toluene	µg/L	2	8,000	800	-	***180***	<2	<2	<2	<2	<2	<1
meta- & para-Xylene	µg/L	2	-	-	-	-	<2	<2	<2	<2	<2	<2
ortho-Xylene	µg/L	2	-	-	-	-	<2	<2	<2	<2	<2	<1
Total Xylenes	µg/L	2	6,000	600	-	***13***	<2	<2	<2	<2	<2	-
Sum of BTEX	µg/L	1	-	-	-	-	<1	<1	<1	<1	<1	-
C6 - C9 Fraction	µg/L	20	150,000	15,000	-	-	<20	<20	<20	<20	<20	<10
C6 - C10 Fraction	µg/L	20	150,000	15,000	-	-	<20	<20	<20	<20	<20	<10
C6 - C10 Fraction minus BTEX (F1)	µg/L	20	150,000	15,000	-	-	<20	<20	<20	<20	<20	<10
C10 - C14 Fraction	µg/L	50	900	90	-	-	<50	<50	<50	<50	<50	<50
C15 - C28 Fraction	µg/L	100	900	90	-	-	<100	<100	<100	<100	<100	<100
C29 - C36 Fraction	µg/L	50	900	90	-	-	<50	<50	<50	<50	<50	<100
>C10 - C16 Fraction	µg/L	100	900	90	-	-	<100	<100	<100	<100	<100	<50
>C10 - C16 Fraction minus Naphthalene (F2)	µg/L	100	900	90	-	-	<100	<100	<100	<100	<100	<50
>C10 - C40 Fraction (sum)	µg/L	100	900	90	-	-	<100	<100	<100	<100	<100	-
>C16 - C34 Fraction	µg/L	100	900	90	-	-	<100	<100	<100	<100	<100	<100
>C34 - C40 Fraction	µg/L	100	-	-	-	-	<100	<100	<100	<100	<100	<100
C10 - C36 Fraction (sum)	µg/L	50	-	-	-	***600***	<50	<50	<50	<50	<50	-

Table A6 - Surface Water Analytical

			Location	Duncan's Creek - downstream	South Creek - Upstream	South Creek - recovery	South Creek - downstream	Thompson Creek - upstream	Thomsons Creek - mid-catchment
			Location ID	DCDS (DN1)	SCUS	SCREC	SCDS	TCUS	T1
			Sample date:	16/03/2015	16/03/2015	16/03/2015	16/03/2015	16/03/2015	22/09/2014
Analyte grouping/Analyte	**Units**	**LOR**	Primary Contact Recreation	Stock Watering	Irrigation	***Freshwater Ecosystem Protection***						
1.1-Dichloroethane	µg/L	5	27	2.7	-	***90***	<5	<5	<5	<5	<5	<1
1.2-Dichloroethane	µg/L	5	30	3	-	***1900***	<5	<5	<5	<5	<5	<1
1.1-Dichloroethene	µg/L	5	300	30	-	***700***	<5	<5	<5	<5	<5	<1
1.1-Dichloropropylene	µg/L	5	-	-	-	-	<5	<5	<5	<5	<5	<1
1.1.1-Trichloroethane	µg/L	5	80,000	8,000	-	***270***	<5	<5	<5	<5	<5	<1
1.1.2-Trichloroethane	µg/L	5	2.8	0.28	-	***6500***	<5	<5	<5	<5	<5	<1
1.1.1.2-Tetrachloroethane	µg/L	5	5.7	0.57	-	-	<5	<5	<5	<5	<5	<1
1.1.2.2-Tetrachloroethane	µg/L	5	0.76	0.076	-	***400***	<5	<5	<5	<5	<5	<1
1.2.3-Trichlorobenzene	µg/L	5	70	7	-	***10***	<5	<5	<5	<5	<5	<1
1.2.4-Trichlorobenzene	µg/L	5	11	1.1	-	***170***	<5	<5	<5	<5	<5	<1
1.2.3-Trichloropropane	µg/L	5	0.0075	0.00075	-	-	<5	<5	<5	<5	<5	<1
1.2-Dibromo-3-chloropropane	µg/L	5	10	1	-	-	<5	<5	<5	<5	<5	<1
1.2-Dibromoethane (EDB)	µg/L	5	10	1	-	-	<5	<5	<5	<5	<5	<1
1.2-Dichlorobenzene	µg/L	5	15,000	1,500	-	***160***	<5	<5	<5	<5	<5	<1
1.3-Dichlorobenzene	µg/L	5	-	-	-	***260***	<5	<5	<5	<5	<5	<1
1.4-Dichlorobenzene	µg/L	5	400	40	-	***60***	<5	<5	<5	<5	<5	<1
1.2-Dichloropropane	µg/L	5	400	40	-	***900***	<5	<5	<5	<5	<5	<1
1.3-Dichloropropane	µg/L	5	3700	370	-	***1100***	<5	<5	<5	<5	<5	<1
2.2-Dichloropropane	µg/L	5	-	-	-	-	<5	<5	<5	<5	<5	<1
2-Chlorotoluene	µg/L	5	2400	240	-	-	<5	<5	<5	<5	<5	<1
4-Chlorotoluene	µg/L	5	2500	250	-	-	<5	<5	<5	<5	<5	<1
Bromobenzene	µg/L	5	620	62	-	-	<5	<5	<5	<5	<5	<1
Bromodichloromethane	µg/L	5	600	60	-	-	<5	<5	<5	<5	<5	<1
Bromoform	µg/L	5	1000	100	-	***320***	<5	<5	<5	<5	<5	<1
Bromomethane	µg/L	50	10	1	-	***16***	<50	<50	<50	<50	<50	<10
Chloroethane	µg/L	50	210,000	21,000	-	-	<50	<50	<50	<50	<50	<10
Chloromethane	µg/L	50	1900	190	-	-	<50	<50	<50	<50	<50	<10
cis-1.2-Dichloroethene	µg/L	5	360	36	-	-	<5	<5	<5	<5	<5	<1
cis-1.3-Dichloropropylene	µg/L	5	-	-	-	-	<5	<5	<5	<5	<5	<1
cis-1.4-Dichloro-2-butene	µg/L	5	0.013	0.0013	-	-	<5	<5	<5	<5	<5	-
Dibromochloromethane	µg/L	5	1000	100	-	-	<5	<5	<5	<5	<5	<1
Dibromomethane	µg/L	5	80	8	-	-	<5	<5	<5	<5	<5	<1
Dichlorodifluoromethane	µg/L	50	2000	200	-	-	<50	<50	<50	<50	<50	<10
Hexachlorobutadiene	µg/L	5	7	0.7	-	***0.04***	<5	<5	<5	<5	<5	<1
Iodomethane	µg/L	5	-	-	-	-	<5	<5	<5	<5	<5	-
Pentachloroethane	µg/L	5	6.4	0.64	-	***80***	<5	<5	<5	<5	<5	-
trans-1.2-Dichloroethene	µg/L	5	3600	360	-	***970***	<5	<5	<5	<5	<5	<1
trans-1.3-Dichloropropylene	µg/L	5	-	-	-	-	<5	<5	<5	<5	<5	<1
trans-1.4-Dichloro-2-butene	µg/L	5	0.013	0.0013	-	-	<5	<5	<5	<5	<5	-
Trichlorofluoromethane	µg/L	50	11,000	1,100	-	-	<50	<50	<50	<50	<50	<10
Acenaphthene	µg/L	1	5300	530	-	***5.8***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Acenaphthylene	µg/L	1	-	-	-	***4840***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Anthracene	µg/L	1	18,000	1,800	-	***0.01***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Benz(a)anthracene	µg/L	1	0.34	0.034	-	***0.018***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Benzo(a)pyrene	µg/L	0.5	0.1	0.01	-	***0.1***	<0.5	<0.5	<0.5	<0.5	<0.5	<0.1
Benzo(b+j)fluoranthene	µg/L	1	-	-	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	-
Benzo(g.h.i)perylene	µg/L	1	-	-	-	***7.64***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Benzo(k)fluoranthene	µg/L	1	3.4	0.34	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1

Table A6 - Surface Water Analytical

						Location	Duncan's Creek - downstream	South Creek - Upstream	South Creek - recovery	South Creek - downstream	Thompson Creek - upstream	Thomsons Creek - mid-catchment
						Location ID	DCDS (DN1)	SCUS	SCREC	SCDS	TCUS	T1
						Sample date:	16/03/2015	16/03/2015	16/03/2015	16/03/2015	16/03/2015	22/09/2014
Analyte grouping/Analyte	**Units**	**LOR**	Primary Contact Recreation	Stock Watering	Irrigation	***Freshwater Ecosystem Protection***						
Chrysene	µg/L	1	34	3.4	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Dibenz(a.h)anthracene	µg/L	1	0.034	0.0034	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Fluoranthene	µg/L	1	8,000	800	-	***1***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Fluorene	µg/L	1	2,900	290	-	***3***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Indeno(1.2.3.cd)pyrene	µg/L	1	0.34	0.034	-	***4.31***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Naphthalene	µg/L	1	1.7	0.17	-	***16***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Phenanthrene	µg/L	1	-	-	-	***0.6***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Pyrene	µg/L	1	1,200	120	-	***0.025***	<1.0	<1.0	<1.0	<1.0	<1.0	<0.1
Sum of polycyclic aromatic hydrocarbons	µg/L	0.5	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Benzo(a)pyrene TEQ (zero)	µg/L	0.5	-	-	-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Carbon Tetrachloride	µg/L	5	30	3	-	***240***	<5	<5	<5	<5	<5	<1
Chlorobenzene	µg/L	5	3,000	300	-	***55***	<5	<5	<5	<5	<5	<1
Chloroform	µg/L	5	3,000	300	-	***370***	<5	<5	<5	<5	<5	<1
Tetrachloroethene	µg/L	5	500	50	-	***70***	<5	<5	<5	<5	<5	<1
Trichloroethene	µg/L	5	-	-	-	-	<5	<5	<5	<5	<5	<1

VOLUME 4

Appendix H
Hazard and risk





GHD

WESTERN SYDNEY AIRPORT EIS
HAZARD AND RISK REVIEW

SEPTEMBER 2015

DOCUMENT CONTROL

This document has been prepared to the particular instructions of our client or responsible R2A director. It should only be used for the purpose for which it has been commissioned.

Risk is peculiar to time, place and circumstance. So unless specifically indicated to the contrary, this report only applies to the particular situation or scenario that is the subject of this commission.

PROJECT DETAILS

Client:	GHD
Project Name:	Western Sydney Airport EIS Hazard and Risk Review
Client Reference:	RFQTS 2014/7540 WSA
R2A Reference:	213-11

REVISION SCHEDULE

VERSION	DATE	DESCRIPTION	PREPARED BY:	REVIEWED BY:	ISSUE AUTH BY:
0.9	18/6/15	Draft report	GF/RR	JA/SR	
0.95	24/6/15	2nd draft	RR	GF	
0.96	13/7/15	Client feedback	RR	GF	
1.0	4/8/15	First release	GF	RR	
2.0	8/9/15	2nd release following advice from AGS	GF	RR	RR

DISTRIBUTION

	DISTRIBUTION	NUMBER	COMMENTS
i	Client	1	Greg Marshall
Ii	R2A	1	Client File
	Total	2	

TABLE OF CONTENTS

EXECUTIVE SUMMARY 4

1. INTRODUCTION AND BACKGROUND 6

1.1 WESTERN SYDNEY AIRPORT PROPOSAL 6

1.2 EXISTING SITE CONTEXT 7

1.3 OBJECTIVE OF THIS REVIEW 8

1.4 STRUCTURE OF THIS REPORT 9

1.5 REVIEW LIMITATIONS 9

2. UNDERSTANDING THE PRECAUTIONARY APPROACH TO RISK MANAGEMENT 10

2.1 LEGISLATIVE CONTEXT 10

2.2 HAZARD VS PRECAUTIONARY BASED RISK APPROACHES 10

3 RELEVANT LEGISLATION AND GUIDELINES 14

3.1 AVIATION LEGISLATION AND GUIDELINES 14

3.1.1 AIRSPACE PROTECTION 15

3.1.2 NAVIGATION SYSTEMS AND AIR TRAFFIC MANAGEMENT 16

3.1.3 DEVELOPMENT IN THE VICINITY OF AIRPORTS 16

3.1.4 THE NATIONAL AIRPORTS SAFEGUARDING FRAMEWORK 16

3.2 DANGEROUS GOODS LEGISLATION & GUIDELINES 18

4. METHODOLOGY 19

5. HAZARD AND RISK REVIEW 20

5.1 OVERVIEW 20

5.2 AIRCRAFT ACCIDENTS 21

5.2.1 BIRD AND BAT STRIKE 29

5.2.2 REMOTELY PILOTED AIRCRAFT 30

5.2.3 HIGH STRUCTURE / TERRAIN STRIKE 30

5.2.4 SPECIAL MILITARY AND EMERGENCY SERVICES OPERATIONS 31

5.2.5 STACK DISCHARGE 31

5.3 FIRE AND EXPLOSION 31
5.3.1 FUEL STORAGE FIRE AND EXPLOSION 31
5.3.2 FUELLING FIRE 34
5.2.3 AIRCRAFT FIRE (ON THE GROUND) 34
5.3.4 BUILDING FIRE 35
5.4 ADVERSE METEOROLOGY 35
5.5 OTHER ISSUES 36
5.5.1 TERRORISM 36
5.5.2 BUSHFIRE / SMOKE (OFFSITE) 36
5.5.3 FLOODING 37
5.5.4 CONTAMINATED LAND 38
5.5.5 RAILWAY INCIDENTS 39
6. FINDINGS AND CONCLUSIONS 40
7. REFERENCES 42
GLOSSARY AND ABBREVIATIONS 43

EXECUTIVE SUMMARY

R2A has been commissioned by GHD to complete a Hazard and Risk review for the Western Sydney Airport Environmental Impact Statement (EIS). The EIS is being undertaken in accordance with the requirements of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the guidelines issued for the EIS (Reference: EPBC 2014/7391).

A precautionary based approach to the risk assessment was adopted which is consistent with the provisions of both the Commonwealth *Work Health and Safety Act 2011* and the NSW *Work Health and Safety Act 2011.* The approach included a desktop review with input from various project stakeholders regarding the key construction and operational safety risks for the nominal design years 2030 (single runway) and 2063 (two runways).

Regarding potential aircraft safety issues associated with the proposed Stage 1 (single runway) development, the indicative flight paths prepared by Airservices Australia mostly eliminate interactions with existing air traffic in the Sydney basin and also avoid existing major infrastructure including Defence Establishment Orchard Hills, Warragamba Dam and Prospect Reservoir. No unmanageable airspace safety issues were identified by the study for the proposed Stage 1 airport development.

The subsequent development of final flight paths and procedures for the proposed Western Sydney Airport (WSA) and related airspace design would occur under the existing airspace management arrangements established by Airservices Australia with approvals from the Civil Aviation Safety Authority (CASA). Those processes include a significant focus on safety and risk management as well as other issues.

The development of the second (southern) runway around 2050 may require significantly greater airspace planning and design due to the complexity of managing aircraft movements at the proposed Western Sydney Airport, Sydney (Kingsford Smith) Airport and other airports in the Sydney basin. To facilitate the expected level of future demand, and based on current air safety controls and technology, a reconfiguration of the Sydney basin airspace may be necessary.

The delivery and storage of fuel is also an important issue which will require further consideration and design. It is expected that the proposed airport would be initially serviced by B-double fuel tanker trucks. In 2030, the forecast fuel demand would require the mobilisation of approximately 43 B-doubles of fuel per day. If a dedicated fuel supply pipeline was not provided, the number of truck movements would need to increase in line with the growth in air traffic. The transport of fuel by trucks presents a potential safety hazard for other road users and adjacent facilities.

A potential worst case fuel storage fire has been modelled at the airport site. Depending on the expected adjacent land use further precautions for off-site facilities may be required with the presently planned 80m buffer. Both fuel supply and fuel storage issues should be further investigated during detailed design to incorporate appropriate hazard elimination and reduction measures.

A number of the issues identified through this risk assessment relate to the construction phase of the proposed Stage 1 airport development. Separate desktop risk assessments were conducted for bushfire, flooding and contaminated land. Risks identified in relation to these matters, are proposed to be managed through the preparation and implementation of issue-specific management plans. Other potential construction issues include storage and management of fuels, chemicals and any combustible gases. In these cases, adoption of industry standard practices would largely manage the risk they pose to users and the environment.

Details regarding the specific risks and precautions are contained in Section 5.

1. INTRODUCTION AND BACKGROUND

1.1 WESTERN SYDNEY AIRPORT PROPOSAL

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million annual passengers. To maximise the potential of the site, the airport is proposed to operate on a curfew free basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the site.

On 23 December 2014, a delegate of the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the airport will be controlled by the *Airports Act 1996* (Cth). The *Airports Act 1996* provides for the preparation of an Airport

Plan which will serve as the authorisation for the development for which it provides.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond the initial stage would be managed in accordance with the existing process in the *Airports Act 1996*. This includes a requirement that for major developments (defined in the Airports Act), a major development plan be approved by the Infrastructure Minister following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 EXISTING SITE CONTEXT

The airport site is situated about 56 kilometres south-west of the Sydney CBD and about 50 kilometres west of Sydney (Kingsford Smith) Airport (KSA). The site terrain comprises low lying hills with several watercourses and farm dams. The major land uses currently comprise low density rural residential and agricultural land uses. The site is bounded by Elizabeth Drive to the north, Willowdene Avenue to the south-west, the village of Luddenham and Adams Road to the west and Badgerys Creek to the south-east. The Northern Road currently passes through the site but would be diverted prior to construction commencing.

In terms of existing major infrastructure, the area surrounding the airport site includes the Defence Establishment Orchard Hills approximately six kilometres to the north, Warragamba Dam approximately 10 kilometres to the west, and Prospect Reservoir approximately 14 kilometres to the north-west. Existing residential areas fringing the site include the villages of Luddenham, Greendale, Bringelly and Badgerys Creek.

Two major future developments will abut the airport site subject to rezoning and based on regional plans undertaken by the NSW Department of Planning and Environment. The South West Priority Growth Area is located directly to the south-east and east of the airport site. The area is approximately 17,000 hectares in size and, on current forecasts, is expected to provide 110,000 new dwellings. The potential extension of the South West Rail Link corridor from Leppington,

which may include an extension to, or through, the airport site and extend further north, is likely to pass through the Growth Area.

The NSW Government has also established the Western Sydney Employment Area (WSEA) to provide businesses in Western Sydney with land for industry and employment generating uses, including transport and logistics, warehousing and commercial office space. In January 2015, the WSEA was extended to include land adjacent to the airport site (known as the Broader WSEA).

1.3 OBJECTIVE OF THIS REVIEW

R2A has been commissioned by GHD to complete a Hazard and Risk (safety) review for the Western Sydney Airport (WSA) Environmental Impact Statement (EIS). The EIS is being undertaken in accordance with the requirements of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. In relation to hazards and risks, the guidelines issued for the EIS (Reference: EPBC 2014/7391) require consideration of (Section 5 (g)):

- bird or bat airstrike
- creation of any risks or hazards to people or property that may be associated with any component of the action (i.e. the construction and operation of the airport).

This review identifies, assesses and documents these risks and other issues using a precautionary based approach that leverages the knowledge of key regulators and stakeholders (refer Section 4).

This review provides an assessment of the following key reference points for the proposed airport:

- the Stage 1 airport development, which has an estimated construction time frame of 2016-2024 and an operational reference date of 2030 (when it is anticipated that the proposed airport will handle approximately 10 million passengers per year); and
- a longer term development, which involves two parallel runways, using an operational reference date of 2063 (when it is anticipated that the proposed airport would handle approximately 82 million passengers per year).

1.4 STRUCTURE OF THIS REPORT

The remainder of this report is structured as follows:

- Section 2 – introduces the philosophy of the precautionary approach to risk assessment.
- Section 3 – outlines the key existing legislation and guidelines relevant to airspace protection, airport operation and transport of dangerous goods.
- Section 4 – presents the methodology adopted for the study
- Section 5 – documents the findings of the risk review
- Section 6 – summarises the key precautions and mitigation measures resulting from the risk review.

1.5 REVIEW LIMITATIONS

This review is being completed at an early stage in the concept development of the proposed new airport to ensure that any overarching safety issues are identified prior to construction and operation. It is based on information available at the time of writing this report. A list of referenced documents is contained in Section 7 *References*.

WHS legislation will apply to the future design, construction and operation of the airport. All safety risks will need to be assessed prior to work commencing by any person who will be conducting a business or undertaking (PCBU) as part of the proposed airport in line with their duty as a PCBU under WHS legislation.

However, it is not possible at this preliminary design stage to identify what businesses or undertakings will be conducted or the persons who will be conducting those businesses or undertakings. This means that it is not possible to demonstrate safety due diligence consistent with the provisions of the WHS legislation at this time.

Accordingly the hazards and risk review process has been limited to:

- A high-level outline of the type and nature of the hazards and risks that may be expected to arise as a result of the construction and anticipated operations of the proposed airport, and
- Identification of possible practicable precautions that could be provided based on the understanding that the relevant PCBUs will complete a full SFAIRP determination in due course.

Further design definition and subsequent safety reviews will be required as the airport concept is developed and prior to the airport commencing operation.

The review primarily focuses on the proposed Stage 1 (single runway) operations.

2. UNDERSTANDING THE PRECAUTIONARY APPROACH TO RISK MANAGEMENT

2.1 LEGISLATIVE CONTEXT

The primary legislation with regards to safety for both the Commonwealth and NSW is the *Work Health and Safety Act 2011* (Cth) (Cth WHS Act) and the *Work Health and Safety Act 2011* (NSW) (NSW WHS Act) respectively. These acts require that persons conducting a business or undertaking should eliminate risks, so far as is reasonably practicable (SFAIRP), and if this is not possible, reduce risks so far as is reasonably practicable. Persons conducting a business or undertaking (PCBUs) have an obligation to ensure that they comply with their duties and obligations.

The enactment of the WHS acts in 2011 has brought with it a change in philosophy for the identification and management of safety risks compared to previous practice. While this study is not being conducted to comply with WHS legislation (refer Section 1.5), the concepts of risk management in the WHS legislation have been considered in undertaking this risk assessment and as far as possible, this new approach has been adopted for this study.

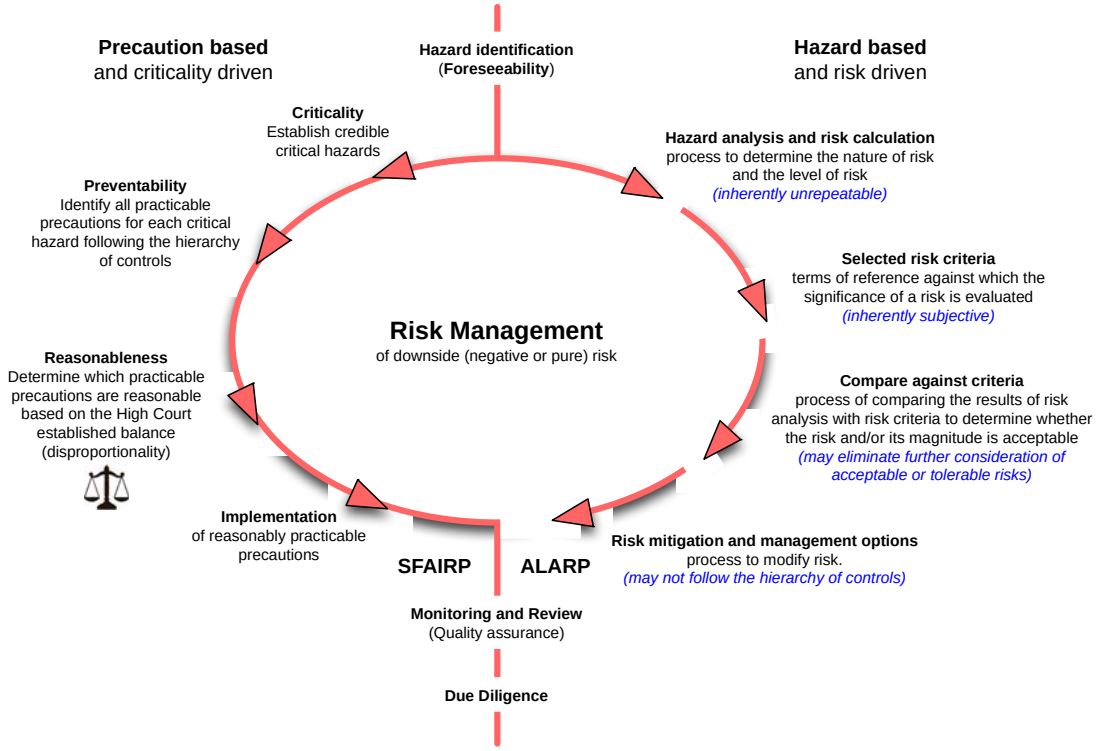
2.2 HAZARD VS PRECAUTIONARY BASED RISK APPROACHES

Two primary paradigms of safety risk management, hazard and precautionary based approaches, have co-existed over the last few decades.

The hazard-based risk management approach requires that hazards be identified, and the risk (likelihood and consequence) associated with them be determined and then compared to acceptable or tolerable risk criteria. If the criteria are not satisfied, then risk treatments are applied until the criteria are satisfied.

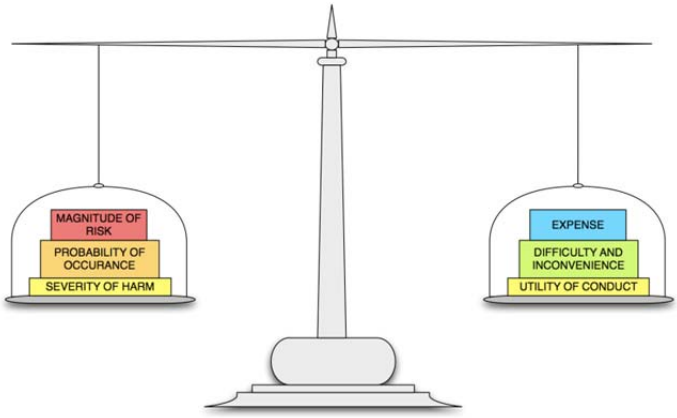
The precautionary-based risk management approach aims to identify practical options that are available to address identified safety issues and then tests to see which options are reasonable in the circumstances and ought to be done, especially recognised good practices.

Both approaches aim for the same result. If all reasonable practicable precautions are in place for all hazards, then the risk associated with those hazards is as low as reasonably practicable. This is shown in the diagram below which summarises the key steps of the two approaches.



Precaution vs hazard based approaches to risk management[1]

The left hand side of the loop in the diagram above describes the precaution based (or precautionary) approach adopted for this study which results in risk being eliminated or reduced *so far as is reasonably practicable* (SFAIRP) such as described in the WHS legislation. Its purpose is to demonstrate that all reasonable practicable precautions are in place by firstly identifying the practicable precautions and then testing these precautions for reasonableness in the circumstances. The diagram below, adapted from Sappideen and Stillman[2] (1995) illustrates the concept of reasonableness:



1 Adapted from Robinson Richard M, Gaye E Francis et al (2015). *Engineering Due Diligence* (10th Edition). R2A Pty Ltd. Page 169.

2 Carolyn Sappideen & R H Stillman (1995). *Liability for electrical accidents: risk, negligence and tort*. Engineers Australia Pty Limited, Crows Nest, Sydney. Page 22.

This is based on a judgement of Justice Sir Anthony Mason of the High Court of Australia[3]:

The perception of a reasonable man's response calls for a consideration of the magnitude of the risk and the degree of probability of its occurrence, along with the expense, difficulty and inconvenience of taking alleviating action and any other conflicting responsibilities which the defendant may have.

As Work Safe Australia notes[4], this is an objective test.

There are two elements to what is 'reasonably practicable'. A duty-holder must first consider what can be done - that is, what is possible in the circumstances for ensuring health and safety. They must then consider whether it is reasonable, in the circumstances to do all that is possible.

This means that what can be done should be done unless it is reasonable in the circumstances for the duty-holder to do something less.

Reasonableness is tested by the PCBU in due course by the designer, owner and operator of the proposed airport.

By contrast, the hazard based approach shown in the loop on the right hand side, aims to demonstrate that risk is *as low as reasonably practicable* or ALARP. There are difficulties with each step of this approach as noted in blue in the diagram. That is:

- hazard analysis and risk calculations are inherently unrepeatable. Risk calculations and characterisations to enable a comparison with risk criteria are always imperfect especially with regard to the estimation of risk associated with human failings and the reliability of management systems.
- risk criteria are subjective. The inconsistency in individual and societal risk criteria between industries is inherently problematic.
- if the risk associated with a hazard is below acceptable thresholds, there is a tendency to say that nothing further needs to be done. However in Turner v. The State of South Australia, Chief Justice Gibbs of the High Court of Australia noted that[5]:

  Where it is possible to guard against a foreseeable risk, which, though perhaps not great, nevertheless cannot be called remote or fanciful, by

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3 *Wyong Shire Council vs Shirt* (1980) 146 CLR 40.

4 From http://www.safeworkaustralia.gov.au/sites/SWA/about/Publications/Documents/607/Interpretive%20guideline%20-%20reasonably%20practicable.pdf viewed 24 July 2013

5 Turner v. The State of South Australia (1982) High Court of Australia before Gibbs CJ, Murphy, Brennan, Deane and Dawson JJ).

adopting a means, which involves little difficulty or expense, the failure to adopt such means will in general be negligent.

That is, it does not matter how low the risk estimate is, if more can be done for very little effort, then the failure to do so will be negligent, in the event of an incident.

- there may be a tendency to implement a precaution that reaches the target risk threshold without formally considering the hierarchy of safety controls.

The purpose of the shift in approaches is to ensure that all reasonable practicable precautions are in place (that is, so that risks are eliminated or minimised so far as is reasonably practicable or SFAIRP), rather than to achieve a target level of risk or safety, which is a typical result of the hazard based approach.

3 RELEVANT LEGISLATION AND GUIDELINES

In addition to the WHS legislation previously outlined in Section 2.1, other legislation relevant to the management of risks and hazards for the proposed airport is summarised below.

3.1 AVIATION LEGISLATION AND GUIDELINES

Prior to the proposed WSA becoming a certified aerodrome under the Civil Aviation Safety Regulations (CASRs), the airport developer will need to satisfy the Civil Aviation Safety Authority (CASA) that appropriate measures including operating procedures, adequate infrastructure and personnel are in place to ensure the safe operation of aircraft.

A key element of this will be the future formal airspace design process which is expected to occur closer to the commencement of operations at the proposed airport. This is discussed elsewhere in the EIS.

The design, construction and operation of the proposed Western Sydney Airport will be informed and regulated by the extensive safety, security and other regulatory requirements which apply to the operation of all airports in Australia. In particular, the operation of the proposed airport will be regulated in accordance with the civil aviation safety requirements and WSA will only commence operations once the airport operator has obtained an aerodrome certificate from CASA under Part 139 of the *Civil Aviation Safety Regulations 1988*. The National Airports Safeguarding Framework will also apply as discussed in Section 3.1.4.

Once certified, aircraft operations around the proposed WSA will be controlled by a range of aviation-specific Commonwealth Acts and Regulations. The following outlines the Commonwealth regulatory controls that affect airports and air traffic operation:

- *Civil Aviation Act 1988;*
- Civil Aviation Regulations 1988;
- Civil Aviation Safety Regulations 1998;
- *Air Navigation Act 1920;*
- *Airports Act 1996;*
- Airports (Protection of Airspace) Regulations 1996;
- Air Navigation Regulations 1947;
- Airport (Building Control) Regulations 1996;
- Airport (Environment Protection) Regulations 1997;
- Airports Regulations 1997;
- Airports (Control of On-Airports Activities) Regulations 1997;
- Airports (Ownership and Interests in Shares) Regulations 1996;
- *Aviation Transport Security Act 2004;* and
- Aviation Transport Security Regulations 2005.

The Civil Aviation Safety Authority (CASA) has the primary responsibility to conduct the safety regulation of civil air operations in Australia. The Civil Aviation Regulations 1988 and the Civil Aviation Safety Regulations 1998 (CASRs) provide the general regulatory controls for the safety of air navigation. The CASRs empower CASA to issue Manuals of Standards (MOS) which support CASRs by providing detailed technical material. The following are relevant to the proposed Western Sydney Airport:

- Manual of Standards Part 139 - Aerodromes
- Manual of Standards Part 139H - Standards Applicable to the Provision of Aerodrome Rescue and Fire Fighting Services
- Manual of Standards Part 172 - Air Traffic Services
- Manual of Standards Part 171 - Aeronautical Telecommunication and Radio Navigation Services
- Manual of Standards Part 173 - Standards Applicable to Instrument Flight Procedure Design

3.1.1 AIRSPACE PROTECTION

The airspace at and around airports is protected under Part 12 of the *Airports Act 1996* and the Airports (Protection of Airspace) Regulations 1996 (APARs). The protected airspace is defined using international standards and is the space above two sets of invisible surfaces above the ground around an airport, namely the:

- Obstacle Limitation Surface (OLS); and
- Procedures for Air Navigation Services – Aircraft Operations (PANS-OPS) surfaces.

The OLS is intended to provide protection for aircraft flying into or out of the airport when the pilot is flying by sight. The PANS-OPS surfaces are intended to safeguard an aircraft from collision with obstacles when the aircraft's flight is guided solely by instruments which is the case for large RPTs.

The *Airports Act 1996* defines any activity resulting in an intrusion into an airport's prescribed airspace to be a 'controlled activity', and requires that controlled activities cannot be carried out without approval. The APARs provide for the Australian Government Department of Infrastructure and Regional Development (DIRD) or the airport operator to assess and approve applications to carry out controlled activities, and to impose conditions on approval. A controlled activity which results in an intrusion into the airspace above the OLS may be permitted if assessed as acceptable by CASA. CASA may require the approved obstacle to be marked and/or lit.

However, intrusions into the airspace above a PANS-OPS surface are not permitted as these have a direct impact on the safety of aircraft flying an instrument approach or departure procedure. Buildings and other structures are considered to be controlled activities within the meaning of the *Airports Act 1996* and the APARs and are dealt with accordingly.

3.1.2 NAVIGATION SYSTEMS AND AIR TRAFFIC MANAGEMENT

A variety of satellite and ground-based navigational aids would be used to provide appropriate levels of safety for aircraft approaches and departures in reduced visibility conditions. The required accuracy, operation and availability of these facilities are strictly controlled under the CASRs. All aircraft operating at WSA in reduced visibility conditions would need to be suitably equipped to use the available navigational aids. Radar services would assist air traffic control to fulfil its responsibilities to manage air traffic in the controlled airspace surrounding the proposed airport under the CASRs.

3.1.3 DEVELOPMENT IN THE VICINITY OF AIRPORTS

The assessment of proposed developments in the vicinity of the airport site is primarily the responsibility of State and local government. Aviation airspace is protected through a formal declaration under Part 12 of the *Airports Act 1996* and the Airports (Protection of Airspace) Regulations 1996 (APARs). The declaration usually comprises an OLS and/or PANS-OPS design. Once the airspace is declared for the proposed Western Sydney Airport, surrounding councils would be be notified and OLS and/or PANS-OPS requirements would be incorporated into local planning instruments.

Any development with the potential to exceed these surfaces must be referred to the airport operator and the Department of Infrastructure and Regional Development for review prior to development proceeding. The OLS applies to both building obstacles (e.g. antennae, masts or tall buildings) as well as hot or high velocity air emissions (such as smoke stacks or vents) which may cause a potential hazard to aircraft. In addition, civil aviation regulations also require approval from CASA for the installation of lighting which might cause a distraction, glare or confusion of pilots.

3.1.4 THE NATIONAL AIRPORTS SAFEGUARDING FRAMEWORK

The National Airports Safeguarding Framework (NASF) is a national land use planning framework, agreed to by Commonwealth, State and Territory Ministers in 2012. The NASF recognises that responsibility for land use planning rests with State and local governments, but that a national approach can assist in improving planning outcomes on and near airports and flight paths. The framework aims to:

- improve community amenity by minimising aircraft noise-sensitive developments near airports including through the use of additional noise metrics and improved noise-disclosure mechanisms; and
- improve safety outcomes by ensuring aviation safety requirements are recognised in land use planning decisions through guidelines being adopted by jurisdictions on various safety-related issues.

The NASF comprises seven key planning principles:

- Principle 1: The safety, efficiency and operational integrity of airports should be protected by all governments, recognising their economic, defence and social significance;
- Principle 2: Airports, governments and local communities should share responsibility to ensure that airport planning is integrated with local and regional planning;
- Principle 3: Governments at all levels should align land use planning and building requirements in the vicinity of airports;
- Principle 4: Land use planning processes should balance and protect both airport and aviation operations as well as community safety and amenity expectations;
- Principle 5: Governments will protect operational airspace around airports in the interests of both aviation and community safety;
- Principle 6: Strategic and statutory planning frameworks should address aircraft noise by applying a comprehensive suite of noise measures; and
- Principle 7: Airports should work with governments to provide comprehensive and understandable information to local communities on their operations concerning noise impacts and airspace requirements.

The NASF guidelines provide comprehensive information and recommendations relating to six airport safeguarding matters. The NASF guidelines are:

- Guideline A: Measures for Managing Impacts of Aircraft Noise;
- Guideline B: Managing the Risk of Building Generated Windshear and Turbulence at Airports;
- Guideline C: Managing the Risk of Wildlife Strikes in the Vicinity of Airports;
- Guideline D: Managing the Risk of Wind Turbine Farms as Physical Obstacles to Air Navigation;
- Guideline E: Managing the Risk of Distractions to Pilots from Lighting in the Vicinity of Airports; and
- Guideline F: Managing the Risk of Intrusions into the Protected Airspace of Airports.

Additional guidelines for the protection of Public Safety Zones and Communication, Navigation and Surveillance infrastructure are proposed to be developed by National Airports Safeguarding Advisory Group in the near future.

3.2 DANGEROUS GOODS LEGISLATION & GUIDELINES

There is other specific legislation related to Dangerous Goods. For the storage and handling of dangerous goods (which includes jet fuel), the responsible authority in NSW is WorkCover (under the provisions of the NSW WHS Act). The authority with regard to the transport of dangerous goods is the NSW Environment Protection Authority (EPA) under the provisions of the *Dangerous Goods (Road and Rail Transport) Act 2008* (NSW)**.** The authorising agency for a fuel pipeline is the NSW Department of Trade and Investment (Resources and Energy) under the provisions of the *Pipelines Act 1967* (NSW).

The NSW Department of Planning and Environment (DP&E) also provides guidelines for the planning and development of hazardous industry in NSW which applies to NSW land. This risk study also includes reference to potential incidents which may occur on areas around the airport site (off-site areas) on NSW land. Relevant guidelines include the NSW Hazardous Industry Planning and Advisory Paper (HIPAP) Guideline series:

- HIPAP 4 – Risk Criteria for Land Use Safety Planning (January 2011); and
- HIPAP 10 – Land Use Safety Planning (January 2011)

HIPAP Guideline 4[6] notes that two aspects of off-site risk to 3rd parties need to be considered:

- *individual risk, which considers the acceptability of a particular level of risk to an exposed individual; and*
- *societal risk, which takes into account society's aversion to accidents which can result in multiple fatalities.*

While it is useful to have objective, quantitative risk criteria, qualitative principles are equally important. These include:

- *all 'avoidable' risks should be avoided;*
- *particular attention needs to be given to eliminating or reducing major hazards, irrespective of whether numerical criteria are met; and*
- *as far as possible, the consequences of significant events should be kept within facility boundaries.*

These regulations were published prior to the commencement of the NSW WHS Act in 2012. As can be seen above, the first part of HIPAP 4 uses a hazard based approach, whereas the latter part considers the precautionary approach. Until such time as the regulations are updated, both approaches continue to apply in NSW.

[6] Department of Planning (NSW) 2011. *HIPAP 4: Risk Criteria for Land Use Safety Planning*

4. METHODOLOGY

The hazard and risk review was undertaken as a desktop study with input from various project stakeholders regarding the key safety issues and possible precautions as well as the hazard and risk study methodology. The following organisations were involved in the consultation process.

- Department of Infrastructure and Regional Development
- Australian Government Solicitor
- Civil Aviation Safety Authority
- Airservices Australia
- NSW Department of Planning and Environment
- Australian Federal Police
- NSW Rural Fire Services
- GHD

The issues and precautionary options identified in the various meetings were considered as part of the risk review.

In addition, a number of EIS background documents were provided as part of the hazard and risk review. The two most relevant documents are the *Western Sydney Airport Referral of proposed action* (DIRD 2014) and the *1997-1999 Draft Environmental Impact Statement*, especially *Technical Paper 10 - Hazards and Risks* (PPK 1997-1999). These were primarily used for background context and as a consistency check to ensure no important safety issue or hazard was overlooked.

In addition, a number of project reports were provided by GHD including:

- Western Sydney Airport: Preliminary Airspace Management Analysis (Airservices Australia 2015)
- Western Sydney Airport Climatological Review (Bureau of Meteorology 2015a)
- Western Sydney Airport Usability Report – meteorological impacts (Bureau of Meteorology 2015b)
- Western Sydney Airport indicative airport layouts

Reports referenced in this report are listed in Section 7.

Owing to the fact that no airport or procedures specific to the airport site currently exist and given the limited nature of the airport design documentation, the necessary focus of this report is the proposed Stage 1 airport development.

5. HAZARD AND RISK REVIEW

5.1 OVERVIEW

The following table summarises the key exposed groups and the risks and hazards to which they would potentially be exposed to from the proposed Western Sydney Airport. This table was developed in consultation with the key stakeholders identified in Section 4. The table provides a summary of the worst-case consequences of each credible threat. It does not consider the likelihood of the event occurring. This is consistent with the precautionary approach.

		Construction crews	Airport Airspace	Airport			Offsite	
	Critical Exposed Groups >		Air crew and passengers	Public at airport	Airport staff and workers including contractors	Airport emergency services	Public outside airport	Offsite emergency services
	Credible Threats							
1.0	Air operations							
1.1	Aircraft fire (inflight)	-	xxx	-	-	-	xxx	-
1.2	Bird or bat strike	-	xxx	-	-	-	xxx	-
1.3	Drones and model a/c strike (RPAVs)	-	xxx	xxx	xxx	xx	xxx	-
1.5	Fuel exhaustion	-	xxx	xxx	xxx	xx	xxx	-
1.6	High structure/terrain strike	-	xxx	-	-	-	-	-
1.7	Mechanical failure	-	xxx	xxx	xxx	xx	xxx	-
1.8	Mid-air collision (other a/c)	-	xxx	-	-	-	xxx	-
1.9	Pilot error (multiple runways)	-	xxx	xxx	xxx	xx	xxx	-
1.10	Runway collision	-	xxx	xxx	xxx	xx	-	xx
1.11	Special military and emergency sevices ops incl bushfire ops in Blue Mountains (RFS)	-	xxx	-	-	-	-	-
1.12	Stack discharge	-	xxx	-	-	-	xxx	-
2.0	Adverse meteorology							
2.1	Aircraft icing (freezing fog)	-	xxx	xxx	xxx	xx	xxx	xx
2.2	Cross wind (especially gusts)	-	xxx	xxx	xxx	xx	-	xx
2.3	Cyclone/tornado	xx	xxx	xxx	xxx	xx	-	xx
2.4	Fog (visibility)	-	xxx	xxx	xxx	xx	-	xx
2.5	Lightning (thunderstorm)	xx	xxx	-	-	xx	-	xx
2.6	Windshear (esp threshold)	-	xxx	-	-	xx	-	xx
3.0	Fire & Explosion (on site)							
3.1	Aircraft fire (on ground)	-	xxx	-	xxx	xx	-	xx
3.2	Building fire	xx	xxx	xxx	xxx	xx	-	xx
3.3	Fuelling fire (esp > 35 deg ambient)	-	xxx	-	xxx	xx	-	xx
3.4	Grass fire (on site)	xx	xxx	-	xxx	xx	xx	xx
3.5	Storage fire & explosion (Jet A-1)	xx	-	-	xxx	xxx	xx	xxx
4.0	Contaminated sites	xx	-	x	x	x	-	x
5.0	Terrorism	xxx	xxx	xxx	xxx	xxx	xxx	xxx
6.0	Bushfire / Smoke (offsite)	xx	xxx	-	-	xx	xxx	xx
7.0	Transport of dangerous goods (Jet A1)	-	-	-	-	xx	xxx	xx
8.0	Flood / inundation	xx	xxx	xx	xx	xx	-	-
9.0	Aircrashes into major (offsite) infrastructure	-	-	-	-	-	xxx	xx
10.0	Railway incidents	-	-	xxx	xxx	xx	xxx	xx

High Level Threat and Safety Vulnerability Table

xxx	Multiple fatalities possible
xx	Single fatality possible
x	Injuries possible
-	No credible vulnerability identified

The table above presents a high level summary of the key safety risks posed by the proposed airport as agreed with the project stakeholders. Based on the precautionary approach, if all these hazards are eliminated, so far as is reasonably practicable (SFAIRP), and if this is not possible, reduced SFAIRP by the appropriate persons conducting a business or undertaking (PCBUs) through the ongoing design, construction and regulatory processes, then the proposed airport will be considered to be safe.

The following sections outline the precautions that should be considered for the proposed airport because of the nature of the safety threat associated with expected operations. PCBUs will be required to assess the reasonableness of these in due course as designers, owners and operators.

Some of the credible critical safety threats identified do not require particular precautionary consideration as the design and operation of the proposed airport could have no material control over these risks. The operator of the proposed airport would have no control over either the risk arising, nor of any measures which could mitigate the risk. These are generic issues associated with the operation of any major airport and current industry (airport and airline) operational procedures and regulatory requirements would be applied to resolve the issues as appropriate. These include:

- aircraft fire (inflight);
- fuel exhaustion;
- mechanical failure;
- pilot error (multiple runways) (not an issue with one runway); and
- collision because of intersecting runways (not an issue with the proposed airport as no cross runways proposed).

Consequently, these have not been considered further in this report.

Related issues in the above table such as grassfire and bushfire have been also merged together in the following sections as precautionary effort is similar.

5.2 AIRCRAFT ACCIDENTS

To gain an appreciation of midair collision risk, a review of past accidents was completed, supported by an internet search for authoritative accident summaries, including the Australian Transport Safety (ATSB)[7], the International Civil Aviation Organization (ICAO) and Boeing.

[7] Australian Transport Safety Bureau (2014). *Aviation Occurrence Statistics 2004 to 2013*. Report AR-2014-084.

Australia has a good aviation safety record comparable to other developed countries such as the USA, Canada and the United Kingdom. There have been no high capacity (above 38 seats) regular passenger transport (RPT) fatal accidents in Australia since at least 1968[8].

Aviation occurrence statistics are updated and published annually by the ATSB. Responsible persons as defined in Part 2.5 of the Transport Safety Investigation Regulations 2003 provide occurrence data to the ATSB. Statistics collected by the ATSB indicate that the number of reported safety incidents in Australia has risen significantly over the past decade. In 2013, there were 23 serious incidents, 1 serious injury accident and 1 total accident among 3.3 million departures for high capacity RPT aircraft similar to those expected to use WSA.

The 23 aircraft involved in serious incidents in 2013 was the highest number for this operation type in more than 10 years. The most common occurrences reported were wildlife strikes, weather affecting aircraft, and aircraft system problems. Most accidents and serious incidents involved reduced aircraft separation, engine malfunction, or runway excursions.

In addition, the Civil Aviation Safety Authority (CASA) recently completed an aeronautical study of the airspace arrangements in the Sydney Basin within 45 nautical miles (NM) of Sydney Kingsford Smith Airport (Sydney). One of the findings of the report was that the Sydney Basin has shown a decreasing rate of total airspace related incidents over the past six years. Most incidents related to airspace involved operational non-compliance or navigation problems resulting in airspace infringements by VFR aircraft and did not result in significant safety hazards. This supports the overall findings of the ATSB review.

The diagram from Boeing below shows the overall global and North American improvement in accident rates from 1959 through 2013[9]. Airplanes manufactured in the Commonwealth of Independent States (CIS) or the former Union of Soviet Socialist Republics (USSR) are excluded because of the lack of operational data. Commercial airplanes operated in military service are also excluded. 'Accidents' do not include experimental test flights or hostile action including sabotage, hijacking, terrorism or military actions.

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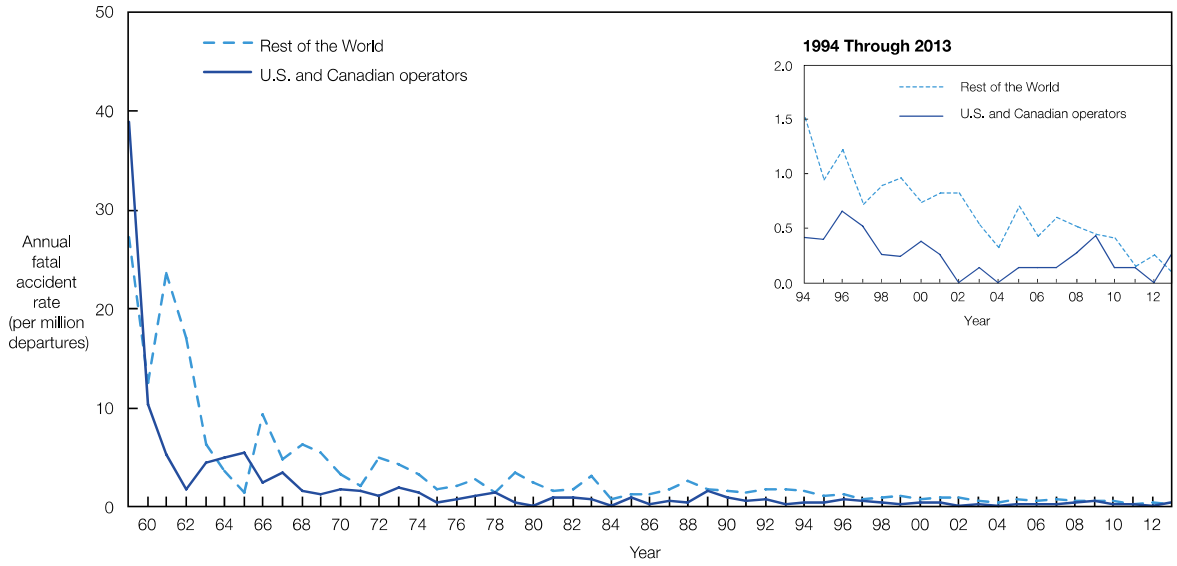
8 Australian Government (2011) *Australia's State Aviation Safety Program* plus R2A's review of accidents from 2010 to the present.

9 Boeing Commercial Services (August 2014). *Statistical Summary of Commercial Jet Airplane Operations I 1959 – 2013.*



Fatal Accidents 1959 through 2013

Of note is that whilst Boeing reports 5 major accidents worldwide in 2013, resulting in the deaths of 62 crew and passengers, no deaths to external parties either on the ground or on other aircraft are recorded. This is based on 25 million departures that year.

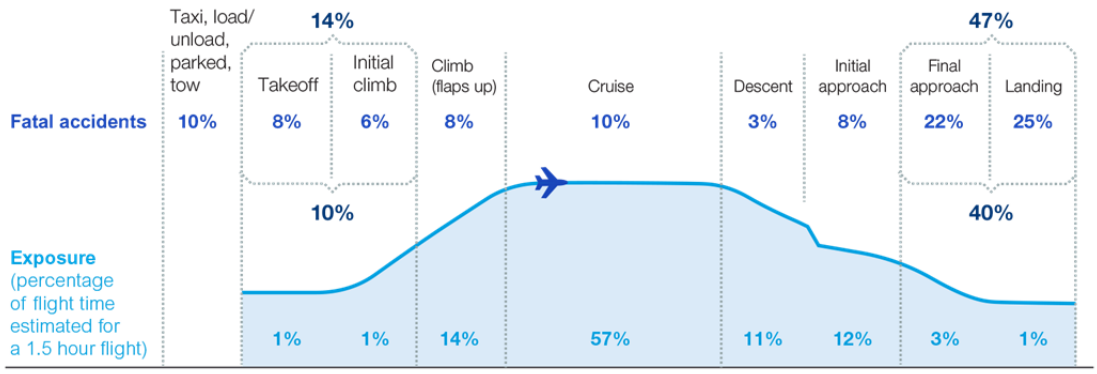
ICAO[10] reports an improving accident rate (for all RPT aircraft including those below 38 seats) worldwide in 2014 as shown below.



Global Accident Rate (accidents per million departures)

The Boeing report also notes that 47% of fatal accidents occur on final approach and landing as shown below.

[10] ICAO (2014). *Safety Report.*



Note: Percentages may not sum precisely due to numerical rounding

Source: Boeing Commercial Services, 2014

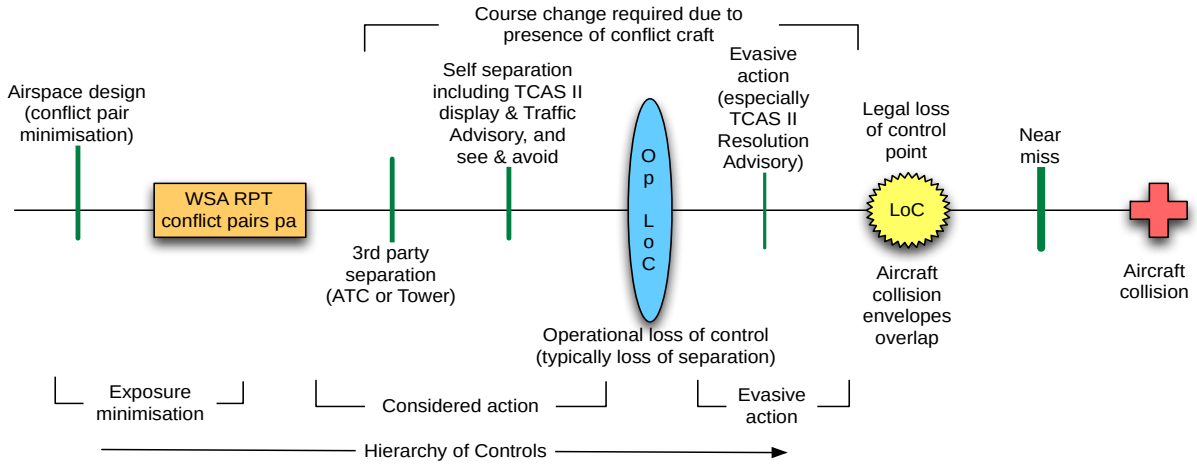
Fatal Accidents and Onboard Fatalities by Phase of Flight (adapted from Boeing)

Worldwide Commercial Jet Fleet 2004 through 2013

In assessing the potential for aircraft accidents at the proposed airport, consideration was given to the surrounding airspace in the Sydney basin and the sources of potential conflict aircraft. The primary potential conflict aircraft to RPT traffic at the proposed airport are those engaged in general aviation and military activities at surrounding airports as summarised below:

- 'lost' students, especially in marginal visual flight rule (VFR) conditions, from various general aviation flying schools in the Sydney Basin including Camden and Bankstown. This includes both VFR and instrument flight rules (IFR) students;
- off-course charter IFR traffic from general aviation airports including Bankstown and Camden;
- unexpected or unknown military movements, particularly from Holsworthy (Military) Airport and RAAF Base Richmond;
- operations at Sydney Airport (only relevant to potential future two runway operations at the proposed Western Sydney Airport post 2050);
- unexpected aircraft from small airfields like Wedderburn and Kennetts Strip and closed facilities like Schofields, particularly for ultralights, remotely piloted aircraft (RPAs), including model aircraft;
- glider operations;
- off-course aviators following the western Sydney VFR route via Richmond airspace which can be used by any aircraft including those to and from Camden; and
- other RPT aircraft operating at the proposed airport particularly under emergency procedural conditions including forced go-rounds and breakouts.

In order to assess the proposed controls to manage these potential airspace conflicts, Airservices Australia's indicative airspace management concept was conceptually tested using the threat barrier diagram shown below.



Single Line Collision Threat Barrier Diagram

The hierarchy of controls is expressed from left to right, with conflict pair[11] minimisation (that is, the elimination option) the first and necessary precautionary test following the hierarchy of controls.

The Stage 1 (northern) runway airspace concept is comparatively straight forward with the airspace designed to minimise conflict pairs. Satellite based navigation and landing aid with ground based augmentation system (GBAS) similar to that recently provided at KSA would also be provided. The proposed WSA Class C air traffic control tower (to 2500ft) would provide third party aircraft separation advice to aircraft. A primary radar feed from KSA for WSA is also expected with common ATC control. This would provide a backup radar system to WSA air traffic control.

The indicative design of the WSA airspace includes adoption of a point merge system which was first introduced in Norway in 2011. The point merge system has since been implemented elsewhere in Europe as well as in Asian cities such as Seoul and Kuala Lumpur. One of the cited benefits of this new concept is safety improvements through a reduction of tactical vectoring, increased situational awareness by pilots and a lower workload for air traffic controller staff.

A formal flight path design process is expected to occur closer to the time operations commence at WSA. Optimal flight path design using improved navigation technologies such as a point merge system should ensure that potential conflicts, even in emergency go-round scenarios are reduced.

[11] A conflict pair refers to an event in which two or more aircraft experience a loss of minimum separation. This does not in itself suggest that the aircraft are at any risk of collision.

During the detailed design of airspace, a number of additional precautions[12] to manage aircraft collisions would be considered as part of the standard airspace design process. These include:

- upgrading the airspace of all airports in the Sydney Basin to Class C and Class E after hours (meaning radio and transponders for all aircraft movements for all VFR aircraft including gliders and ultralights). There is a continuing enhancement of navigation and transponder equipment occurring. For example, Global Navigation System Satellite System navigation and Automatic Dependent Surveillance – Broadcast transponder technology is being rolled out for all IFR aircraft[13];
- redesign VFR corridors to and from Bankstown Airport to encourage a greater use of GPS navigation;
- redesign the western VFR routes via Richmond airspace; and
- ATC confirmation response to all calls including VFR calls.

During the detailed design process and beyond, the above options need to be tested for reasonableness by the relevant PCBU to determine which precautions would be implemented to demonstrate SFAIRP.

In order to investigate the potential level of off-site risk posed by an aircraft accident, in accordance with NSW DP&E requirements, the following preliminary analysis has been completed using the Boeing statistics of five major accidents in 25 million departures (that is a likelihood of 2 x 10^{-7} (or 0.0000002) per departure), as well as having regard to the expected aircraft movement types at the proposed airport[14]. The major accident rates for the proposed Stage 1 development and the longer term development scenarios are presented in the table below.

Airport development scenario	Total annual air traffic movements (passenger & freight)	Departures (per year) (half movements)	Likelihood of major accident per departure	Major accidents per year	Years between major accidents	Years between major accidents on final approach or runway
Stage 1 (c. 2030)	63,000	31,500	0.0000002	0.0063	159	317
Longer term (c. 2063)	370,000	185,000	0.0000002	0.037	27	54

WSA major accident rate projection

(assuming no improvement in safety from 2013)

[12] Legally, precautions act before the loss of control point, mitigations afterwards. In aircraft collision terms, there few mitigations, it is almost all precautions.

[13] See Airservices Australia (undated). *Fact Sheet – Regulation Reform: Performance based navigation: GNSS and ADS-B equipment mandates.*

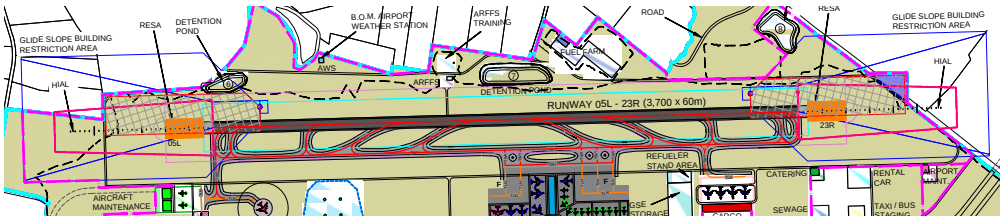
[14] DIRD (June 2015). Airport Plan Version 2.1 Western Sydney Airport.

Assuming no improvement in aircraft safety from the 2013 statistics, in 2030, the expected fatal accident rate for aircraft operating from the proposed airport would be around 1 in 300 years on final approach and/or landing based on statistics from Boeing which indicate about 50% of accidents occur during these stages, and around 1 in 300 years for all other phases of flight.

However, these results have limited meaning, as aviation technology (aircraft, navigation aids, avionics etc.) is most likely to substantially improve over time, and population densities around the proposed airport will change. For example, ASD-B (automatic dependent surveillance-broadcast) for all IFR aircraft [15] is presently being rolled out in the Sydney basin, and KSA is the first airport in the Southern hemisphere and fifth in the world to certify a satellite-based navigation and landing aid, with a ground based augmentation system (GBAS) recently going into service in May 2015[16]. This replicates and will eventually supplant the six existing ILS services at KSA. This is typical of the continuing developments in commercial aviation.

It is presently proposed that the WSA would also adopt GBAS and that other superior technology will emerge over time. The likelihood of future accidents that might result in aircraft accidents having off-site impacts is expected to continue to decrease with the adoption of such systems.

The likelihood of an off-site impact as a result of an aircraft accident is further reduced by the proposed 1,000m public safety zone (PSZ) at either end of the runway as shown in the indicative airport layout below (area bound by pink borders at each runway end). The Australian Airports Association[17] refers to ICAO reports that most aircraft crashes occur within 1,000 m of landing and 500 m of takeoff. No building or occupied structure is expected in this area.



Public Safety Zones[18] Runway 05L & 23R
(shown as the truncated red trapezoids adjoining the runway ends)

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15 Civil Aviation Safety Authority (undated). *Fact Sheet – Regulation Reform: Performance based navigation: GNSS and ADS-B equipment mandates.*

16 See http://www.flightsafetyaustralia.com/2014/07/satellite-ground-station-opens-at-sydney-airport/ viewed 12jun15.

17 Australian Airports Association (Oct 2014). *Airport Practice Note 5.* Page 7

18 DIRD (June 2015). Master Plan Layout. Concept 11C. Phase 1 – Year 2030, Scenario 2A.

The actual shape and size (primarily the length) of the PSZ required for a particular airport varies according to a large number of factors. This includes:

- the crash frequency per departure (which is aircraft size/type dependent and seems to be steadily improving with time, and appears to be lower in Australia than other places);
- the STARs (standard terminal arrival routes) and standard instrument departures (SIDs) flight paths;
- the number and aircraft mix of departures and arrivals;
- a historical spatial crash location distribution model which generally assumes crashes will be closer to runways and dissipate away from flight paths (which can also be aircraft type dependent); and
- an estimation of the size of the area affected by the crash (bigger aircraft with larger fuel loads have bigger damage areas although this is also related to shallow or vertical impacts). Fuel loads are also usually greater on takeoff for larger aircraft on long haul routes.

These factors have been used to calculate PSZs for many UK airports. Results vary although generally a 1km zone includes the 10^{-4} pa individual risk contour[19] which is considered by the Health and Safety Executive in the UK as the limit of tolerable risk to a member of the public. In terms of the NSW HIPAP 4 Guideline, no development should occur within 10^{-4} pa individual risk contour[20]. The risk calculation has not been completed at this stage, but given that the PSZ at either end of the runway extends beyond the airport site boundary, additional airport design control measures may need to be provided in order to meet NSW DP&E off-site risk criteria. This would be reviewed during detailed design and any necessary controls implemented.

Aircraft crashes into major infrastructure were also cited by DP&E as an issue for investigation. The indicative Stage 1 flight paths avoid Defence Establishment Orchard Hills and the Warragamba Dam. The indicative flight paths also keep aircraft clear of other critical infrastructure like Prospect Reservoir. All aircraft are expected to be provided with precision based GPS navigation by the time the proposed airport commences operation in the mid-2020s ensuring the exact location of all aircraft is known at any time.

An obstruction charting survey is underway to identify any high structures and terrain. The Airservices Australia report recommendation was to remove obstacles if possible. Where obstacle removal is not feasible, air traffic operational rules

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19 Department of Transport (1/120) Farnborough Airport Public Safety Zones (PSZs) and NATS (May 2004) A Second Runway for Gatwick Appendix A27 Public Safety Zones. Version 1.0 Final

20 NSW Department of Planning (2011). HIPAP 4. Risk Criteria for Land Use Safety Planning.

would be established to avoid obstacles. The report also recommended that a risk assessment would be required prior to commencement of parallel runway operations to provide guidance on whether independent simultaneous ILS/ microwave landing system (MLS) operations to parallel runways should be approved.

Consideration of these recommendations would be part of the formal flight path design process that is expected to occur closer to the time operations commence at WSA. Optimal flight path design using improved navigation technologies should ensure that potential conflicts with critical infrastructure and other obstacles are reduced.

The report also indicates that, when parallel runway operations are in use in the longer term, the (emergency) Breakout Areas provided for conflict resolution for departing aircraft from the proposed airport would be in conflict with Defence Establishment Orchard Hills when it is active for military operations. This issue would require further consideration during airspace design prior to the second runway commencing operations, which is anticipated to occur around 2050.

The following sections further consider the precautionary options associated with particular air operation threats.

5.2.1 BIRD AND BAT STRIKE

A preliminary bird and bat strike risk assessment by Avisure[21] identifies the type, number and flocking characteristics of species in the vicinity of the proposed airport.

Construction of the proposed airport would in itself reduce the habitat of various species at the airport site, particularly in the longer term as clearing of the remainder of the vegetation on the airport site would be undertaken. Other precautions to reduce the attractiveness of the site to birds would also be implemented during the construction and operational phases of the proposed development, including draining or covering dams to discourage wader birds and ensuring landscape and grassed areas at the airport are not conducive to particular species.

Avisure concludes that the proposed airport, being inland from the coast, is dissimilar to other existing airports including KSA where this risk is overall much higher. It concludes that the likelihood of bird strikes by large flocking birds is considered very low and that the most probable consequence of bird and bat strike is damage to aeroplanes (particularly engines) and inconvenience to the travelling public. Notwithstanding, further seasonal surveys of bird behaviour should be undertaken and the ongoing design reviewed to ensure birds and bats are not encouraged onto the airport and surrounds.

[21] Avisure May 2015. *Preliminary Bird and Bat Strike Risk Assessment*. Draft.

There is also a range of regulatory guidelines and controls which address this risk at airports including CASA and ICAO operational regulations and procedures as well as the *National Airports Safeguarding Framework Guideline C - Managing the risk of wildlife strikes in the vicinity of airports* and the CASA Advisory Circular AC 139-26(0) Wildlife hazard management at aerodromes.

5.2.2 REMOTELY PILOTED AIRCRAFT

Remotely piloted aircraft (RPAs) (which includes drones, model aircraft and unmanned aerial vehicles) are considered to be a generic but increasing hazard for all airport airspaces and is a focus for CASA[22], Airservices Australia and other authorities.

It is expected that the operator of the proposed airport would implement the recognised good practice precautions used at similar airports like KSA, which is keeping abreast of RPA developments, reporting RPA incidents and facilitating relevant RPA publicity.

Australia was the first country in the world to regulate remotely piloted aircraft, with the first operational regulation for unmanned aircraft in 2002 ([CASR]). CASA is currently reviewing Part 101 of the *Civil Aviation Safety Regulation 1998* regarding unmanned aircraft to address their increasing use.

5.2.3 HIGH STRUCTURE / TERRAIN STRIKE

Airspace obstructions are a primary threat at any airport. It is anticipated that clearance criteria described in existing regulations[23] would be applied as outlined in Section 3.1.1. Obstacle Limitation Surfaces (OLS) and Procedures for Air Navigation Services – Aircraft Operations (PANS-OPS) would also be prescribed. An obstruction charting survey is underway to identify any such structures. Treatment options include relocation of obstructions or if this is not practicable in the circumstances, identifying and appropriately managing those high structures during detailed airspace design activities.

Existing height restriction planning rules for new structures would need to be confirmed as appropriate to accommodate possible future flight paths.

As outlined in Section 3.1.1, once the WSA airspace is declared, Councils would be informed and relevant planning instruments updated to include definition of these areas and any new developments which may impact on the airspace would be referred to the airport operator for comment.

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[22] See for example, CASA's website: *CASA and remotely piloted aircraft*. http://www.casa.gov.au/scripts/nc.dll?WCMS:STANDARD::pc=PC_100376 viewed 23jun15.

[23] *Airports (Protection of Airspace) Regulations 1996* (Cth).

5.2.4 SPECIAL MILITARY AND EMERGENCY SERVICES OPERATIONS

In an emergency, other aircraft may require use of the airspace, especially NSW Rural Fire Service (RFS) bushfire operations in the Blue Mountains to the west of the proposed airport. Other emergency operations can include military, security, police, ambulance and RFS aircraft from Richmond, Holsworthy, Bankstown and Camden. This creates potential for mid air collisions.

Such emergency aircraft would be expected to have priority over RPT traffic. Western Sydney Airport ATC would facilitate these operations and communicate with pilots any changes to procedures required in the event of these operations occurring.

5.2.5 STACK DISCHARGE

Stack discharge refers to emissions to air that might affect aircraft flight. Gas efflux from industrial chimneys with an average vertical velocity exceeding 4.3 m per second at the OLS or 110 m above ground level is a controlled activity under the *Airports (Protection of Airspace) Regulations 1996* (Cth).

With regards to the proposed Western Sydney Airport, a survey should be completed to identify any current or proposed future emissions and the results integrated into the refinement of proposed flight paths.

5.3 FIRE AND EXPLOSION

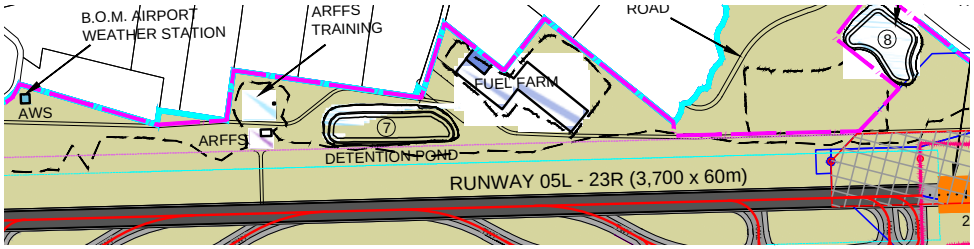
The following sections investigate fire and explosion potentials on the proposed airport site and the possible on and off site consequence.

5.3.1 FUEL STORAGE FIRE AND EXPLOSION

A key issue at this early design stage relates to the bulk storage of jet fuel and the ability to contain the risks presented by storage within the on-site facility.. No bulk storage of avgas or diesel for aircraft use is proposed. Small quantities of other fuels would be available for airport surface vehicles, but this would be addressed in the detailed design phase.

The indicative airport layout and draft Airport Plan provides for a fuel farm with storage of 3-days average demand[24]. The proposed Stage 1 (single runway) development commences with up to 10 ML storage whilst longer term airport development (two runways) sees onsite storage increase to 66 ML. The proposed fuel farm location is shown below.

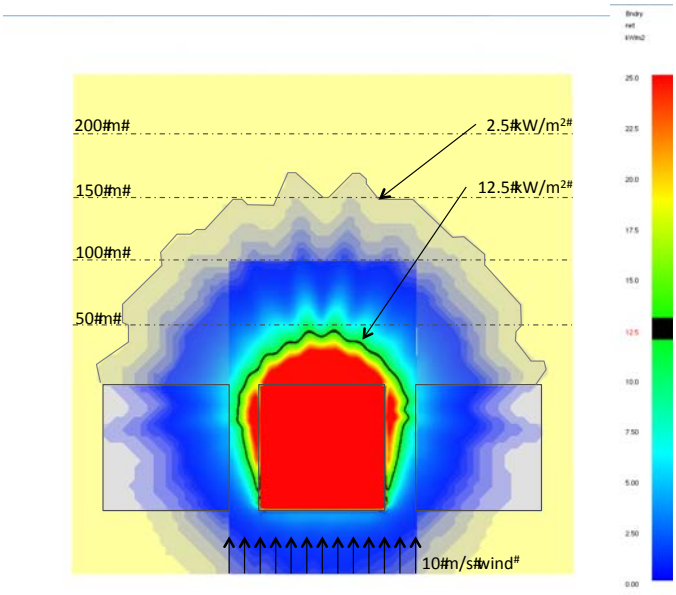
[24] DIRD (June 2015). Airport Plan, Western Sydney Airport. Draft.



Fuel Farm Location - Stage 1 (2030)

Stage 1 operations provide for an indicative build of up to four tanks in 100 m x 100 m square bunds, with 25 metres between bunds. Standard industry precautions for a fuel tank farm would be assumed to be present, namely tank foam injection and water spray thermal exposure protection consistent with Australian Standard 1940-2004 *The storage and handling of flammable and combustible liquids*. Two days on site storage of water for fires is planned. The distance from the edge of the bund to the nearest airport site boundary is approximately 80 m.

In order to investigate the potential level of off-site risk posed by the fuel facility, in accordance with NSW DP&E requirements, a worst case design fire scenario was assessed comprising a full bund fire (100 m x 100 m) with a 20 kt wind blowing towards the edge of the airport site. The following figure shows the results of the fire simulation conducted using the National Institute of Standards and Technology's Fire Dynamics Simulator[25] for a design kerosene fire with a 20 kt (10 m/s) wind.



Plan View 100 m x 100 m Kerosene Fire with 20 kt wind

[25] National Institute of Standards and Technology. Fire Dynamics Simulator (FDS) is a computational fluid dynamics (CFD) model of fire-driven fluid flow. The software solves numerically a form of the Navier-Stokes equations appropriate for low-speed, thermally-driven flow, with an emphasis on smoke and heat transport from fires.

The effects of varying levels of heat radiation as provided in HIPAP 4 and depicted in the above figure, are shown below.

Table 6: Consequences of Heat Radiation

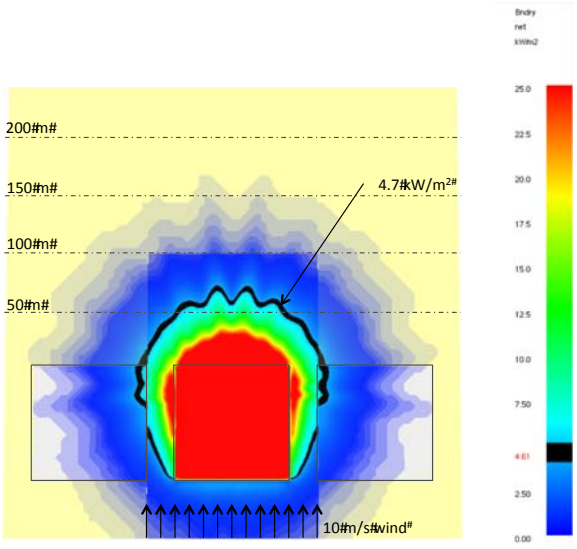
Heat Radiation (kW/m^2)	Effect
1 .2	Received from the sun at noon in summer
2.1	Minimum to cause pain after 1 minute
4.7	Will cause pain in 1 5-20 seconds and injury after 30 seconds' exposure (at least second degree burns will occur)
12.6	• Significant chance of fatality for extended exposure. High chance of injury • Causes the temperature of wood to rise to a point where it can be ignited by a naked flame after long exposure • Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure
23	• Likely fatality for extended exposure and chance of fatality for instantaneous exposure • Spontaneous ignition of wood after long exposure • Unprotected steel will reach thermal stress temperatures which can cause failure • Pressure vessel needs to be relieved or failure would occur
35	• Cellulosic material will pilot ignite within one minute's exposure • Significant chance of fatality for people exposed instantaneously

In terms of good practice fire engineering, all buildings should be outside of the cellulosic pilot ignition heat flux (12.6 kW/m^2) contour. The preliminary modelling shows that a minimum 50 m buffer from the tank farm to all airport site boundaries is required to achieve this. This would be achieved by the current 80 m buffer.

Buildings outside the pain threshold criteria (2.1 kW/m^2) do not typically require special fire protection. Off-site facilities between the 12.6kW/m^2 and 2.1 kW/m^2 thresholds require consideration of alternate measures including appropriate land use zoning and building construction.

Further, HIPAP 10[26] indicates that incident heat flux radiation at residential and sensitive use areas (such as those adjacent to the proposed WSA) should not exceed 4.7 kW/m^2 at a frequency of more than 50 chances in a million per year.

[26] NSW Department of Planning 2011. *HIPAP 10: Land Use Safety Planning.* p 33.



Plan View 100 m x 100 m Kerosene Fire with 20 kt wind (4.7kW/m^2 contour)

Based on the above figure, a level of 4.7 kW/m^2 is reached approximately 80 m from the edge of the bund. This is on the site boundary. Further risk calculations may be required to determine the frequency of such an event in order to meet NSW DP&E off-site risk criteria. Additional control measures may need to be considered including land use zoning and building construction.

Other fires associated with tanker truck discharge would also be possible, but are likely to be smaller. Standard fuel and fire-fighting runoff containment is assumed in all cases. An Airservices Australia ARFFS station is proposed for single runway operations with an additional station being provided for the second runway.

5.3.2 FUELLING FIRE

It is planned that all jet fuelling operations would be provided by hydrants delivered through underground pipes from the airport fuel farm. Standard industry precautions for aircraft fuelling at major airports would be implemented including:

- provision of appropriate clearances for refuelling aircraft and ground fuelling equipment in relation to buildings and other aircraft;
- appropriate passenger boarding and disembarking procedures during refuelling operations;
- earth bonding; and
- designating refuelling areas as non-smoking areas.

Airport tanker operations are expected to be minimal as general aviation operations are not proposed.

5.2.3 AIRCRAFT FIRE (ON THE GROUND)

Fire-fighting facilities similar to other major airports would be provided. This includes the provision of an Airservices Australia's Airport Rescue Fire Fighting Service (ARFFS) station for each runway. A mutual aid agreement with the New South Wales Rural Fire Service (NSW RFS) is also expected to be in place before airport operations commence.

5.3.4 BUILDING FIRE

Fire detection, suppression and response systems would be incorporated into buildings in accordance with relevant regulations and consistent with other major airports. The specific features of fire detection and suppression systems would be determined during the detailed design phase.

5.4 ADVERSE METEOROLOGY

In 2014 the Bureau of Meteorology was engaged by the Australian Government Department of Infrastructure and Regional Development (DIRD) to provide a preliminary report[27] on the meteorological parameters affecting the usability of the Badgerys Creek site for the development of the Western Sydney Airport (WSA).

With respect to the planned nomination of runways at Badgerys creek, it is expected that the current runway configuration proposed will be usable approximately 99.5% of the time based on crosswinds alone. Other weather phenomena such as fog, low cloud and low visibility conditions may lower the usability of the airport; however mitigation is obtainable through navigational systems and aids.

The report outlined the following precautionary options to address these issues:

i. Clearance of vegetation to the west and south-west of the airport site should be avoided as reducing drag may cause increases in wind speeds from downslope winds.

ii. Orientation of buildings containing large surface areas should avoid the direction of strongest wind (westerly sector) as much as possible to avoid creating turbulent effects.

iii. The effect of high temperatures may need to be considered during the construction of jet fuel facilities at the proposed airport.

iv. De-icing equipment may need to be considered in order to optimise operations at WSA during periods of low temperature.

[27] Bureau of Meteorology (April 2015). *Western Sydney Airport Usability Report – Meteorological impacts.*

v. Changes in land surface coverage would need to be accounted for in hydrological studies to ensure appropriate control measures and engineering can mitigate surface runoff.

vi. Automatic instrumentation for cloud and visibility (including fog) should be installed for the collection of climatological information and for the production of forecasting products in future.

vii. Appropriate low visibility (including fog) landing equipment, such as runway visual range (RVR) needs to be considered in order to optimise operations at the proposed airport.

viii. A Doppler LIDAR system at Badgerys Creek can provide the necessary information for observing wind movement in the lower atmosphere including detection of wind shear and rotors. The Doppler LIDAR system is costly and a cost-benefit analysis would be recommended.

ix. The Bureau of Meteorology would implement an Automated Thunderstorm Alert Service (ATSAS) at the proposed airport to improve the accuracy of thunderstorm forecasting for the airport whilst increasing the operational safety of ground staff and aircraft.

Provided appropriate airport operating parameters were established (for example, for crosswinds and visibility etc.), and complied with, there would be no particular or unique safety concerns associated with the Western Sydney Airport site in relation to adverse meteorology.

5.5 OTHER ISSUES

5.5.1 TERRORISM

At this conceptual stage, no issues or precautions above those in use at KSA or other similar international facilities are envisaged for the proposed airport.

The airport is expected to be designated as a category 1 airport under the *Aviation Transport Security Act 2004* and this would dictate detailed security planning for the infrastructure and operational requirements which would take place during detailed design.

5.5.2 BUSHFIRE / SMOKE (OFFSITE)

A bushfire risk assessment was conducted by GHD as part of the design process for the proposed airport[28]. The airport site is located in a landscape that contains vegetation that may represent a bushfire risk to users of the airport, on-site workers and the general community.

[28] Western Sydney Airport EIS – Bushfire Risk Assessment, July 2015

A history of bushfires[29] in NSW as provided by the RFS suggests that bushfire is an issue of concern. The airport site is located within the northern portion of the Macarthur Bushfire Fire Management Centre area where an average of 417 bushfires are recorded annually, of which around five develop into major fires (Macarthur BFMC, 2012).

Construction and operation of the proposed airport would have the potential to provide a source of ignition, which under adverse winds could allow a fire to escape off-site. As such fires could develop quickly in this landscape and where suppression resources are remote from the site, site specific mitigation measures are the primary means to reduce the risk.

A clear mown area around the inside of the airport fence line is anticipated once the proposed Stage 1 airport is complete. DIRD are currently preparing an updated Bushfire Management Plan in consultation with the NSW RFS for current site management purposes. This would be augmented with the Emergency Response Plan to be developed by the airport lessee company as part of the requirements for obtaining the aerodrome certificate.

Risks during construction could include ignition sources such as welding and angle grinding, sparks from machinery operating in rocky environments, combustion of vegetation heaps and vegetation contact with power lines.

Risks to airport assets which adjoin vegetated areas (e.g. at the airport site perimeter) may be reduced through the creation and maintenance of asset protection zones, use of appropriate construction materials and appropriate operational preparedness actions.

The Bushfire Management Plan would contain procedures which document how on site personnel should respond in the event of a bushfire occurring within or threatening the site.

5.5.3 FLOODING

An assessment of the potential for flooding of the site was conducted by GHD[30]. A summary of the report *Draft proposed Western Sydney Airport Environmental Impact Statement, Surface Water and Geomorphology Assessment,* July 2015 is as follows.

The indicative concept design for the proposed airport has included a drainage strategy for the site.

The airport infrastructure is located outside the 100 year ARI flood extent of Badgerys Creek, Duncans Creek and Oaky Creek. The existing creeks on the

[29] NSW Rural Fire Service (2015). *History of Fires in NSW.*

[30] Draft proposed Western Sydney Airport Environmental Impact Statement, Surface Water and Geomorphology Assessment, July 2015

airport site would be removed and replaced with an extensive stormwater drainage network including a series of detention basins which would be created during the construction stage and remain in use during airport operation.

The indicative airport concept layout has considered the *Stormwater Drainage Design Manual* (former Department of Construction, Roads and Aerodrome Branch 1978) which identifies Average Recurrence Interval (ARI) standards for Aerodromes and is consistent with current industry practice. The guideline states minimum flood immunity requirements for airport infrastructure as shown below. Consideration has also been given to Australian Rainfall and Runoff (Engineers Australia, 1987) recommendations including the need to make appropriate allowances in the design for blockage of stormwater structures.

Aerodrome Area	Criterion	Storm Frequency (ARI, years)
Pavements		
Runways	No Ponding	50
Taxiways	No Ponding	50
Apron Other paved areas	No Ponding No Ponding within 30 m of buildings	10 50
Grassed Areas		
Runway Strip	Ponding within 75 m of runway centreline not to exceed 12 hours	5
Taxiway Strip and Apron Flanks	Ponding within 15 m of pavement edge not to exceed 12 hours	5

Typical Annual Recurrence Intervals for Aerodromes

The table shows that, for key infrastructure such as runways and taxiways, flood immunity would be at least a 50-year ARI event, with additional restrictions on the duration for which any water can pond nearby.

During construction, the effects of changes to the site topography would be mitigated by the use of a network of flood detention basins. A detailed surface water management plan would be developed to manage the impacts of flooding on site during the construction period.

Assessment by GHD as part of the EIS concluded that there was a need to further develop the detention basin strategy during detailed design to be more effective at mimicking natural flows across a range of storm durations and magnitudes. The GHD assessment found that further consideration should also be given to providing a basin or other form of water detention on a tributary of Duncans Creek prior to discharge from the site.

5.5.4 CONTAMINATED LAND

No particular operational safety concerns are expected from contamination at this time. This will primarily be an issue for construction. A preliminary contamination assessment identifies that the site is currently occupied by a mixture of rural residential, agricultural and light commercial properties. Waste dumping, stockpiling of soils and the potential for asbestos was identified at many of the properties.

The assessment recommended that the following actions be completed:

- preparation and implementation of an asbestos and lead based paint management plan to prevent contamination during demolition of existing buildings including procedures for clearance of building footprints following demolition;
- intrusive contamination investigation (soil and/or groundwater sampling) as part of an early works package to assess the requirement for site remediation and/or management of contamination to prepare the site for bulk earthworks. Intrusive investigation should also include classification of waste soils (in accordance with EPA *Waste Classification Guidelines* (2014) which would require management during early works;
- preparation of a detailed remediation action plan to facilitate coordinated remediation and management of contamination during early works with consideration of the program and scope of bulk earthworks and airport development;
- remediation and validation of identified contamination to prepare the site for bulk earthworks; and
- preparation of an Unexpected Findings Protocol pertaining to contamination which would be implemented during bulk earthworks and construction of the proposed airport.

5.5.5 RAILWAY INCIDENTS

The proposed Western Sydney Airport is expected to be serviced by a rail in the future. To avoid critical airport infrastructure, the onsite portion of the rail line is expected to be predominantly underground. Underground trains and stations require particular safety matters to be addressed during design and operation and fall within the jurisdiction of the Transport for New South Wales, Office of the National Rail Safety Regulator and the NSW Independent Transport Safety Regulator. The regulatory requirements would be considered during the design of the proposed underground rail corridor.

6. FINDINGS AND CONCLUSIONS

Section 5 provides the results of a review of the key safety risks posed by the proposed airport as identified by key project stakeholders. It discusses either specific measures or outcomes which are required to further analyse the potential risks and/or resolve the identified issues. A number of these require further definition through the detailed design or related processes and a number of these studies are currently underway or will need to be undertaken in the future to achieve airport approvals.

The Stage 1 (single runway) development indicative flight paths prepared by Airservices Australia mostly eliminate interactions with existing air traffic in the Sydney basin and also avoid existing major infrastructure including Defence Establishment Orchard Hills, Warragamba Dam and Prospect Reservoir. At this stage, no unmanageable airspace safety issues have been identified for the proposed Stage 1 airport development.

A formal flight path design process would occur under the existing airspace management arrangements established by Airservices Australia with approvals from the Civil Aviation Safety Authority (CASA) closer to the time operations commence at WSA. Optimal flight path design using improved navigation technologies should ensure that potential aircraft conflicts, even in emergency go-round scenarios are reduced. Conflicts with critical infrastructure and other obstacles would also be considered during this process.

The proposed 1000 m public safety zones (PSZs) at either end of the Stage 1 runway exceeds the airport site boundary. Further risk analysis to determine individual risk levels at the airport site boundary may be required in order to meet NSW DP&E off-site risk criteria. This would be reviewed during detailed design and any necessary controls implemented.

The delivery and storage of fuel is also an important issue which will require further consideration and design. The worst case design fuel storage fire has been modelled at the airport site and indicates that in order to meet NSW DP&E off-site risk criteria, additional control measures may need to be provided. This should be further investigated during detailed design.

The other key safety risks have adequate and effective precautions available not dissimilar to other operating airports in Australia and overseas.

If all these hazards are eliminated, so far as is reasonably practicable (SFAIRP), and if this is not possible, reduced so far as is reasonably practicable by the appropriate persons conducting a business or undertaking (PCBUs) through the ongoing design, construction and regulatory processes, then the proposed airport would be considered to be safe.

Considering a possible longer term airport development around 2063, it is assumed that all design issues and risk studies identified as being required for the proposed Stage 1 operation in Section 5 have been undertaken and completed. Further development of the airport however would entail similar design and operations procedures to be addressed for any additional infrastructure in accordance with all relevant industry legislation and standards and where appropriate, adaption of existing processes and procedures to the new operations area. Additionally, the aerodrome manual would need to be updated.

The development of the second (southern) runway around 2063 may require greater airspace planning and design due to the expected growth in aircraft movements and the complexity of managing aircraft movements at a number of airports in the Sydney basin including the proposed Western Sydney Airport and, Sydney (Kingsford Smith) Airport. At the time of this study, to facilitate the expected level of future demand, and based on current air safety controls and technology, a reconfiguration of the Sydney basin airspace may be necessary. However, the action that needs to be taken cannot be ascertained this far in advance and may change in response to for example, land use changes, operating practices and new technologies introduced in the intervening period.

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GLOSSARY AND ABBREVIATIONS

AAA	Australian Airport Association
ASD-B	Automatic dependent surveillance-broadcast
AFRRS	Airport Rescue Fire Fighting Service (Airservices Australia)
AFP	Australian Federal Police
ATC	Air Traffic Control
BOM	Bureau of Meteorology
CAA	Civil Aviation Authority, New Zealand
CASA	Civil Aviation Safety Authority
Cth	Commonwealth
DIRD	Department of Infrastructure and Regional Development
DP&E	NSW Department of Planning and Environment
EIS	environmental impact statement
EPA	NSW Environment Protection Authority
FDS	fire dynamics simulator
GA	general aviation
GNSS	global navigation satellite system
GPS	global positioning system (USA)
HIPAP	Hazardous Industry Planning Advisory Paper
ICAO	International Civil Aviation Organisation
IFR	instrument flight rules
ILS	instrument landing system
Individual risk	The frequency at which an individual may be expected to sustain a given level of harm from the realisation of specified hazards (Institution of Chemical Engineers (2005) *Nomenclature for Hazard and Risk Assessment in the Process Industries)*.
KSA	Sydney Kingsford Smith Airport
NDB	non directional beacon
NSW	New South Wales
OAR	Office of Airspace Regulation (CASA)
OLS	obstacle limitation surfaces
PANS-OPS	Procedures for Air Navigation Services – Aircraft Operations
PCBU	person conducting a business or undertaking
PSZ	public safety zone
PBN	performance based navigation
R2A	R2A Due Diligence Engineers
RFS	Rural Fire Service, New South Wales
RPA	remotely piloted aircraft
RPT	regular passenger transport
SID	standard instrument departure
Societal Risk	The relationship between frequency and the number of people suffering from a specific level of harm in a given population from the reaslisation of specified hazards. (Institution of Chemical Engineers (2005) *Nomenclature for Hazard and Risk Assessment in the Process Industries)*.
STAR	standard terminal arrival route
TCAS	traffic collision avoidance system
VFR	visual flight rules
VOR	VHF omnidirectional radio range
WHS	Work Health and Safety
WSA	Western Sydney Airport



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VOLUME 4

Appendix I
Bird and bat strike

AVISURE
MITIGATING BIRD STRIKE RISK

Western Sydney Airport Environmental Impact Statement

Preliminary Bird and Bat Strike Risk Assessment

September 2015



Executive summary

GHD engaged Avisure to conduct an assessment of the bird and bat strike risk at the proposed Western Sydney Airport (the airport) as part of its Environmental Impact Statement. The Preliminary Bird and Bat Strike Risk Assessment report (this document) provides a preliminary risk assessment of birds and bats present on and in the vicinity of the airport site and has been used to inform the Hazards and Risk and the Biodiversity Assessment components of the Environmental Impact Statement.

The assessment was based on a desktop review of relevant literature and a three-day site visit conducted in March 2015. The site visit included investigations within the airport site and study area. The study area included the area within a 25 km radius of airport site centre point. The justification for this distance is based on international standards (International Civil Aviation Organization and World Birdstrike Association) and national guidelines (National Airports Safeguarding Framework) that recommend identifying, and where necessary managing, potential wildlife attractants within 13 km of runways.

The assessment found that there would be a bird and bat strike risk at the proposed airport due to species presence and abundance, habitat available on the airport site and within the study area, projected aircraft movements and staged construction. The presence of farm dams presents the greatest risk for bird strike at the proposed airport. Despite the complexity involved in managing an abundant and highly distributed habitat type outside of the airport site, it is important to consider this risk relative to other possible features which could present significant bird and bat strike risk for an airport. For example, the proposed site does not have a large estuary in close proximity, is not within a major bird migratory route, does not have flying-fox roosts or ibis colonies in close proximity, and is likely to have reduced available habitat as the airport surrounds urbanise.

Each potential contributor to bird and bat strike risk at the proposed Western Sydney Airport can be managed to an acceptable risk level so the preliminary assessment of overall bird and bat strike risk for the airport is low. Risk management would require the airport operator to implement a suite of mitigation measures and develop an integrated management program designed for ongoing implementation. The mitigation measures detailed in this report are specific to Stage 1 of the proposed airport site development. Similar strategies will apply to the longer-term development with the additional risk of bird and bat strike risk due to the operation of one runway during the construction of a second. Further review of appropriate mitigation strategies will be required during the detailed design, construction and operation stages of longer term development.In addition, the airport operator would need to comply with the International Civil Aviation Organization, the Civil Aviation Safety Authority, and the National Airports Safeguarding Framework regulations, standards and guidelines.

The mitigation strategies listed in this report are based on our preliminary assessment and need to be refined as more information about the detailed design and construction of the proposed airport becomes available. Key considerations include: that the design does not create bird and bat attractive features; that bird and bat populations are monitored to assess strike risk; and, that a plan to implement mitigation actions where hazards are identified is developed.

To confirm the level of bird and bat strike risk and to refine the mitigation strategies, further works in the airport site and study area are required. These include additional bird and bat surveys and the review of detailed design and construction documents. The required study area works include additional surveys and the review of development plans for the area surrounding the airport.

Abbreviations

AC	Advisory Circular
ATSB	Australian Transport Safety Bureau
CASA	Civil Aviation Safety Authority
DIT	Department of Infrastructure and Transport
EIS	Environmental Impact Statement
ICAO	International Civil Aviation Organization
MOS	Manual of Standards
NASF	National Airports Safeguarding Framework
NSW	New South Wales
WHMP	Wildlife Hazard Management Plan

Table of contents

Executive summary 1
Abbreviations 3
Table of contents 4
1. Introduction 6
1.1 Overview 6
1.2 Project description 6
1.3 The bird and bat strike issue 7
1.4 Western Sydney Airport site 8
1.5 Limitations 9
2. Methods 10
2.1. Desktop review 10
2.1.1 Assessment of Existing Environment 10
2.1.2 Bird and bat attracting habitat 10
2.1.3 Western Sydney Airport plans 10
2.1.4 Regulations, standards and guidelines 11
2.2. Site visit 13
2.2.1 Western Sydney Airport site assessment 13
2.2.2 Western Sydney Airport study area assessment 13
2.2.3 Data analysis and risk assessment 15
3. Regulations, standards and guidelines 18
3.1 International regulations and standards 18
3.2 National regulations, standards and guidelines 18
4. Bird and bat strike risk assessment 20
4.1 Species assessment 20
4.2 Habitat assessment 23
4.2.1 Airport site 23
4.2.2 Study area 25
4.3 Projected aircraft movement 35
4.4 Staged construction assessment 36
4.5 Overall airport risk assessment 39
5. Strike risk mitigation strategies 40
5.1 Detailed design 40
5.2 Construction 41

5.3 Operation 41
6. Strike risk assessment next steps 42
6.1 The airport site work recommendations 42
6.2 The airport study area recommendations 42
7. Summary and conclusion 43
References 44
Appendix A: National Airports Safeguarding Framework Guideline C 47

1. Introduction

1.1 Overview

GHD engaged Avisure to conduct a preliminary assessment of the bird and bat strike risk at the proposed Western Sydney Airport (the airport) as part of its Environmental Impact Statement (EIS). The Preliminary Bird and Bat Strike Risk Assessment Report (this document) provides a preliminary risk assessment of birds and bats present on and in the vicinity of the airport site and has been used to inform the Hazards and Risk and the Biodiversity Assessment components of the EIS.

The assessment included a review of:

- existing habitat on the airport site and surrounding area
- birds and bats that are known to be or are likely to be present
- species that present a potential risk to aircraft operations.

The report includes:

- assessment methods
- an overview of relevant regulations, standards and guidelines
- a preliminary risk assessment for the airport based on habitat, species and indicative airport operations
- a review of the Draft Airport Plan to determine the design and construction considerations that present a bird and bat strike risk
- staged mitigation strategies to reduce the bird and bat strike risk based on international and national regulations, standards and guidelines
- recommendations for ongoing work and assessments to confirm the preliminary findings and to plan for operational bird and bat hazard management at the airport.

1.2 Project description

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the delegate of the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.3 The bird and bat strike issue

Birds and bats are attracted to airport environs in response to the availability of food, water, shelter and the safety of a relatively predator-free environment. The presence of birds or bats on an airport can lead to conflict in the form of strikes.

The consequence of bird and bat strikes with aircraft can be very serious. Since 1912, 120 aircraft have been destroyed due to bird strike incidents with 60 of these incidents leading to the death of 297 people (Thorpe 2014). Bird strikes cost the commercial civil aviation industry an estimated US$1.2 billion per annum and involve more than just the repair of damaged engines and airframes (Allan 2002). Even apparently minor strikes which result in no damage can reduce engine performance, cause concern among aircrew and add to airline operating costs.

The main factors determining the consequences of a strike are the number and size of animals struck, the phase of flight when struck, and the part of the aircraft hit. Generally, the larger the animal the greater the damage. Large animals have the ability to destroy engines and windshields and cause significant damage to airframe components and leading edge surfaces. Strikes involving more than one animal (multiple strikes) can be serious, even with relatively small animals, potentially disabling engines and/or resulting in major accidents.

The probability of strikes is specific to each airport. The availability of habitat on the airport and in the surrounding areas determines the number of animals that potentially may collide with aircraft. Each species and/or age class also has its own propensity for being struck (i.e. some species are better than others for avoiding aircraft). In addition, the number of aircraft movements, approach and departure paths and flight times can influence the likelihood of bird and bat strikes. Based on the characteristics of the airport, surrounding areas and aircraft movements, it is possible to broadly define an airport location as having a high, moderate or low overall bird and bat strike risk. Generally, if an airport is located within a biologically productive region, has suitable habitat on the airport and in its proximity, and has a high number of daily aircraft movements, it is likely to have a higher strike risk than an airport located in a biologically poor region with little habitat diversity and few aircraft movements. Man-made habitats however, can sometimes offer more potential for hazardous bird populations to develop than natural ones. A prime example is putrescible waste facilities which in many parts of Australia support very large populations of large flocking species such as Australian White Ibis, Australian Pelican and Silver Gull.

The seriousness of bird and bat strikes is recognised through a network of international and national regulations, standards and guidelines. These documents form the basis for the approach to the bird and bat strike risk assessment conducted and for the mitigation and management measures proposed.

1.4 Western Sydney Airport site

The airport site is located in a temperate climate and predominantly consists of cleared pastures with scattered woodlands. The landholdings on the site support farm dams, agriculture fields, residential housing, market garden infrastructure and other infrastructure such as power lines and roads. Immediately adjacent the airport site, is a mosaic of land uses that contain similar habitat, and within 25 km of the airport site there are urban residential areas, small towns, parklands, conservation areas, large waterbodies and waste disposal facilities. Consideration of the airport site relative to the land uses within the study area is important as birds and bats are likely to use the whole landscape interchangeably, transiting to and from the various habitats and potentially impacting on operational airspace in the form of bird and bat strikes. The attractiveness of sites on and around the airport site for species such as Australian White Ibis and Grey-

headed Flying-fox is particularly important given their high strike consequence (i.e. rates of damage) due to their flocking nature and relatively large sizes.

1.5 Limitations

This preliminary risk assessment is based on information available at the time of the assessment, a three day site assessment, and our knowledge of bird and bat strike issues at other airports. Assessment results will need to be further refined as the design, construction and operation of the airport progresses. The site assessment has particular limitations:

- There was restricted access to some potentially hazardous bird sites due to tenant limitations.
- The scope to complete only one set of surveys. Limited data reduced the power of the risk assessment to determine any seasonal impacts or other anomalies at the time of the surveys.
- The assessment and recommended mitigation and management measures are focused on birds and bats. However, other animals were recorded in the airport site surveys. The airport operator will also be obligated to manage terrestrial animals, including reptiles and mammals other than bats.

The mitigation and management measures presented in this report are flexible, allowing for refinement as the project progresses. Recommendations for further work are provided to address the limitations of this preliminary study (refer Section 6).

2. Methods

The assessment included a desktop review and field assessment of the airport site and the study area (within a 25 km radius of the centre of the airport site) (Figure 1).

2.1. Desktop review

Prior to the site assessment, Avisure reviewed literature and data to develop a preliminary understanding of the current strike risk for a new airport presented by bird and bat populations.

2.1.1 Assessment of Existing Environment

The following documents provided information on the existing environment and historical data on bird and bat populations:

- Draft Environmental Impact Statement, Second Sydney Airport (PPK1997a)
- Technical Paper 10 – Hazards and Risks (PPK 1997b)
- Supplement to the Draft Environmental Impact Statement, Second Sydney Airport (PPK 1999)
- Draft Environmental Impact Statement, Second Sydney Airport Proposal, Auditor's Report (SMEC 1998)
- Supplement to the Draft Environmental Impact Statement, Second Sydney Airport Proposal, Auditor's Report (SMEC 1999)
- Australian Aviation Wildlife Strike Statistics 2004 to 2013 (Australian Transport Safety Bureau 2014)
- *Western Sydney Airport EIS Biodiversity Assessment* (GHD 2015a).

2.1.2 Bird and bat attracting habitat

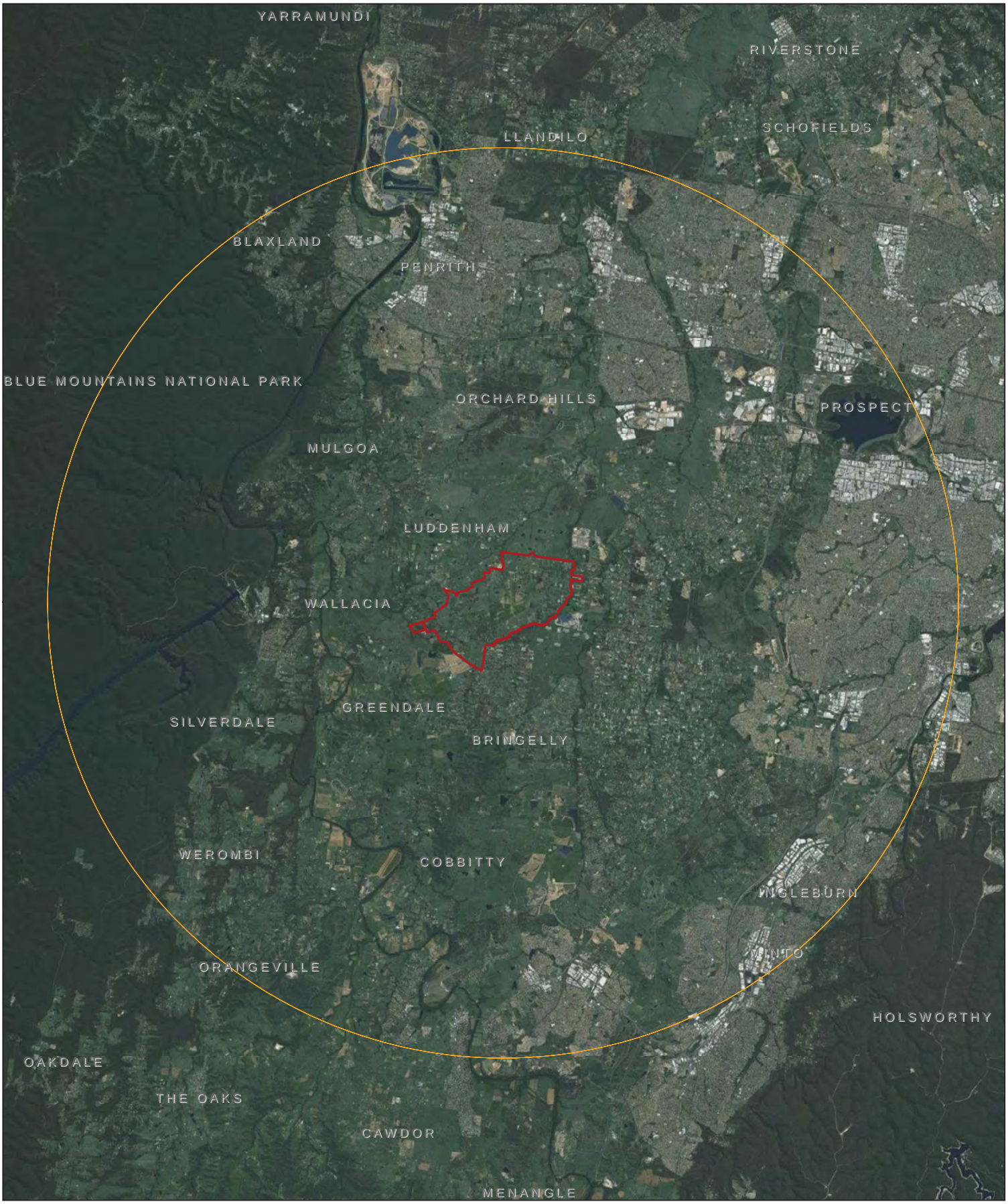
The following resources were used to identify key areas for the field assessment, including Australian White Ibis colonies and Grey-headed Flying-fox roosts (refer Section 2.2.2):

- Sydney Basin Australian White Ibis Regional Management Plan (Ecosure 2009)
- Australian Government Department of the Environment Interactive Flying-fox Web Viewer (Department of Environment 2015).

2.1.3 Western Sydney Airport plans

The following documents provided an overview of the proposed airport design, construction and operation stages. The overall design of the airport and its staged construction was incorporated into the risk assessment and resultant management recommendations. Included in the review of airport plans is the number and profile of aircraft movements:

- Western Sydney Airport Preliminary Airspace Management Analysis (Airservices 2015)



LEGEND

Airport property

Study area

Paper Size A3

0 750 1,500 3,000 4,500 6,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Western Sydney Unit, Department of Infrastructure and Regional Development
WSA Bird and Bat Strike Risk Assessment

Job Number 21-24265
Revision A
Date 18 Jun 2015

Airport and surrounding area

Figure 1

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Data source: Data source: Aerial Imagery - ESRI 2015, General & Topo Data - Geoscience Australia, NSW LPI DTDB & DCDB 2012, Avisure Pty Ltd 2015 Created by: jrichardson

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- Western Sydney Airport Design Basis Report (May 2015) (GHD 2015b)
- Western Sydney Airport: Airport Land Use Master Plan – Concept Design Report (April 2015) (L&B 2015)
- Draft Airport Plan Western Sydney Airport (Department of Infrastructure and Regional Development 2015).

2.1.4 Regulations, standards and guidelines

- The following documents provided context for the assessment of bird and bat strike risk and the identification of appropriate mitigation and management recommendations:
- Civil Aviation Safety Authority Advisory Circular AC 139-26(0) (Civil Aviation Safety Authority 2011)
- Civil Aviation Safety Authority Manual of Standards Part *139* – Aerodromes (Civil Aviation Safety Authority 2014)
- *Civil Aviation Safety Regulations 1998* (Cth) (Regulations)
- National Airports Safeguarding Framework – Guideline C: Managing the Risk of Wildlife Strikes in the Vicinity of Airports (Department of Infrastructure and Transport 2012)
- Recommended Practices No. 1 – Standards for Aerodrome Bird/Wildlife Control (International Birdstrike Committee 2006)
- Doc 9137 Airport Services Manual. Part 3: Wildlife Control and Reduction (International Civil Aviation Organization 2012)
- Annex 14 to the Convention on International Civil Aviation: Aerodromes, Volume 1 Aerodrome Design and Operation (International Civil Aviation Organization 2013).

2.2. Site visit

A site visit was conducted from 23 to 25 of March 2015 by Avisure's Principal Wildlife Biologist, Phil Shaw and Senior Wildlife Biologist, Jeff Follett. The site visit included an inspection and verification of habitats on the airport site, and an inspection of key bird and bat habitats in the study area identified during the desktop review.

2.2.1 Western Sydney Airport site assessment

The airport site was inspected on 24 of March 2015. Bird and bat surveys were conducted by vehicle along a set route of publicly accessible roads across three periods; morning, midday and afternoon (Figure 2). Birds and bats observed were recorded with species, number, behaviour, location and habitat noted against each observation. Observations were aided by the use of 42 x 10 Leica binoculars.

The purpose of the surveys was to record species presence, species numbers and attractive habitats within the airport site and to gather information on the movement of bird and bat populations to, from and over the site. The presence of attractive habitats on the site is particularly important due to the airport's staged construction. It is likely that the existing habitat that is not modified in Stage 1 would continue to attract similar species and numbers whilst the northern runway is operational.

2.2.2 Western Sydney Airport study area assessment

Thirty-one likely bird attracting habitats that were accessible for surveys including landfills, waste transfer stations, nature refuges, golf courses, known Australian White Ibis colonies (Ecosure 2009), and flying-fox camps (Department of the Environment, 2015) within the study area were inspected on the 24 and 25 of March 2015. At each site bird and/or bat species, number of individuals and behaviour were recorded.

The study area included the area within a 25 km radius from the airport site centre point. This distance was adopted based on international standards from International Civil Aviation Organization (ICAO) and the World Birdstrike Association and national guidelines in accordance with the National Airports Safeguarding Framework (NASF) that recommend identifying, and where necessary managing, potential wildlife attractants within 13 km of runways. A 25 km buffer was adopted for this preliminary study to include sites that may be hazardous and to be deliberately conservative.

Some sites within the study area were not assessed due to access restrictions as mentioned in the limitations (Section 1.5). This includes Duncan Creek to the southwest of the airport site as well as some rural properties, waste management facilities and quarries surrounding the site. Section 6 details requirements for further work to address study area assessment limitations. Some study area sites were amalgamated as one location for the determination of potential to increase bird and bat strike risk (e.g. farm dams, cattle farms and poultry farms) to acknowledge their prevalence on the site and in the study area but also to address the time available to visit each site to assess risk (refer to Section 4.2).



LEGEND

- Airport property
- Survey route

Paper Size A3

0 145 290 580 870 1,160

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Western Sydney Unit, Department of Infrastructure and Regional Development
WSA Bird and Bat Strike Risk Assessment

Job Number 21-24265
Revision A
Date 18 Jun 2015

Airport site survey route

Figure 2

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Data source: Data source: Aerial Imagery - Dept of Lands 2013, General & Topo Data - Geoscience Australia, NSW LPI DTDB & DCDB 2012, Avisure Pty Ltd 2015 Created by: jrichardson

2.2.3 Data analysis and risk assessment

Management of bird and bat hazards at airports requires an understanding of bird and bat populations, their behaviour, and the risk management process. The process outlined in Australian and New Zealand Standard 31000:2009 Risk Management has been followed for this assessment:

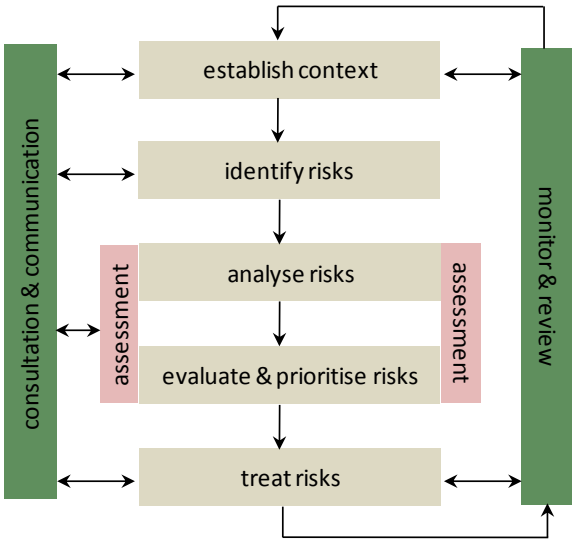


Figure 3. The risk management process (Source: AS/NZS 31000:2009 Risk Management).

Efforts to rank species according to risk level generally involve one of the following:

1. Using national databases to indicate risk level across a country (Dolbeer et al., 2000). This lacks the resolution required to determine risk at a particular airport, although may be useful as a guide.
2. Subjective assessment based on knowledge of bird species present, interpretation of the strike history, and professional judgement for an operational airport. This is the primary methodology used by advisors to airports worldwide.
3. A more formalised, yet still subjective assessment of risk based on scoring a species for categories such as population size, bird mass, flock size, time of day, location on airport site, time spent in air, etc. (Carter, 2001; Morgenroth, 2003). This assessment is open to the vagaries of professional interpretation and cannot be easily used to compare one airport with another, or objectively compare one year to the next.
4. A determination of probability of strike based on bird strike history at the operational airport over the previous five years to determine a yearly average for each species and using percentage of strikes causing damage for each species in a national bird strike database to determine consequence levels (Allan et al., 2006). This is probably the most frequently used method but does not consider the effect of differences in numbers of aircraft movements both between airports and across the same airport for different time periods. It also cannot categorise species which have not been struck in the previous five year period, yet may still remain a significant risk. It is also dependent on effective bird strike reporting which is consistent over time.
5. Avisure has developed a model for determining risk categories using professional bird survey data (Shaw, 2004). The survey data is used to derive probability factors (population size,

position on airport, time spent in air and the species ability to avoid) and consequence factors (bird mass and flock size) for all species recorded. The combination of these probability and consequence factors give a numerical risk index, the Survey Risk Index. This provides a real-time method of risk assessment as it is able to react to observed changes in airside bird assemblages and movement patterns.

Each of these approaches is based on the existence of historical data in the form of strike records or long-term, standardised surveys (options 1, 2, 4, 5) or lacks the necessary rigour to apply to a specific location (options 2, 3). For these reasons, Avisure has evaluated the risk of bird and bat strike at the airport site based on the risk presented by individual species, airport site and study area habitats, projected aircraft movements, airport design and construction plans and operational considerations and has compiled these into an overall qualitative assessment of risk for the airport (Section 4).

Species assessment

The surveys conducted in March 2015 form the basis for the assessment of species risk. The total number of records across the survey set was divided by three to determine the average number recorded for each species per survey. This is done to account for the variability in numbers recorded in morning, midday and afternoon surveys. Behaviour was recorded for each observation to determine the possible impact on aircraft movements and to identify possible mitigation strategies.

Airport site habitat assessment

Habitat present on the airport site has the potential to attract birds and bats. It is understood that a portion of the current habitat will be removed during Stage 1 of construction. However, a portion of existing habitat will remain on the airport site until the construction of the longer term development and even after construction of the final stages, some habitat will remain within the airport site such as the environmental conservation zones along Badgerys and Oaky Creeks. An interpolation of survey data was used to determine the possible attraction of the remaining habitat (Figure 5). During the surveys, comments were recorded as to the attractiveness of various structures, dams, grasslands, agricultural areas, riparian areas and remnant woodlands. These areas were noted because they will become the airport operator's responsibility to reduce the attractiveness to birds and bats in habitats located on its property (refer to Section 3).

Study area habitat assessment

The presence of attractive habitat surrounding the airport site will increase the probability of bird and bat strikes due to increased populations and the possibility of aircraft colliding with birds and bats transiting to and from sites. The study area assessment focused on sites identified in Guideline C of the NASF, *Managing the Risk of Wildlife Strikes in the Vicinity of Airports* (Department of Infrastructure and Transport, 2012). The NASF is embedded within the broader regulatory framework identified in Section 3, and it is the most suitable tool to determine the appropriateness of mitigation and monitoring measures for study area sites.

Projected aircraft movement

The total number of aircraft movements can influence the probability of strikes, with the number of strikes directly correlated with the number of aircraft movements assuming that all other variables remain constant (type of aircraft, weather and mitigation measures, etc.). Strike probability is also influenced by the positioning of the runways and subsequent flight paths for arrivals and departures. For example, a flight path positioned over attractive habitats (e.g. farm dams) increases the likelihood of a strike. For these reasons, the report includes an assessment of the risk presented by the projected aircraft movements and indicative flight paths for the airport. To assist the analysis, additional information comprising a table of airport key design parameters and synthetic aircraft movement schedules for 2030, 2050 and 2063 was reviewed.

Staged construction assessment

Airport design can be used to limit the creation of attractive habitat when applied to landscaping, lighting, buildings, fencing, drains, detention and retention basins, and various other airport infrastructure. Construction itself can have a significant impact on the behaviour of bird and bat populations (e.g. earthworks, exposed soils, exposed seeds, temporary water retention areas, availability of roosting and loafing opportunity on stockpiles of soil and other construction materials), and is of particular concern for this project due to the plan to operate the first runway during the construction of the second runway. The assessment of the design and construction of the airport assumes that the airport will implement the mitigation and management measures outlined in Section 5 and will comply with the regulations, standards and guidelines outlined in Section 3.

Overall airport assessment

The overall bird and bat strike risk for the airport is a compilation of the five aforementioned assessments. Where data or information was not available, Avisure made professional judgements on the risk presented, informed by our eighteen years of aviation experience. The overall risk is based on the airport's responsibilities under international and national regulations, standards and guidelines; however, Avisure has used the data from all of the assessments to ensure recommendations suit the airport site, whilst complying with legislative and regulatory requirements. Our assessment of the overall risk considers: species behaviour and size; habitat attraction to particular species; aircraft movements and time of day; and, staged construction of the site.

3. Regulations, standards and guidelines

There are a number of regulations, standards and guidelines for the assessment and management of activities that contribute to an airport's bird and bat strike risk.

3.1 International regulations and standards

ICAO is a specialised United Nations agency that coordinates and regulates international civil aviation. As a signatory of the Convention on International Civil Aviation, Australia is required to maintain aviation rules that align with the requirements of the Convention. This includes standards for wildlife hazard management at civilian airports in accordance with Annex 14, Volume 1 (Aerodrome Design and Operation), which establishes requirements for the management of collisions between wildlife and aircraft, and requires authorities to take actions to reduce the prevalence of wildlife attracting sites in the vicinity of airports.

ICAO's Doc 9137 (Airport Services Manual Part 3, Wildlife Control and Reduction) (2012) elaborates on the wildlife management responsibilities of airports, providing guidance on the development and implementation of effective airport wildlife management programs, whilst recognising that geographic location, climate, attractiveness of the site to wildlife and air traffic density are site specific and that programs should be developed accordingly. Doc 9137 also includes recommendations on hazard review and habitat management, and identifies a recommended boundary for monitoring off-airport wildlife hazards and land uses.

ICAO's regulations and standards inform Civil Aviation Safety Authority (CASA) regulations and recommendations for wildlife management at airports, and are therefore relevant to the airport bird and bat strike risk assessment.

3.2 National regulations, standards and guidelines

CASA defines and regulates wildlife hazard management at Australia's civilian airports, in accordance with the *Civil Aviation Safety Regulations* 1998 and the CASA Manual of Standards (MOS) Part 139. The regulations establish the requirements for monitoring and recording information on wildlife hazards and identify the airport's responsibilities in the event that a wildlife hazard is identified.

To assist with the interpretation and implementation of MOS Part 139, CASA released *Advisory Circular (AC) 139-26(0)*. The AC provides airport operators with further guidance on how to meet their monitoring obligations and how to address wildlife management issues.

Under these national regulations, the airport is obliged to monitor on- and off-airport sites, and to mitigate wildlife hazards within the airport site through the development and implementation of a Wildlife Hazard Management Plan. The national regulations and related AC assisted the development of the risk management strategies in Section 5.

In May 2012, the Department of Infrastructure and Transport (DIT)[1] released the NASF which aims to develop informed land use planning regimes to safeguard airports and their adjacent communities based on the international and national regulatory framework.

Guideline C of the NASF (Managing the Risk of Wildlife Strikes in the Vicinity of Airports) aims to provide wildlife management guidelines to land users and planning decision makers. Based on the ICAO guideline of reviewing land use within 13 km of an airport, the NASF allocates risk categories to particular land use types from very low to high, and recommends actions for both existing and proposed developments (i.e. incompatible, mitigate, monitor, no action), within zones at 3, 8 and 13 km radial distances. The NASF encourages a coordinated approach between airport operators and land use planning authorities to mitigate risks.

The guideline is particularly useful when considering the establishment of new airports because planning agencies can consider land usage that is incompatible, or requires mitigation or monitoring before commencing work.

NASF Guideline C (included in Appendix A) is relevant to the airport's responsibilities to monitor and mitigate wildlife hazards within the study area. It provides guidance on how the airport operator should work with local councils or other land use planning authorities to establish mechanisms to prevent the creation of land uses that would increase the risk of bird or bat strike risk. Guideline C was incorporated into the study area habitat assessments (Section 4) and the mitigation measures recommended in Section 5.

[1] Now called the Department of Infrastructure and Regional Development

4. Bird and bat strike risk assessment

The overall airport risk assessment included consideration of the species, the airport study site habitat, study area, projected aircraft movement, and staged construction assessments.

4.1 Species assessment

The Australian Transport Safety Bureau (ATSB) identify kites, bats/flying-foxes, lapwings/plovers and Galahs as the four most frequently struck species for Australian airports between 2004 and 2013 (ATSB 2014) with aircraft operating at New South Wales (NSW) airports mostly striking bat/flying-foxes, Galahs, lapwing/plover and magpies. For high capacity air transport[2], the ATSB identify bat/flying-fox, Galah, kite, duck, hawk and magpie as the species most involved in damaging strikes. Galahs were involved in the most multiple strikes with 38% of Galah strikes involving more than one bird. A multiple strike has a greater likelihood of damage and has the potential to disable more than one engine which can result in catastrophic incidents.

Of the aforementioned species, Avisure recorded Masked Lapwing, Galah, Australian Magpie, and various duck species in the airport site surveys. Of particular note was the number of Galahs recorded, with an average of 9.33 per survey and four duck species (Pacific Black Duck, Grey Teal, Australian Wood Duck, and Hardhead), with greater than 10 per survey (Figure 4). In addition, the presence of Straw-necked Ibis in high numbers presents a risk as they are a flocking species of significant mass (1.3 kg) and are relatively difficult to manage on an operating airport.

In addition to the species listed above, several species recorded on the airport site are likely to remain in the area post-construction. Despite their lower ATSB ranking, these species present at least a moderate strike risk due to the availability of food, water and shelter on and adjacent to the airport site (see Sections 4.2 and 4.3). These include, but are not limited to; Common Starling, Feral Pigeon, Cattle Egret and Australian White Ibis. Their risk potential is based on their strike history at other airports, their size, and the likelihood that they will be involved in multiple strikes due to flocking behaviour.

Figure 4 illustrates the average number of individuals observed during the survey period. The figure excludes species that had an average of less than five individuals per survey. These species were excluded because a lower bird number generally equates to a lower strike probability. Additional surveys are required to determine if the observed averages are a true indication of abundance.

The behaviours recorded during the airport site surveys indicate that the site itself is attractive to birds, rather than the site simply acting as a transit pathway between various sites in the adjacent study area. Approximately 88% of the recorded birds were foraging, loafing or perching within the airport, compared to

[2] Includes Regular Public Transport and charter operations on aircraft certified as having a maximum capacity exceeding 38 seats or a maximum payload exceeding 4,200 kg.

only 11% transiting or soaring over the site. This observation is of particular importance for the staged construction discussed in Section 4.4.

No flying-foxes were recorded by Avisure on the airport site. The afternoon survey included the dusk period to provide an opportunity to observe foraging flying-foxes; however, eucalypts were not flowering at the time of the assessment. Additional surveys in other seasons are required to identify flying-fox use of the site as GHD (2015a) recorded a small number of Grey-headed Flying-fox foraging in the riparian corridor (Badgerys Creek). No flying-fox roost sites were observed within the airport site. GHD (2015a) also recorded 12 species of microbats; however, these have been excluded in the bird and bat strike risk assessment as they are unlikely to present a significant strike risk due to their relatively small size and population.

Although potentially moderate and high risk species were recorded in surveys at the airport site, their numbers were not unusually large and there were limited transits through the air. While it is considered necessary to conduct additional surveys to confirm this it is the preliminary conclusion that the bird and bat hazard could be effectively managed to an acceptable risk level through the implementation of a Wildlife Hazard Management Plan.

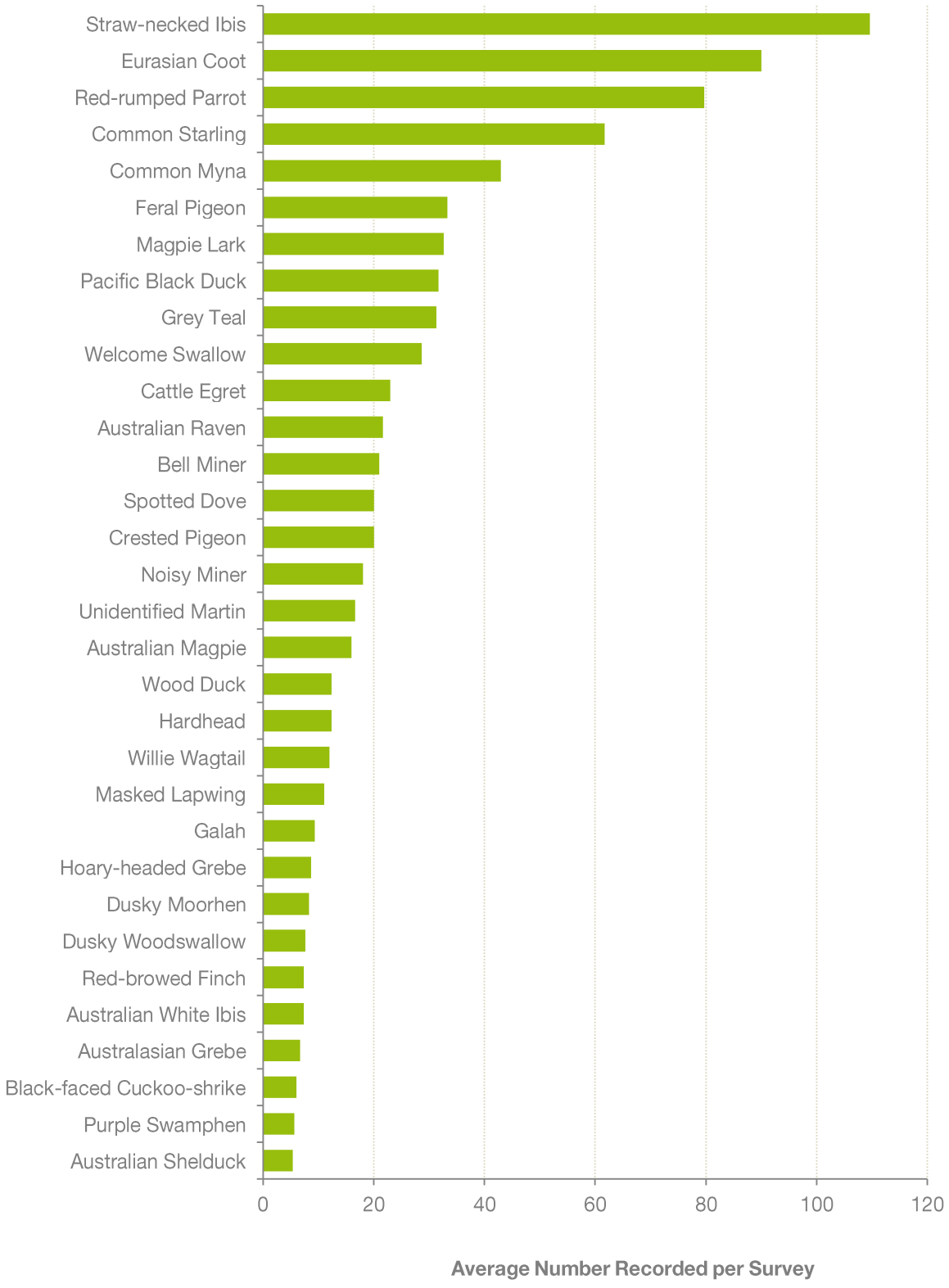


Figure 4. Species and average numbers observed per survey, site for the Western Sydney Airport, March 2015. Note: includes only species with an average number of individuals per survey greater than 5. An additional twenty-eight species were recorded, but had an average less than 5 per survey.

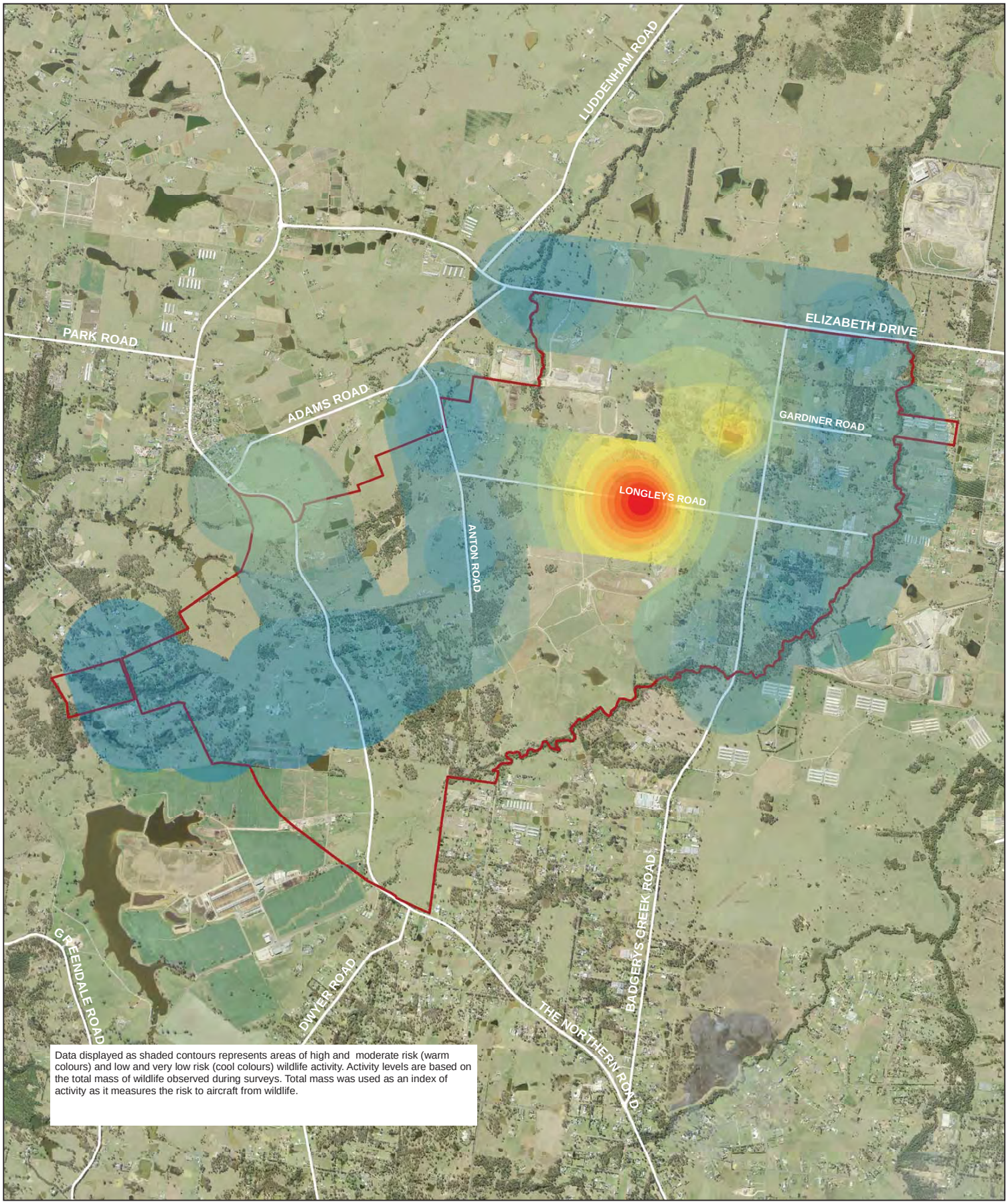
4.2 Habitat assessment

4.2.1 Airport site

The airport site consists of habitats attractive to grassland, wetland, riparian (including the environmental conservation zones along Badgerys and Oaky Creeks) and remnant woodland bird species, with a relatively equal proportion of habitat use observed (grasslands (24%), trees (23%) and ponded water (23%)). The observations recorded for built environment (12%) included residential and agricultural structures, power lines, light poles and other infrastructure. These areas were predominantly used for perching. Despite the absence of flying-foxes, the site does include areas of suitable foraging habitat for Grey-headed Flying-foxes. Eucalypts were not flowering at the time of the site assessment; however, GHD recorded Grey-headed Flying-fox in its surveys (GHD 2015a).

The greatest concentration of birds was observed along Longleys Road (agricultural field and farm dam) and at the retention pond on Taylors Road. Birds were predominantly recorded around farm dams, and the grasslands, trees and infrastructure immediately surrounding them (Figure 5). The implications of staged development of the site and its impact on the availability of habitat at the airport site is discussed in Section 4.4.

Overall, the airport site contains attractive habitat for grassland and wetland species; however, with proper design of airport facilities and landscapes and the implementation of habitat management at the construction and operation phases of the airport, the attractiveness of habitat can likely be managed to achieve an acceptable risk level.



Data displayed as shaded contours represents areas of high and moderate risk (warm colours) and low and very low risk (cool colours) wildlife activity. Activity levels are based on the total mass of wildlife observed during surveys. Total mass was used as an index of activity as it measures the risk to aircraft from wildlife.

LEGEND

Airport property boundary

Survey density (kg)

465
232.5
0

Paper Size A3

0 145 290 580 870 1,160

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

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WSA Bird and Bat Strike Risk Assessment

Job Number 21-24265
Revision A
Date 18 Jun 2015

Airport site wildlife activity

Figure 5

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4.2.2 Study area

New airport developments must consider the impacts of potentially conflicting airspace between birds and aircraft due to movements of birds to and from off-airport sites. The attractiveness of a particular habitat is not the sole consideration. A highly attractive habitat that does not have a complementary habitat on the other side of the aerodrome, may have little or no impact on strike risk because birds and bats will not be inclined to transit though critical airspace. Whereas a habitat with relatively low attraction may pose a significant risk due to its close proximity and position, causing birds and bats to transit through critical airspace (Figure 6). Figure 6 shows an example of a major hazard increase as a result of a new development on the opposite side of a runway.

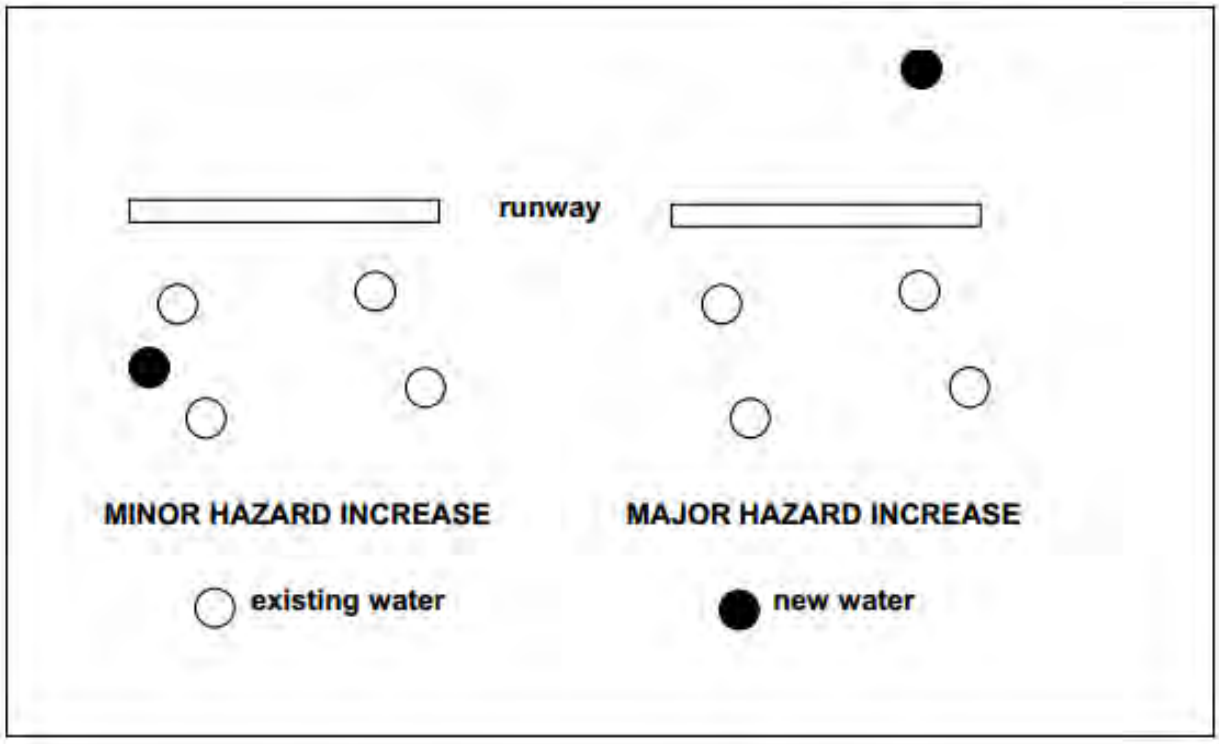

Figure 6. Impact of hazard location in relation to a runway, United Kingdom, Civil Aviation Publication 680.

Figure 6 is relevant to the proposed airport site as there are locations that are potentially attractive to birds and bats throughout the study area (Figure 7). The study area assessment focused on the location of these sites, their attractiveness to birds and bats (determined through site visits where possible), their distance from the airport site, and current management actions to determine their contribution to the bird and bat strike risk at the airport. Table 1 summarises the potential for study area sites to contribute to the bird and bat strike risk at the airport. The table includes the NASF land use description and wildlife attraction risk for the purposes of baseline risk determinations, and Avisure's determination of, and justification for, specific risk to the airport site.

Due to their quantity and distribution, farm dams, cattle farms and poultry farms have been listed as amalgamated locations. Their patchwork distribution throughout the study area, and the general attraction of water to birds, creates a potentially serious risk if birds infringe operational airspace whilst transiting from one location to another. The distribution of farm dams within 3 km of the airport (Figure 8) site is comparable to the scenario provided in Figure 6 with hazards on either side of the runway.

Overall, the presence of off-airport farm dams presents the greatest risk for bird strike at the airport site. The other locations identified within the study area are not currently considered to constitute high risk due to the reasons outlined above. Despite the complexity involved in managing an abundant and highly distributed habitat type outside of the airport site, it is important to consider this risk relative to other possible features which could present significant bird and bat strike risk for an airport. For instance, unlike some airports, the proposed site does not have a large estuary in close proximity, is not within a major migratory route, does not have flying-fox roosts or ibis colonies in close proximity and is likely to have reduced natural habitat available as urbanisation surrounds the airport site. The risk presented by study area sites can be managed through effective relationships with surrounding land owners and planning authorities and by having a standardised monitoring system in place to identify the locations that present an increased bird and bat strike risk. Consistent identification and monitoring of key risk locations as per the NASF guideline will assist in determining changes in risk presented by surrounding land uses and in building relationships to manage sites likely to increase bird or bat strike risk.



Paper Size A3

0 700 1,400 2,800 4,200 5,600

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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WSA Bird and Bat Strike Risk Assessment

Job Number 21-24265
Revision A
Date 18 Jun 2015

Study area assessment locations

Figure 7

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Table 1. Study area assessment locations, National Airport Safeguarding Framework Guidelines and potential risk to Western Sydney Airport, March 2015.

Name	Location from the airport site	NASF Land Use Description	NASF Wildlife Attraction Risk	Potential Risk Posed to Western Sydney Airport	Justification of Potential Risk Rating
Farm Dams	Various	Not described	Not applicable	High	Australian Pelican, Black Swan, various species of ducks, cormorants, grebes, coots and others were observed on the numerous ponds within the airport site and study area. The movement of these birds between various water bodies could result in birds infringing aircraft flight paths.
Eastern Creek Landfill	14.87 km NE	Putrescible waste facility - landfill	High	Moderate (High)	Despite the significant number of large flocking birds present, the facility is scheduled for closure in 2017. If the current development application to delay closure is approved, the risk will elevate to high.
Penrith Waste Services	10.39 km NW	Non-putrescible waste facility - landfill	Moderate	Low to Moderate	Due to the relative proximity of the airport site to this location, concern is that mixed waste (including food waste) could enter the landfill and attract birds. Further assessment required to determine bird use of the location and likelihood to transit operational airspace.
Spring Farm Landfill (formerly Jacks Gully Landfill)	20.66 km S	Putrescible waste facility - landfill	High	Low to Moderate	Although significant numbers of large birds present, they appear to roost locally (Mount Annan) and do not appear to travel north toward the airport site. As a regional food source it contributes to the regional bird population growth, potentially contributing to the new airport's strike risk. Further assessment required to determine if birds transiting to and from this location transit operational airspace.

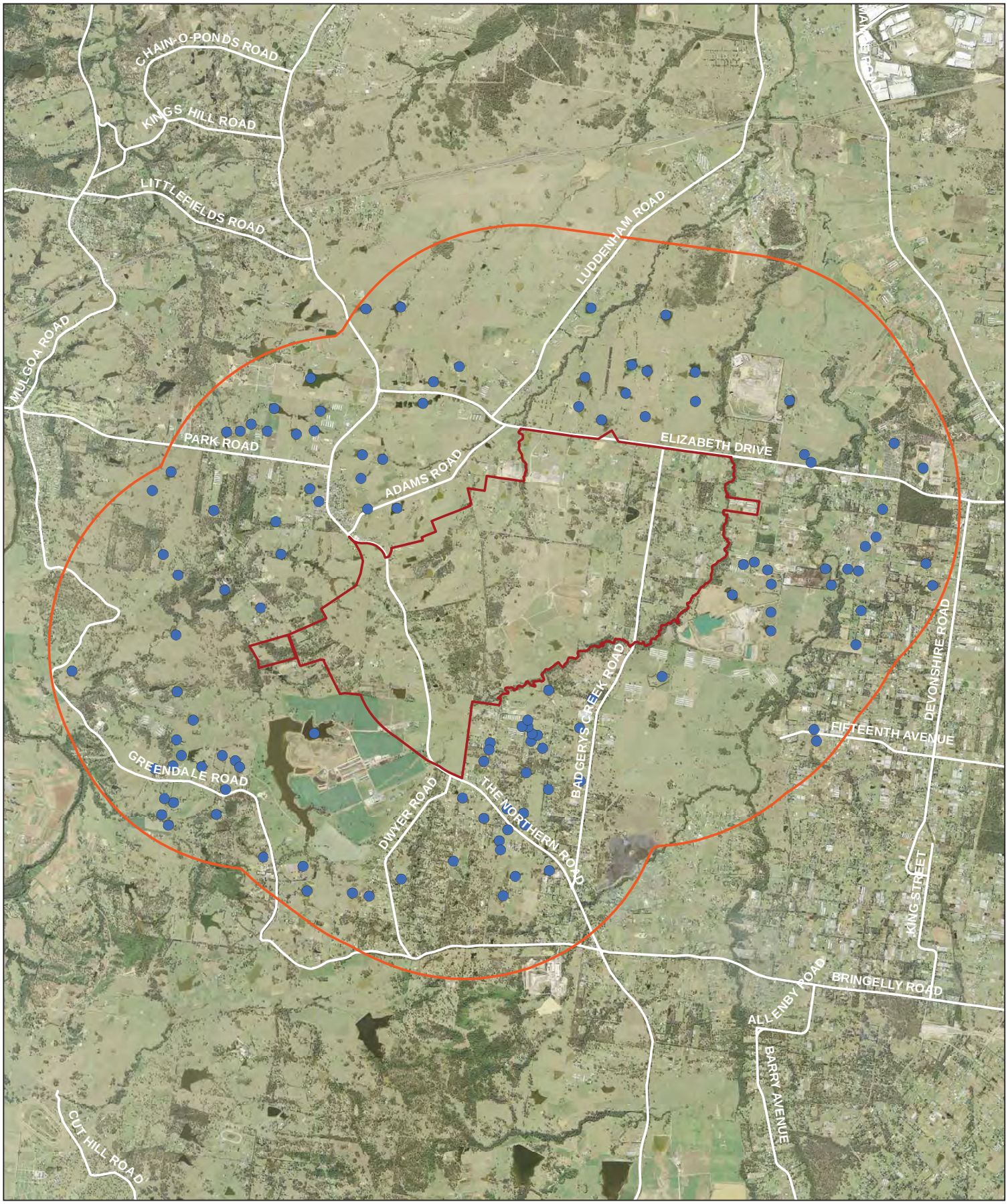
Name	Location from the airport site	NASF Land Use Description	NASF Wildlife Attraction Risk	Potential Risk Posed to Western Sydney Airport	Justification of Potential Risk Rating
Blue Hills Wetland	10.93 km NW	Wildlife sanctuary / conservation area - wetland	High	Low to Moderate	Has the potential to be a roost or nesting location for wetland species. Further assessment required to determine if birds transiting to and from this location transit operational airspace.
Glenmore Loch	13.12 km NW	Wildlife sanctuary / conservation area - wetland	High	Low to Moderate	Has potential to provide roosting and nesting opportunities for wetland species. Further assessment required to determine if birds transiting to and from this location transit operational airspace.
Kemps Creek Landfill	4.4 km NE	Non-putrescible waste facility - landfill	Moderate	Low to Moderate	Mixed waste (including food waste) could enter the landfill and attract birds, contributing to the airport's strike risk. Further assessment required to determine bird use of the location and likelihood of operational airspace transits.
Ched Towns Reserve	12.22 km NW	Sports facility (tennis, bowls, etc.)	Moderate	Low to Moderate	Has the potential to support flocks of corellas and Galahs. Further assessment required to determine if birds transiting to and from this location transit operational airspace.
Cattle farms	Various	Cattle /dairy farm	Moderate	Low to Moderate	Cattle Egrets and Straw-necked Ibis forage on the grasslands. The movement of these birds between various farms could see birds infringing aircraft flight paths. Further assessment required to determine movement patterns amongst the sites.
Poultry farms	Various	Poultry farm	Moderate	Low to Moderate	European Starlings, Feral Pigeons and other birds could be attracted to chicken food, their presence in flocks may present a hazard to aircraft if they transit

Name	Location from the airport site	NASF Land Use Description	NASF Wildlife Attraction Risk	Potential Risk Posed to Western Sydney Airport	Justification of Potential Risk Rating
					operational airspace. Further assessment required to determine movement patterns amongst the sites.
Warragamba Dam	11.63 km W	Not described	Not applicable	Low to Moderate	Could potentially support Australian Pelican and other large water birds. Further assessment required to determine use of the location and to assess movement patterns to and from the site.
Fairfield City Council Resource Recovery	18.67 km NE	Non-putrescible waste facility - landfill	Moderate	Low	Waste is inaccessible to birds.
Wetherill Park Resource Recovery	17.37 km NE	Non-putrescible waste facility - transfer station	Moderate	Low	Waste is inaccessible to birds.
Mulgoa Nature Reserve	11.72 km NW	Wildlife sanctuary / conservation area - dryland	Moderate	Low	May provide forage for flying-fox, but its location relative to the airport site and flying-fox camps reduces the hazard level.
Glenmore Heritage Valley Golf Course	12.22 km NW	Golf course	Moderate	Low	Unlikely to support large flocking species, however corellas, cockatoos and Galahs may use the site from time to time.
Twin Creeks Golf Course	6.65 km NE	Golf course	Moderate	Low	Although pelicans, lapwings and cormorants were present, it is unlikely to support large numbers. Corellas, cockatoos and Galahs may use the site from time to time. Further assessment required to determine if birds transiting to and from this location transit operational airspace.

Name	Location from the airport site	NASF Land Use Description	NASF Wildlife Attraction Risk	Potential Risk Posed to Western Sydney Airport	Justification of Potential Risk Rating
Wallacia Golf Course	7.77 km W	Golf course	Moderate	Low	Unlikely to support large flocking species; however, corellas, cockatoos and Galahs may use the site from time to time. Further assessment required to determine if birds transiting to and from this location transit operational airspace.
Cabramatta Flying-fox Camp	20.42 km E	Not described	Not applicable	Low	Distant camp. Further assessment required to determine the attractiveness of airport site habitat in other months.
Campbelltown Flying-fox Camp	21.97 km SE	Not described	Not applicable	Low	Distant camp. Further assessment required to determine the attractiveness of airport site habitat in other months.
Cobbitty Flying-fox Camp	16.25 km SW	Not described	Not applicable	Low	Distant camp. Further assessment required to determine the attractiveness of airport site habitat in other months.
Emu Plains Flying-fox Camp	16.97 km NW	Not described	Not applicable	Low	Distant camp. Further assessment required to determine the attractiveness of airport site habitat in other months.
Lake Gillawarna / Mirambeena Regional Park Ibis Colony	24.15 km E	Not described	Not applicable	Low	Bankstown City Council have a management plan in place for limiting population growth of Australian White Ibis. Its location relative to the airport site, and the lack of known food sources on or beyond the airport site, reduces its hazard potential.

Name	Location from the airport site	NASF Land Use Description	NASF Wildlife Attraction Risk	Potential Risk Posed to Western Sydney Airport	Justification of Potential Risk Rating
Macquarie Fields Flying-fox Camp	18.39 km SE	Not described	Not applicable	Low	Distant camp. Further assessment required to determine the attractiveness of airport site habitat in other months.
Mount Annan Ibis Colony	18.68 km S	Not described	Not applicable	Low	Although significant numbers of large birds present, they appear to feed locally (Spring Farm Landfill) and do not appear to travel north toward the airport site. Further assessment required to determine bird use of the location and likelihood of operational airspace transits.
Roper Creek Flying-fox Camp	14.66 km NE	Not described	Not applicable	Low	Distant camp. Further assessment required to determine the attractiveness of airport site habitat in other months.
Wetherill Park Flying-fox Camp	18.97 km NE	Not described	Not applicable	Low	Distant camp. Further assessment required to determine the attractiveness of airport site habitat in other months.
Sydney Catholic Garden Cemetery	5.45 km E	Not described	Not applicable	Low	Landscape may attract grassland foraging species such as lapwings, ibis and magpies. Further assessment required to determine if transits to and from the site intersect operational airspace.
Boral Selection Facility	3.4 km E	Not described	Not applicable	Low	Ponds may attract water birds. Further assessment required to determine bird use of the location and likelihood of operational airspace transits.

Name	Location from the airport site	NASF Land Use Description	NASF Wildlife Attraction Risk	Potential Risk Posed to Western Sydney Airport	Justification of Potential Risk Rating
Duncan Creek	5.3 km SE	Wildlife sanctuary / conservation area - wetland	Moderate	Not determined	Further assessment required to determine bird use of the location and likelihood of operational airspace transits.
Prospect Reservoir	17.32 km NE	Not described	Not applicable	Not determined	Further assessment required to determine bird use of the location and likelihood of operational airspace transits.



LEGEND

- Airport property
- 3km
- Farm dam

Paper Size A3

0 260 520 1,040 1,560 2,080

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Western Sydney Unit, Department of Infrastructure and Regional Development
WSA Bird and Bat Strike Risk Assessment

Job Number 21-24265
Revision A
Date 18 Jun 2015

Farm dams within 3 km of airport site boundary

Figure 8

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4.3 Projected aircraft movement

The projected annual aircraft movements for the airport would be responsive to demand; however, for the purposes of the EIS, is assumed to grow as follows: 56,000 (2030), 79,300 (2035), 164,200 (2050) and 339,900 (2063). For 2004 to 2013, the average strike rate for the major Australian airports was 5.4 strikes per 10,000 movements (ATSB 2014). Australian major airports have a range of 3.13 strikes per 10,000 movements to 10.96 per 10,000 (Figure 9). Each major airport has a unique bird and bat strike risk profile; however, assuming that the proposed airport will have an average similar to that across all of the major airports, approximately 30 (2025), 43 (2035), 89 (2050) and 184 (2063) strikes within the airport confines could be expected. The international benchmark for adverse effect on flight (i.e. delay or damage) is 1 per 100,000 movements (Begier and Dolbeer 2011). Assuming that the airport aligns with the international benchmark, this represents a damaging strike approximately every two years from the opening date and will increase to approximately three per year by the year 2063.

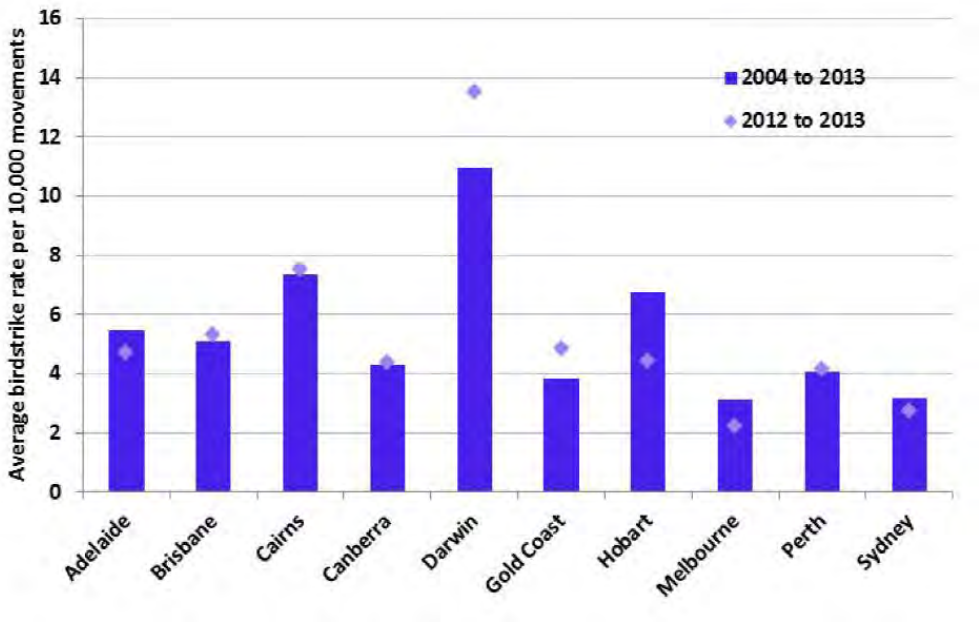


Figure 9. Average rate of birdstrike for major aerodromes (inside aerodrome confines) per 10,000 movements, 2004 – 2013 (source: Australian Transport Safety Bureau 2014).

The time of day profile for projected aircraft movements is similar to other airports in Australia, peaking in the morning and afternoon periods. Based on other airports' bird and bat strike history, it is likely that the airport would record its greatest number of strikes in the morning with a second peak in the afternoon, corresponding with the peak aircraft movements and high bird activity periods. In general, airports that have significant flying-fox populations in close proximity to the airport, or that have large areas of suitable foraging habitat, experience an additional strike peak during dusk and post-dusk periods as flying-foxes depart their roosts and begin their nightly foraging.

The planned approach and departure paths for Stage 1 and the longer term development would take aircraft over or close to potentially significant sites such as the Eastern Creek Landfill, Prospect Reservoir and Warragamba Dam. Based on indicative flight paths for Stage 1, aircraft will be at approximately 2,250 feet

(Prospect Reservoir and Warragamba Dam) on arrival and at approximately 630 feet (Eastern Creek Landfill) on departure whilst close to these sites. In addition, the approach and departure paths are over a number of farm dams which may present a significant bird and bat strike risk. The altitude at which aircraft intersect these locations partially determines the risk level as 93% of bird strikes occur below 3,500 feet (Dolbeer 2006). Bird and bat strike risk should therefore be considered when finalising the flight paths as the height of intersection with significant sites will partially determine their contribution to bird and bat strike risk at the proposed airport (see Section 5).

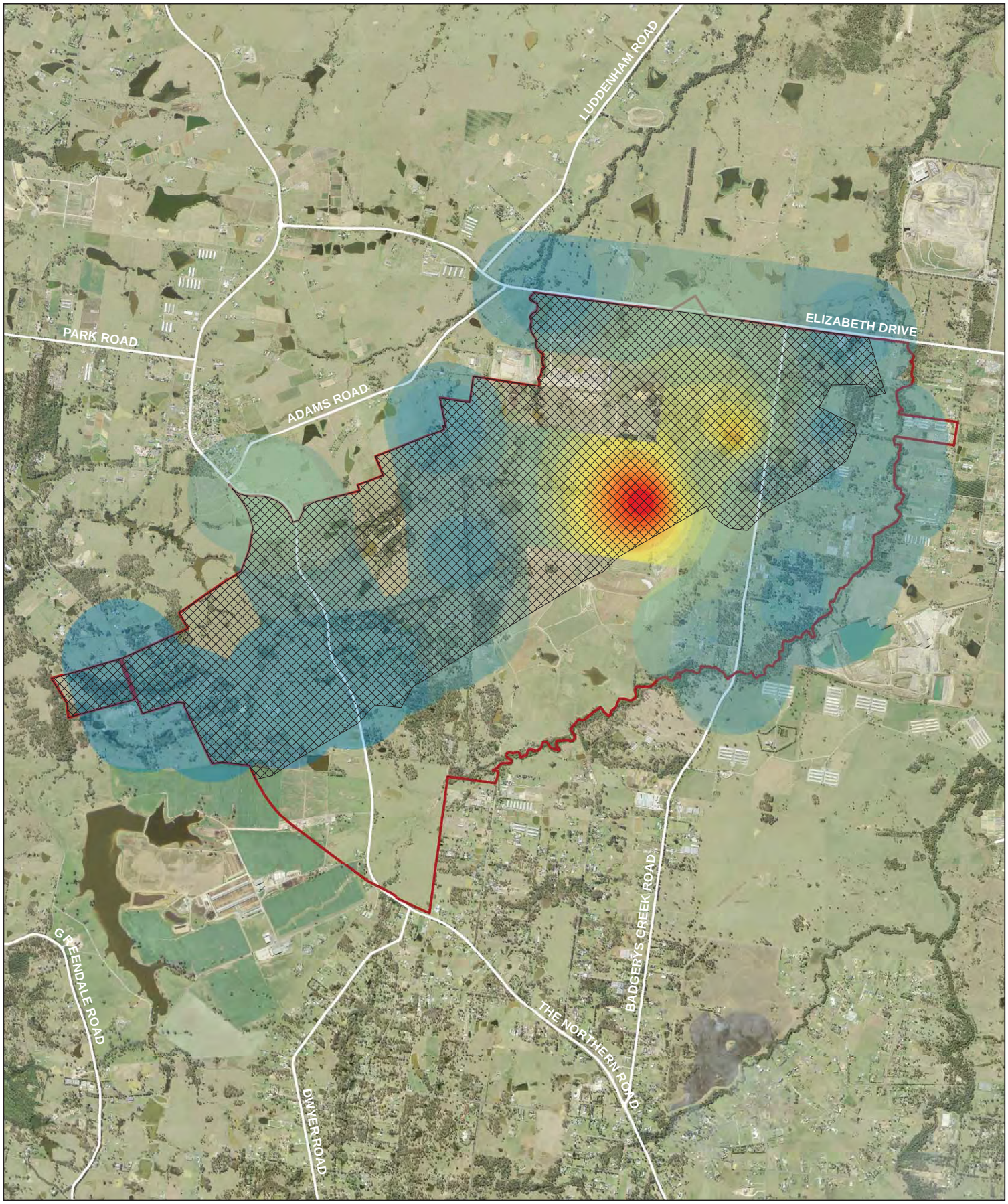
Assuming effective consideration of flight path impact on bird and bat strike risk and the implementation of a robust wildlife management program, projected aircraft movements are unlikely to present a greater bird and bat strike risk when compared to other airports and the impact of significant risks such as consistent, large-scale bird or bat movements can be managed to an acceptable risk level through notification systems and operational modifications such as flight arrival and departure times.

4.4 Staged construction assessment

The airport would be developed across a number of stages. Stage 1 is to be completed with one operational runway (northern). The longer term development anticipates construction of a second runway in the southern half of the site to be completed around 2050. The staged approach to construction presents additional risk of bird and bat strikes at the airport in two ways. Firstly, Stage 1 leaves suitable habitat at the airport site in close proximity to the northern runway operations. Secondly, construction of the second runway could temporarily increase bird and bat strike risk as it will disturb pre-existing populations within the airport site.

Stage 1 construction would reduce the overall habitat available at the airport site (Figure 10); however, suitable habitat would remain in the eastern and southern portions of the site. Approximately 32% of the birds recorded during surveys were utilising habitats that would not be disturbed for the Stage 1 construction. Stage 1 also includes the creation of detention ponds, catering areas, commercial developments and the terminal complex. Each of these has the potential to attract birds from the eastern and southern portions of the airport site, as well as from adjacent properties on all sides of the airport. The full determination of bird and bat attraction implications is limited because the draft airport plan does not include detailed designs and mitigation plans for drainage systems, grasslands, landscaping and other known bird and bat attractants. The draft airport design includes the management of stormwater runoff to ensure no ponding on runways, taxiways and aprons (Department of Infrastructure and Regional Development 2015). It allows for ponding within 75 m of runways and 15 m of taxiways for less than 12 hours. The detention basins will operate as dry basins when they are not providing detention and treatment of stormwater.

The longer term development of the airport site has the potential to disturb birds and bats present in the eastern and southern portions of the airport site during construction. Construction would displace birds and microbats present in the area and has the potential to change bird and bat (including flying-fox) movement patterns due to changed foraging, roosting and nesting behaviours. With an active northern runway, this could increase the probability of bird and bat strikes temporarily until bird and bat patterns adapt to changed



LEGEND

Airport property boundary

To be cleared

Survey density (kg)

465

232.5

0

Paper Size A3

0 145 290 580 870 1,160

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Western Sydney Unit, Department of Infrastructure and Regional Development
WSA Bird and Bat Strike Risk Assessment

Habitat implications of Stage 1 construction

Job Number	21-24265
Revision	A
Date	18 Jun 2015

Figure 10

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conditions. Birds and bats present in the area are likely to seek similar habitats in surrounding areas, potentially altering their movement patterns around the airport site. As with Stage 1, the second phase has the potential to attract birds and bats from surrounding areas due to the design of drainage systems, detention basins, grassland areas, landscaped areas and other infrastructure. Birds and bats present in the area will seek the nearest suitable habitat on the airport site or within the study area, and will probably use these sites interchangeably. Careful consideration should be given the location of the detention basins planned for the northern and southern sides of the runways, as birds may transit critical aircraft movement areas to access them. Despite their design, detention basins have the potential to increase risk at times when they are detaining stormwater for treatment, even if the risk is only temporary (United States Department of Transportation 2007, Transport Canada 2010).

A staged approach to construction with the operation of one runway during the construction of a second runway presents a temporarily greater risk than alternative development approaches. However, the temporarily increased bird and bat strike risk due to staged construction can be managed to an acceptable level through the implementation of proper planning and routinely updating the Wildlife Hazard Management Plan to reflect key changes at the airport site.

4.5 Overall airport risk assessment

In accordance with the limitations (Section 1.5) and the methods (Section 2), the overall assessment is based on an analysis of the species surveyed, habitat at the airport site and study area, projected aircraft movements, and the proposed staging of construction. In addition, it assumes the airport operator would comply with ICAO, CASA and NASF and implement the mitigation measures outlined in Section 5.

Based on this analysis and these assumptions, the preliminary assessment of the overall bird and bat strike risk for the proposed airport is low during both stages of development.

Recommendations for further work are provided in Section 6 to address the limitations of this preliminary study and to ensure that bird and bat strike risk is appropriately managed.

5. Strike risk mitigation strategies

Mitigation strategies recommended for each stage of the proposed airport development aim to maintain the bird and bat strike risk at an acceptable level, and have been derived according to the regulations, standards and guidelines outlined in Section 3, along with the assessments detailed in Section 4.

The airport lessee company has the opportunity to design the airport in a way that limits its attractiveness to birds and bats. The current design and construction specifications lack sufficient detail to provide specific recommendations to reduce the strike risk. However, the following general strategies, when implemented at the specified stage, would contribute to mitigating the strike risk.

The mitigation strategies listed in this report are based on our preliminary assessment and will be refined as more information about the design and construction of the airport becomes available. Key considerations will be to ensure that the design does not create wildlife attractive features, that bird and bat populations are monitored to assess strike risk, and that a plan to implement mitigation actions where hazards are identified is developed.

The strategies listed below are specific to Stage 1 of the proposed airport site development. Similar strategies will apply to the longer-term development with the additional risk of bird and bat strike risk due to the operation of one runway during the construction of a second. Further review of appropriate mitigation strategies will be required during the detailed design, construction and operation stages of longer term development.

5.1 Detailed design

1. Engage a wildlife strike specialist to develop a Wildlife Hazard Management Plan (WHMP) that documents at least the following:
    a. hazard assessment, including monitoring action and analysis
    b. pilot notification
    c. liaison and working relationships with land use planning authorities
    d. on-airport bird and animal attractors which provide food, water or shelter, including stockpile management and induction programs for workers to ensure food wastes are disposed of appropriately
    e. suitable harassment methods
    f. an ongoing strategy for bird and animal hazard reduction through subsequent project development stages
    g. wildlife strike reporting.
2. Implement a standardised and robust bird and bat monitoring system within the airport site and study areas as per the WHMP.
3. Design options and exclusion devices to exclude roosting, nesting and perching opportunities for birds on lighting and fencing, and in aircraft hangars, drains, culverts, and other airport

infrastructure where birds are known to roost, perch and establish nests should be incorporated in accordance with NASF guidelines.

4. Drainage systems, retention ponds and swales should be designed and located to minimise the availability of standing water. Detention basins should be designed to be 'dry' otherwise provision for nets should be included.
5. All-weather access roads for wildlife management should be provided, particularly close to the runway and with easy access to runways and taxiways.
6. Proposed grassland areas should be managed in a way to reduce the attractiveness to birds and the maintenance protocol should be documented. A separate investigation into the preferred grass seed selection may be required to ensure seed mixes are not attractive to granivorous birds, yet are suitable to the climate and soils.
7. Ensure waste receptacles are designed to reduce the accessibility of putrescible waste to scavenging species such as ibis and crows.
8. The detailed design is to be reviewed by a wildlife strike specialist prior to finalisation.

5.2 Construction

1. Monitor birds and bats within the airport site and study areas as per the WHMP.
2. Initiate active management six months prior to the commencement of runway operations. This can assist in determining how birds will use the airport site in the long-term.

5.3 Operation

1. Develop a wildlife management committee that includes the airport operations team, airport environment team, airlines, air traffic control, local and state planning authorities, off-airport landowners, regulators, wildlife strike specialists and conservation groups.
2. Ensure the wildlife management committee meets routinely to assess changing bird and bat activity and how this will impact the airport's strike risk during the operational stage.
3. Engage a wildlife strike specialist to review and revise the WHMP after six months of operation and then according to the review schedule outlined in the WHMP. Where monitoring identifies wildlife hazards, within the airport site or surrounding areas, apply the mitigation actions detailed in the WHMP to reduce the strike risk.
4. Reassess the bird and bat strike risk monthly to determine up to date risks that can inform management actions, resource allocation, as well as monitor program progress.

6. Strike risk assessment next steps

The next step of the bird and bat strike risk assessment is to complete further works in the airport site and broader study area to confirm the level of bird and bat strike risk and to refine the mitigation strategies. The work outlined below is in addition to, and precedes, the mitigation strategies listed in Section 5.

6.1 The airport site work recommendations

1. Conduct monthly bird and bat surveys for one year before the airport design for Stage 1 is completed. Additional surveys will provide a more robust understanding of bird and bat abundance and distribution at the airport site, accounting for seasonal changes. The data can be used to help develop appropriate mitigation measures.
2. Conduct a detailed analysis of the species recorded in surveys to determine the specific habitat requirements, likely areas of attraction, and appropriate management actions for the most abundant species. The monthly surveys would provide an indication of which species or species assemblages would be the focus of this detailed analysis. The result of the analysis would be a predictive tool that could be used to determine the probability of strikes per species.
3. Review design and construction documents as developed to identify any potential bird and bat attractants. This can allow for modifications to be implemented at the design and construction, negating the potential for retrospective management actions if the design is finalised or once construction has begun.

6.2 The airport study area recommendations

1. Conduct monthly bird and bat surveys for one year before the airport design for Stage 1 is completed. Additional surveys will provide a more robust understanding of bird and bat abundance and distribution in the airport study area, accounting for seasonal changes. The data can be used to help develop appropriate mitigation measures, and may even contribute to long-term cost savings. The inclusion of radar data to track bird and bat movements would further inform the assessment. This is an emerging technology that is likely to be used regularly in the future to make operational decisions to reduce overall bird and bat strike risk.

   Surveys should include:

   a. All identified sites within 3 km of the airport, including farm dams, cattle farms and poultry farms. Access to private property will be required.

   b. All identified sites within 8 km of the airport along approach and departure paths. Access to private property will be required.

2. Review all development plans for the area around the airport site. The review should identify land uses within 13 km of the airport site that are likely to increase the bird and bat strike risk at the airport and prioritise monitoring to determine changes in bird and bat strike risk at these locations.

7. Summary and conclusion

The preliminary bird and bat strike risk assessment included a desktop review of literature and data related to the airport environment; the regulations, standards and guidelines related to wildlife management at airports; the airport plans and forecast aircraft movements; and bird and bat attracting habitat. In addition, the assessment included a three-day airport site and study area visit to conduct surveys of bird and bat activity at the airport site and to investigate potential bird and bat attracting sites in the study area. The information gathered in the desktop review and the site visit was compiled to make a preliminary assessment of the overall bird and bat strike risk at the future airport.

It was concluded that each identified contributor to bird and bat strike risk at Western Sydney airport can be managed to an acceptable risk level and as a result, this preliminary assessment has concluded that overall bird and bat strike risk for the airport is low. The overall airport risk assessment included consideration of the species, the airport study site habitat, study area, projected aircraft movements, and staged construction assessments.

Risk management will require the airport operator to implement a suite of mitigation measures across subsequent project development stages and develop an integrated management program designed for ongoing implementation. In addition, the airport lessee will need to comply with the ICAO, the CASA and the NASF regulations, standards and guidelines during operation.

To confirm the preliminary findings of the bird and bat strike risk assessment, it is necessary to complete further works at the airport site and broader study area during subsequent stages of design development. The recommended airport site work includes additional bird and bat surveys and the review of more detailed design and construction documents. The recommended study area works include additional surveys, and the review of development plans for the area surrounding the airport. These works are required to confirm the level of bird and bat strike risk and to refine the mitigation strategies.

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Appendix A: National Airports Safeguarding Framework Guideline C

GUIDELINE C

NATIONAL AIRPORTS SAFEGUARDING FRAMEWORK

MANAGING THE RISK OF WILDLIFE STRIKES IN THE VICINITY OF AIRPORTS

REVISION DATE	VERSION NUMBER	CHANGES MADE	APPROVED BY
Feb 2012	3.1.1	Document Creation	NASAG
Apr 2012	3.1.2	Drafting changes post consultation process	SCOTI
15/7/12	3.1.3	Version control table added. Page numbers added.	S. Stone, GM Aviation Environment, DOIT.

Purpose of Guideline

1. This document provides guidelines to State/Territory and local government decision makers to manage the risk of collisions between wildlife and aircraft at or near airports where that risk may be increased by the presence of wildlife-attracting land uses.

Why it is important

2. The *Principles for a National Airports Safeguarding Framework* acknowledge the importance of airports to national, state/territory and local economics, transport networks and social capital.
3. Wildlife strikes and / or avoidance can cause major damage to aircraft and / or reduction of safety. The consequences of wildlife strike can be influenced by the number and size of wildlife involved, phase of flight and the aircraft part hit by the wildlife.
4. Land use planning decisions and the way in which existing land use is managed in the vicinity of airports can significantly influence the risk of wildlife hazards. Many existing airports are surrounded by areas which are attractive to wildlife, especially birds. As examples, land uses such as agriculture, wildlife sanctuaries, wetlands and land fill sites can attract a high number of birds which increase the risk of interference with aviation activity.
5. The number of wildlife strikes and the attendant risk of fatalities, injuries, aircraft damage and operational delays can be reduced by managing land use around airports to minimise the potential for wildlife to be in conflict with aircraft operations.

How it should be used

6. Some States/Territories already have planning guidelines or polices in place and this document provides guidance for review. For those without policies in place, these Guidelines (in addition to the associated Safeguarding Framework) will provide input to new policies.

Roles and Responsibilities

7. State/Territory and Local Governments are primarily responsible for land use planning in the vicinity of all airports.

8. Australia's 19 major airports are under Australian Government planning control and are administered under the Airports Act 1996. Planning on other airports is undertaken by State/Territory and Local Governments or private operators.

9. As a contracting state to the Convention on International Civil Aviation (the Convention) Australia has international obligations regarding the regulation and management of aviation safety. The International Civil Aviation Organisation (ICAO), which was established by the Convention, has established Standards and Recommended Practices covering all aspects of civil aviation safety.

10. Australian civil aviation safety legislation includes provisions to meet Australia's international obligations. Part 139 of the Civil Aviation Safety Regulations 1998 (the Regulations) imposes an obligation on airports to reduce the risks of wildlife strikes. These regulations are administered by the Civil Aviation Safety Authority (CASA). All Certified Airports are required to document procedures for wildlife hazard management in their Aerodrome Manual. Certified Airports with a confirmed wildlife hazard are also required to develop and implement wildlife hazard management plans. CASA regulates and conducts surveillance of all regulated airports to ensure that that airport operators are adequately managing the risk of on-airport wildlife strikes.

11. Under the Regulations, CASA can address the risk of waste foodstuffs being dumped near airports that may pose a risk to aviation safety by attracting wildlife. When CASA identifies a property that is being used to dump waste food stuffs, it has powers to make it an offence to dump waste foodstuffs there. CASA can also require the property owner to remove waste foodstuffs from the property and can, if necessary, make arrangements to remove the waste material.

Key considerations for managing risk of wild life strikes in the vicinity of airports

12. Most wildlife strikes occur on and in the vicinity of airports, where aircraft fly at lower elevations. The risk of a strike on airport relates to the level and form of wildlife activity both within the boundary of an airport and in surrounding areas. Wildlife attracted to land uses around airports can migrate onto the airport or across flight paths, increasing the risk of strikes. Airports actively reduce wildlife populations and manage the risk of strikes on airport land. Such on-airport activities are underpinned by current aviation safety regulations.

13. Australia's international aviation safety obligations as a contracting state to the Convention on Civil Aviation include responsibilities to take action to manage the risk from wildlife hazards. Specifically, the following standards and recommendations relating to wildlife hazards apply. Clauses 9.4.3 and 9.4.4 and 9.4.5 of Annex 14 of ICAO state:

- Action shall be taken to decrease the risk to aircraft operations by adopting measures to minimize the likelihood of collisions between wildlife and aircraft;
- The appropriate authority shall take action to eliminate or to prevent the establishment of garbage disposal dumps or any source which attracts wildlife to the aerodrome, or its vicinity, unless an appropriate wildlife assessment indicates that they are unlikely to create conditions conducive to a wildlife hazard problem. Where the elimination of existing sites is not possible, the appropriate authority shall ensure that any risk to aircraft posed by these sites is assessed and reduced to as low as reasonably practicable; and
- States should give due consideration to aviation safety concerns related to land developments in the vicinity of the aerodrome that may attract wildlife.

GUIDELINES FOR MANAGING THE RISK OF WILD LIFE STRIKES IN THE VICINITY OF AIRPORTS

14. Aviation safety regulations do not address the risk of wildlife strikes occurring outside the boundary of airports in the same way as they address on-airport risk. The risk of a strike off airport relates mostly to wildlife activity in areas surrounding the airport. There is a need to strengthen arrangements to address the risk of wildlife hazards that occur off airport and ensure Australia is in step with its local and international obligations.

15. The International Civil Aviation Organisation (ICAO) has developed specific advice on land uses with the potential to become high risk wildlife attractants. These include:

- food garbage disposal;
- sewage treatment and disposal;
- artificial and natural lakes;
- abattoirs and freezing works;
- fish processing plants;
- bird sanctuaries; and
- outdoor theatres.

16. The table at **Attachment 1** aligns with international benchmarks set by ICAO and other international aviation regulators. It provides guidance on the land uses that present a risk of attracting wildlife and triggers (based on distance from an airport) for adopting active measures to mitigate that risk. Attachment 1 is a tool to assess plans for new or revised land uses within 3km, 8km and 13km of an airport.

17. The guidelines recognise that at many existing airports it may be difficult or impossible to change the existing usage of the land which serves as a wildlife attractant. In such cases, airport operators should work with land use planning authorities to mitigate the risk of wildlife strike.

18. The guidelines can also be used when considering the establishment of new airports. When a greenfields site is being considered for a new airport, selection agencies can consider the degree of incompatible land usage, including wildlife attracting land usage, in the vicinity of potential sites.

Managing on-airport wildlife strike risk

19. All certified airports (airports certified under Part 139 of the Civil Aviation Safety Regulations 1998 – CASR Part 139) are required to document procedures for wildlife hazard management in their aerodrome manual. Certified airports with a confirmed wildlife hazard are also required to have a wildlife hazard management plan (WHMP). The role foreshadowed for aerodrome operators in these guidelines should form part of future WHMPs and be incorporated in revisions of existing WHMPs.

Managing off-airport wildlife strike risk -general

20. There are many existing locations where there would be advantages in mitigating existing risk. It is also essential that new land uses and changes to land zoning within 13 km of the airport property are regularly monitored and action plans created to mitigate any unacceptable increase in the risk of bird strike. For example, the ICAO document 'Airport Services Manual- Bird Control and Reduction' suggests that dumps should be not be sited within 13km of airport property.

Managing off-airport wildlife strike risk – the role of airport operators and council/land use planning authorities

21. Airport operators should work with local councils (or the relevant land-use planning authority) to establish mechanisms that will identify land uses and prevent the creation of land uses that would cause hazardous wildlife attraction or activity at or across the airport and/or its approaches and departures. This can be accomplished through the following:

- airport operators and land use planning authorities should use the guidance at Attachment 1 as the criteria for deciding on appropriate action in relation to a particular existing or proposed development within a 13 km radius of an aerodrome. Airport operators should conduct ongoing and regular consultation with planning authorities on land uses of concern;
- airport operators should conduct ongoing consultation with bodies such as national /state wildlife and parks management and wetlands management agencies on land uses of concern;
- land use planning authorities should ensure that airport operators are given adequate opportunity to formally comment on planning applications for new or revised land uses that fall within the guidance provided in **Attachment 1**. Airport operators will be expected to respond with comments on how the proposed changes to land use might increase the risk of wildlife strike and on any regulatory actions that could increase the risk of wildlife strike, such as permits related to land uses of concern;
- airport operators should conduct regular outreach/education activities to sensitise relevant stakeholders and the surrounding community to bird strike hazards and land uses that may increase these hazards;
- airport operators should be in a position to provide assistance or advice to relevant stakeholders on bird and wildlife mitigation measures, drawing on knowledge obtained in managing this issue on the airport site; and
- airport operators should include relevant external stakeholders (including, but not limited to, planning authorities, relevant landowners, national /state wildlife and parks

management and wetlands management agencies) on the Airport's Bird and Animal Hazard Management Committee or equivalent group.

22. Airport operators should negotiate with land use planning authorities and land owners if required on agreed action plans for monitoring and, where necessary, reducing wildlife attraction to areas in the vicinity of airports, in accordance with **Attachment 1**. These plans could include:

- regular monitoring surveys;
- wildlife hazard assessments by qualified ornithologists or biologists;
- wildlife awareness and management training for relevant staff;
- establishment of bird population triggers;
- implementation of activities to reduce hazardous bird populations; and
- adoption of wildlife deterrent technologies to reduce hazardous bird populations.

23. Airport operators should maintain files to track all contacts with land use planning authorities regarding land uses near the airport that could attract birds. The log should be used to conduct the reviews below and maintain contact with relevant parties. Under the WHMP, airport operators should consult this log annually to:

- review the status of individual bird attractants sites and any changes required;
- identify existing/potential flyways (regular bird flight paths) between separate bird attractant sites;
- identify measures and on-airport wildlife management procedures that would address risk; and
- document the participants in the review, items discussed and changes identified.
- Airport operators should document the procedures provided here in their WHMP as well as in any relevant documentation required under CASR Part 139, such as the airport's Safety Management System.

Managing risk when new land uses are to be established which increase risk of wildlife strike

24. Where local authorities seek to establish land uses which may increase the risk of wildlife strike near existing airports, steps should be taken to mitigate risk in consultation with the airport operator and qualified bird and wildlife management experts. Risk mitigation measures that should be considered in such cases include:

- a requirement for a Wildlife Management Program;
- the establishment of wildlife management performance standards;
- allowance for changes to design and/or operating procedures at places/plants where land use has been identified as increasing the risk of wildlife strike to aircraft;
- establishment of appropriate habitat management at incompatible land uses;
- creation of performance bonds to ensure clean–up and compensation should obligations not be met;
- authority for airport operators to inspect and monitor properties close to airports where wildlife hazards have been identified; and
- consistent and effective reporting of wildlife events in line with Australian Transport Safety Bureau (ATSB) guidelines.

25. Attached to these guidelines are the following:

- **Attachment 1**: Wildlife attraction risk and actions by land use: This identifies the risk posed by a range of land uses and the actions required , if any.
- **Attachment 2**: Brisbane Airport Buffers: Using Brisbane airport as an example, this is a depiction of the proposed buffers. The shape of the buffers would vary depending on the runway layouts.

Background information on managing the risk of wildlife strike

26. The vast majority of wildlife strikes take place at or close to airports. Almost all involve birds and flying mammals (such as bats and flying foxes). Land animal (mainly terrestrial mammals) strikes are relatively rare and the risk of these has been reduced by the implementation of stringent fencing requirements to keep out unauthorised persons.

27. There would be safety benefits if airport operators and land use planning authorities follow a common, coordinated approach to managing existing wildlife hazards at, and within the vicinity of, airports. Managing wildlife attractants is a key strategy in discouraging wildlife on and around airports.

28. In essence, the guidelines propose distance separation benchmarks between airports and land use practices that attract wildlife species which may be hazardous to aviation. Proposed separation distances based on the radial distances of 3km, 8km and 13 km respectively are proposed. This is consistent with advice from ICAO.

29. The guidelines provide examples of land uses that are acceptable and those that require mitigation measures. In the case of land uses that need to be mitigated, advice regarding appropriate risk mitigation measures is provided.

30. The guidelines recognise that it can be impractical to consider changing existing land use or zoning around established airports which are often located in built up areas and where options for alternative land use can be limited. However, the guidelines allow for improved planning for land uses which may attract wildlife around new airports and new land uses proposed around existing airports.

31. Airport operators already have legislative obligations under aviation safety legislation to manage the risk of on-airport wildlife hazards. They do actively manage and deter wildlife, often reducing wildlife numbers. Given that aviation safety legislation regarding management of wildlife applies only on airport land, there is an opportunity to improve land use management in the vicinity of airports to further minimise the risk of wildlife hazards to aviation.

Land Use	Wildlife Attraction Risk	Actions for Existing Developments			Actions for Proposed Developments/ Changes to Existing Developments		
		3 km radius (Area A)	8 km radius (Area B)	13 km radius (Area C)	3 km radius (Area A)	8 km radius (Area B)	13 km radius (Area C)
Agriculture							
Turf farm	High	Mitigate	Mitigate	Monitor	Incompatible	Mitigate	Monitor
Piggery	High	Mitigate	Mitigate	Monitor	Incompatible	Mitigate	Monitor
Fruit tree farm	High	Mitigate	Mitigate	Monitor	Incompatible	Mitigate	Monitor
Fish processing /packing plant	High	Mitigate	Mitigate	Monitor	Incompatible	Mitigate	Monitor
Cattle /dairy farm	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Poultry farm	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Forestry	Low	Monitor	Monitor	No Action	Monitor	Monitor	No Action
Plant nursery	Low	Monitor	Monitor	No Action	Monitor	Monitor	No Action
Conservation							
Wildlife sanctuary / conservation area - wetland	High	Mitigate	Mitigate	Monitor	Incompatible	Mitigate	Monitor
Wildlife sanctuary / conservation area - dryland	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Recreation							
Showground	High	Mitigate	Mitigate	Monitor	Incompatible	Mitigate	Monitor
Racetrack / horse riding school	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Golf course	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Sports facility (tennis, bowls, etc)	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Park / Playground	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Picnic / camping ground	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Commercial							
Food processing plant	High	Mitigate	Mitigate	Monitor	Incompatible	Mitigate	Monitor
Warehouse (food storage)	Low	Monitor	Monitor	No Action	Monitor	Monitor	No Action
Fast food / drive-in / outdoor restaurant	Low	Monitor	Monitor	No Action	Monitor	Monitor	No Action
Shopping centre	Low	Monitor	Monitor	No Action	Monitor	Monitor	No Action
Office building	Very Low	Monitor	No Action	No Action	Monitor	No Action	No Action
Hotel / motel	Very Low	Monitor	No Action	No Action	Monitor	No Action	No Action
Car park	Very Low	Monitor	No Action	No Action	Monitor	No Action	No Action
Cinemas	Very Low	Monitor	No Action	No Action	Monitor	No Action	No Action
Warehouse (non-food storage)	Very Low	Monitor	No Action	No Action	Monitor	No Action	No Action
Petrol station	Very Low	Monitor	No Action	No Action	Monitor	No Action	No Action
Utilities							
Food / organic waste facility	High	Mitigate	Mitigate	Monitor	Incompatible	Mitigate	Monitor
Putrescible waste facility - landfill	High	Mitigate	Mitigate	Monitor	Incompatible	Mitigate	Monitor
Putrescible waste facility - transfer station	High	Mitigate	Mitigate	Monitor	Incompatible	Mitigate	Monitor
Non-putrescible waste facility - landfill	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Non-putrescible waste facility - transfer station	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Sewage / wastewater treatment facility	Moderate	Mitigate	Monitor	Monitor	Mitigate	Mitigate	Monitor
Potable water treatment facility	Low	Monitor	Monitor	No Action	Monitor	Monitor	No Action

GLOSSARY

Airport operators	These include operators, managers and owners at both regional and major airports.
ATSB	Australian Transport Safety Bureau
CASA	Civil Aviation Safety Authority
Flying mammals	Animals with vertebrae, having the body more or less covered with hair, nourishing the young with milk from the mammary glands, and, with the exception of the egg-laying monotremes, giving birth to live young which are able to fly. For example, bats and flying foxes.
High capacity air transport operations	A high capacity air transport operation involves an aircraft that is certified as having a maximum seating capacity exceeding 38 seats or a maximum payload exceeding 4,200 kg.
ICAO	International Civil Aviation Organization
Land Managers	These include local governments, local planning authorities, state governments, national park/wetland management agencies, private landowners and owners of properties.
SARP	Standards and Recommended Practices
Terrestrial mammals	Animals with vertebrae, having the body more or less covered with hair, nourishing the young with milk from the mammary glands, and, with the exception of the egg-laying monotremes, giving birth to live young which dwell on land. For example, kangaroos and foxes.
WHMP	Wildlife Hazard Management Plan

Revision History

Rev. No	Rev. Date	Details	Prepared by	Reviewed by	Approved by
00	14/08/2015	Preliminary Western Sydney Airport Bird and Bat Strike Risk Assessment	Jeff Follett Snr Wildlife Biologist	Phil Shaw Managing Director	Jeff Follett Snr Wildlife Biologist
01	29/09/2015	Preliminary Western Sydney Airport Bird and Bat Strike Risk Assessment	Jeff Follett Snr Wildlife Biologist		Jeff Follett Snr Wildlife Biologist

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GB243 GHD-RE.Preliminary Western Sydney Airport Bird and Bat Strike Risk Assessment.FI.R1

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VOLUME 4

Appendix J
Surface transport and access





Western Sydney Unit

Western Sydney Airport EIS

Surface Transport and Access Study

October 2015

Limitations

GHD has prepared this report pursuant to the conditions in the Department of Infrastructure and Regional Development Deed of Standing Quotation (SON2030181), the Commonwealth RFQTS Number 2014/7540/001, the subsequent response accepted and referenced in the relevant Official Order (collectively the "Contract"):

In particular, this report has been prepared by GHD for the Commonwealth (and to the extent expressly stated in the Contract (and for the purposes stated therein) the parties referred to in the Contract ("Other Parties") and may only be used and relied on by the Commonwealth and the Other Parties in accordance with the Contract for the purpose agreed between GHD and the Commonwealth as set out in the Contract.

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The services and the purpose undertaken by GHD under the Contract in connection with preparing this report were limited to those specifically detailed in the Contract and this report and are subject to the scope limitations set out in the Contract and this report.

Other than as expressly stated in this report to the contrary, the opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

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Executive summary

Introduction

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

This Assessment

This report has been prepared for inclusion in the EIS. It provides an assessment of the traffic and transport impacts during the operational and construction stages of the proposed Western Sydney Airport (WSA) and identifies mitigating measures necessary to address identified impacts. It focuses on the traffic implications from the proposed initial stage development and the longer term development on the surrounding road network.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.4 and the assumptions and qualifications contained throughout the report.

The periods considered in this traffic and transport impact assessment were the following:

- Construction – approximately 2016 - 2024
- Initial (Stage 1) airport development – assessed as occurring in 2031
- Longer term airport development – assessed as occurring in 2063.

The key findings of this traffic and transport assessment are outlined as following sections.

Existing conditions and planned infrastructure developments

The existing land use in the vicinity of the airport site is generally rural/agricultural, consisting mainly of farming land and residential properties. However, significant urban development is expected in Western Sydney in the coming years, especially in the areas designated by the NSW Government for growth, such as the South West Priority Growth Area (which lies adjacent to the airport site) and the Broader Western Sydney Employment Area.

The existing traffic volumes on the surrounding road network are within the expected functional classification outlined by NSW Roads and Maritime Services, as the majority of roads in proximity to the proposed airport are arterial roads.

The Australian and NSW government's Western Sydney Infrastructure Plan (WSIP) is investing more than $3.5 billion over 10 years in major road infrastructure upgrades to capitalise on the economic gains from the proposed airport development at Badgerys Creek. This package of works is expected to increase the capacity of the region to handle future traffic growth. In addition, the future development of the Broader Western Sydney Employment Area and South West Priority Growth Area will result in significant upgrades to road and transport infrastructure.

The surrounding transport system is currently being upgraded by the Australian and NSW governments through the WSIP. Road infrastructure works are proposed to be undertaken in preparation for the airport and include major road upgrades on the following roads:

- The Northern Road;
- Bringelly Road;
- Cowpastures Road;
- Camden Valley Way;
- Narellan Road;
- M4 with development of a managed motorway system; and
- M12 motorway, broadly along the current Elizabeth Drive alignment.

Pedestrian and cycling infrastructure is provided within the study area but is currently very limited.

Construction

The construction of the proposed WSA would generate an additional 1,254 vehicle movements per day on the surrounding road network during the construction period. This equates to around 314 peak hour vehicle movements which would occur during the morning traffic peak period on the surrounding road network.

The construction stages for the airport would not impact significantly on the surrounding transport system with the exception of potential oversized vehicle movements for the earthworks. These movements may require temporary road closures or police escorts.

A Construction Transport Management Plan (CTMP) would be developed by the construction contractor for approval by the Department of Infrastructure and Regional Development and NSW Roads and Maritime Services. The CTMP would provide the overall plan and staging for managing traffic through and around each work site.

An important measure relating to construction traffic impacts is the implementation of a community information awareness program. This program would be initiated prior to construction commencing and throughout the entire construction period to ensure that local residents are aware of the construction traffic issues, with particular regard to diversions, temporary road closures, traffic signalling and speed limits.

Initial airport development – key features

The main access to the airport site from the north would be via the new M12 Motorway that would generally run parallel to Elizabeth Drive. It is expected to include a grade separated interchange for vehicular access to the proposed airport. The proposed access corridors within the airport site will be 100 m wide comprising of six traffic lanes, two bus lanes and a 40 metre rail reserve corridor (including provision for station(s) within the corridor).

Access to the airport site from the south-west would be via The Northern Road, which would be relocated and upgraded prior to the commencement of operations. This access point is anticipated as being primarily for secure commercial access to operational areas of the site, including cargo and maintenance. This access road into the site is expected to consist of a 50 metre wide corridor allowing four trafficable lanes.

Parking for at least 11,500 vehicles would be provided, consisting of short and long stay parking, employee and operational parking, commercial vehicle parking and storage, parking for rental cars and emergency services vehicle parking.

Pedestrian and cycle access would be included in the Terminal and Ground Transport precincts and parking areas, and pedestrian and cycle routes will be provided throughout the airport site.

Initial airport development operational impact assessment

This surface transport assessment has used 2031 as the design year for the assessment of future impacts resulting from the proposed initial airport development. The year 2031 has been used in this study because it represents a midpoint between the current available traffic and transport models for Sydney, which includes the years 2026 and 2036. For the purpose of this analysis, it is assumed that the proposed airport rail link is not operational before 2036.

The following key findings concerning passenger and employee trip generation and freight trip generation were identified:

- the daily passenger and employee vehicle trip generation is 22,134 vehicles to the proposed airport and 24,857 vehicles from the airport;
- the peak passenger and employee vehicle demand to the proposed airport is between 7:00 and 8:00 AM and is 2,406 vehicles per hour;
- the peak passenger and employee vehicle demand away from the proposed airport is between 6:00 and 7:00 PM and is 2,429 vehicles per hour;
- a daily freight vehicle trip generation of 20,922 vehicles to the proposed airport and 20,936 vehicles from the airport;
- the freight AM peak (2 hour) vehicle demand is 3,966 to the proposed airport and 2,295 from the airport; and
- the freight PM peak (2 hour) vehicle demand is 1,905 to the airport and 2,117 from the airport.

The introduction of the proposed airport and the M12 has the following effects on the capacity of the major road network:

- a small increase in congestion on the Northern Road and the M4 at the intersection of the two roads; and
- a small increase in congestion on Mamre Road.

The public transport and walking and cycling systems proposed by the NSW Government and local councils and identified in Chapter 5 would also have sufficient capacity to cater for the expected passenger and employee demand of the proposed airport.

From the analysis contained within this study, it can be concluded that initial operation of the proposed airport would not impact significantly the surrounding transport system as planned.

Longer term development operational impact assessment

For assessment purposes in the EIS, the design year for the assessment of future impacts resulting from the longer term development of the proposed airport was 2063.

The following key findings concerning passenger and employee trip generation and freight trip generation were identified:

- a daily passenger and employee road vehicle trip generation of 87,575 vehicles to the proposed airport and 102,785 vehicles from the airport, with 242 trains per day;
- the peak passenger and employee vehicle demand to the proposed airport is between 7 and 8 AM and is 13,122 vehicles per hour;
- the peak passenger and employee vehicle demand away from the proposed airport is between 6 and 7 PM and is 17,382 vehicles per hour;
- a daily freight vehicle trip generation of 85,077 vehicles to the airport and 85,291 vehicles from the proposed airport;
- peak AM (2 hour) vehicle demand is 12,201 to the proposed airport and 7,914 from the airport; and
- peak PM (2 hour) vehicle demand is 10,263 to the proposed airport and 10,753 from the airport.

Given the time horizon being forecast and that there is no available information from either the NSW or Australian governments concerning long term road or transport infrastructure upgrades beyond 2041, the assessment of the impact of public transport is limited to the forecast reduction in traffic volumes as a consequence of the proposed rail line from Leppington to St Marys via the proposed airport.

As demonstrated, the long term operations of the proposed airport and forecast development growth in Western Sydney would have a significant combined impact on both the roads and transport systems

The longer term airport operations would be reliant on the introduction of the South West Rail Link extension after 2031. Even with the South West Rail Link extension, the assessed increases in demand vs capacity for 2063 show that detailed planning is required to preserve additional corridors and transport upgrades to cater for the population and development growth associated with the proposed airport and urban development.

It is recommended that more detailed planning is commenced to address this envisioned capacity shortfall such that potential future upgrades are not constrained by encroachment from surrounding development.

Table of contents

Executive Summary i

1. Introduction 1
   - 1.1 Background 1
   - 1.2 Study area 2
   - 1.3 Purpose and structure of this report 2
2. Methodology 5
   - 2.1 Scope 5
   - 2.2 Data sources 5
   - 2.3 Modelling methodology 6
   - 2.4 Assessment criteria 9
3. Existing environment 11
   - 3.1 Existing road network characteristics 11
   - 3.2 Existing daily traffic volumes 16
   - 3.3 Daily traffic profiles 16
   - 3.4 Existing network peak period performance 18
   - 3.5 Public transport 23
   - 3.6 Pedestrian and cycle facilities 26
   - 3.7 Crash statistics 28
   - 3.8 Key findings 32
4. Construction traffic assessment 33
   - 4.1 Overview 33
   - 4.2 Construction methodology 33
   - 4.3 Construction programme 34
   - 4.4 Estimated workforce 34
   - 4.5 Hours of work 34
   - 4.6 Key access routes to/from site 35
   - 4.7 Construction traffic impacts 37
   - 4.8 Road network performance 38
   - 4.9 Construction mitigation measures 42
   - 4.10 Key findings 43

Part A – Assessment of the initial airport development 45

5. Airport facilities and road network conditions 47
   - 5.1 Airport access 47
   - 5.2 Airport parking 47
   - 5.3 Pedestrian and cycling facilities 48
   - 5.4 Future road network conditions 48
   - 5.5 Local road network improvements 51
   - 5.6 Public transport 52

5.7 Pedestrian and cycling facilities 54
6. Trip generation 55
6.1 Introduction 55
6.2 Passenger trip generation 56
6.3 Employee trip generation 70
6.4 Combined air passenger and employee trip generation 78
6.5 Total air passenger and employee traffic generation 79
6.6 Freight trip generation 82
6.7 Total airport traffic generation estimate 82
6.8 Airport traffic distribution 83
7. Operational impact assessment 85
7.1 Background traffic growth 85
7.2 Future road network performance 86
7.3 Impacts on roads and access 93
7.4 Key findings 93
Part B – Assessment of the longer term airport development 95
8. Airport facilities and road network conditions 96
8.1 Airport access 96
8.2 Road network improvements 96
8.3 Public transport 96
8.4 Pedestrian and cycling facilities 98
9. Trip generation 100
9.1 Introduction 100
9.2 Passenger trip generation 100
9.3 Employee trip generation 110
9.4 Combined air passenger and employee trip generation 115
9.5 Total air passenger and employee traffic generation 116
9.6 Freight trip generation 118
9.7 Total traffic trip generation estimate 119
9.8 Airport traffic distribution 120
10. Operational impact assessment 121
10.1 Background traffic growth 121
10.2 Future road network performance 122
10.3 Impacts on roads and access 124
10.4 Public transport impacts 129
10.5 Key findings 129
11. Summary and conclusions 131
11.1 Existing conditions 131
11.2 Construction traffic impact 131
11.3 Initial airport development 131

11.4 Operational assessment of the proposed initial airport development....132
11.5 Operational assessment of the indicative longer term airport development....133
12. References....135

Table index

Table 2-1 Level of service descriptions for roads....10
Table 3-1 Historical two-way daily traffic volumes - 2005....16
Table 3-2 Elizabeth Drive – historical traffic volumes (AADT)....16
Table 3-3 Elizabeth Drive - historical traffic growth rate (AADT)....16
Table 3-4 Existing daily traffic volumes - 2015....17
Table 3-5 Level of Service for 2011 Existing Network....19
Table 4-1 Peak on site construction personnel....34
Table 4-2 Access gates to airport site....35
Table 4-3 Peak construction vehicle generation....37
Table 4-4 Level of Service for 2021 With and Without Construction Traffic....39
Table 5-1 Estimated parking capacity requirements....48
Table 5-2 Future road network changes by 2031....50
Table 6-1 Daily flight movements 2031....56
Table 6-2 Peak hour flight movements 2031....57
Table 6-3 2031 assumed mode split....63
Table 6-4 2031 assumed dwell times by mode....63
Table 6-5 Airport employment characteristics – USA airports....71
Table 6-6 WSA assumed 2031 shift profiles....72
Table 6-7 Employee mode split for areas adjacent to WSA in 2011....75
Table 6-8 2031 freight vehicle expansion factors....82
Table 6-9 2031 two-way freight truck movements....82
Table 6-10 Total modelled traffic to/from the proposed airport in 2031....83
Table 7-1 Level of Service for 2031 With and Without Western Sydney Airport....90
Table 9-1 Daily flight movements 2063....100
Table 9-2 Peak hour flight movements 2063....100
Table 9-3 2063 assumed mode split....103
Table 9-4 2063 assumed dwell times by mode....103
Table 9-5 Proposed WSA assumed 2063 shift profiles....110
Table 9-6 2063 freight vehicle expansion factors....119
Table 9-7 2063 two-way freight truck movements....119

Table 9-8 Total modelled trips to/from the proposed airport in 2063 119
Table 10-1 Level of Service for 2063 With and Without Western Sydney Airport 126

Figure index

Figure 1-1 Regional location of the Western Sydney Airport 2
Figure 2-1 Modelling methodology 6
Figure 3-1 Major road network around Western Sydney Airport 12
Figure 3-2 Map of existing roads in and around the airport site 14
Figure 3-3 Map of land use surrounding the airport development site 15
Figure 3-4 Traffic profile at The Northern Road north of Bringelly Road 17
Figure 3-5 Traffic profile at The Northern Road south of Bringelly Road 17
Figure 3-6 Traffic profile at Bringelly Road east of The Northern Road 18
Figure 3-7 Location of Tabulated Level of Service output 20
Figure 3-8 2011 AM Peak Volume/Capacity - existing conditions 21
Figure 3-9 2011 PM Peak Volume/Capacity - existing conditions 22
Figure 3-10 Bus services within study area 25
Figure 3-11 Cycling infrastructure within study area 27
Figure 3-12 Location of crashes (last five years) 29
Figure 4-1 Key site access routes 36
Figure 4-2 Volume/Capacity (AM Peak) in 2021 without (left) and with construction traffic (right) 40
Figure 4-3 Volume/Capacity (PM Peak) in 2021 without (left) and with construction traffic (right) 41
Figure 5-1 Western Sydney Infrastructure Plan 49
Figure 5-2 Proposed bus routes 53
Figure 6-1 Passenger trip generation and mode assignment 55
Figure 6-2 Employee trip generation 56
Figure 6-3 Synthesized 2031 daily flight profile 57
Figure 6-4 Assumed landside arrival – percentage of passengers 58
Figure 6-5 Assumed landside departure profile – percentage of passengers 58
Figure 6-6 Landside arrival profile for passengers – volumes 59
Figure 6-7 Landside departure profile for passengers – volumes 59
Figure 6-8 Two minute passenger ground transport demand - 2031 60
Figure 6-9 2031 ground transport demand per hour 60
Figure 6-10 Airport taxi movements 61

Figure 6-11 Domestic air departures – ground arrival at the proposed airport 64
Figure 6-12 Domestic air arrivals – ground departure from the proposed airport 64
Figure 6-13 International air departures – ground arrival at the proposed airport 65
Figure 6-14 International air arrivals – ground departure from the proposed airport 65
Figure 6-15 Total air departures – ground arrival at the proposed airport 66
Figure 6-16 Total air arrivals – ground departure from the proposed airport 66
Figure 6-17 Passenger vehicles entering at the northern boundary of the proposed airport by mode 67
Figure 6-18 Passenger vehicles exiting at the northern boundary of the proposed airport by mode 67
Figure 6-19 Passenger vehicles entering at the northern boundary of the proposed airport by vehicle type 68
Figure 6-20 Passenger vehicles exiting at the northern boundary of the proposed airport by vehicle type 68
Figure 6-21 Passenger vehicles arriving at terminal and car park entrances 69
Figure 6-22 Passenger vehicles leaving the terminal and car park exits 69
Figure 6-23 Employee arrival and departure profile - percentage 73
Figure 6-24 Employee arrival and departure profile - volume 73
Figure 6-25 Sydney (Kingsford-Smith) Airport employee mode split 74
Figure 6-26 2031 employee mode split by time of day 75
Figure 6-27 Employee arrivals by mode by time of day 76
Figure 6-28 Employee departures by mode by time of day 76
Figure 6-29 2031 employee vehicle arrivals by mode 77
Figure 6-30 2031 employee vehicle departures by mode 77
Figure 6-31 Total arrival trip generation by mode 78
Figure 6-32 Total departure trip generation by mode 78
Figure 6-33 Mode split across the day 79
Figure 6-34 Traffic generation to the main entrance of the proposed airport by mode 80
Figure 6-35 Traffic generation from the main entrance of the proposed airport by mode 80
Figure 6-36 Traffic generation to the main entrance of the proposed airport by vehicle type 81
Figure 6-37 Traffic generation from the main entrance of the proposed by vehicle type 81
Figure 7-1 Statistical areas in the vicinity of the airport site 85
Figure 7-2 Vehicle movements originating within surrounding SA3 (24 hour) 86
Figure 7-3 Traffic volume difference plot 2031 with Proposed Airport – 2031 Do Minimum AM Peak 87
Figure 7-4 Traffic volume difference plot 2031 with Proposed Airport – 2031 Do Minimum PM Peak 88
Figure 7-5 Location of Tabulated Level of Service output 89

Figure 7-6 2031 AM Peak Volume/Capacity - Do Minimum (Left), with Proposed Airport (Right) 91
Figure 7-7 2031 PM Peak Volume/Capacity - Do Minimum (Left), with Proposed Airport (Right) 92
Figure 8-1 Southwest Rail Link extension and Badgerys Creek Airport 97
Figure 8-2 South West Priority Growth Area Structure Plan 98
Figure 8-3 Proposed BWSEA bicycle network 99
Figure 9-1 Synthesized 2063 daily flight profile 101
Figure 9-2 Two minute ground passenger transport demand - 2063 101
Figure 9-3 2063 ground transport demand per hour 102
Figure 9-4 Domestic air departures – ground arrival at the proposed airport 104
Figure 9-5 Domestic air arrivals – ground departure from the proposed airport 104
Figure 9-6 International air departures – ground arrival at the proposed airport 105
Figure 9-7 International air arrivals – ground departure from the proposed airport 105
Figure 9-8 Total air departures– ground arrival at the proposed airport 106
Figure 9-9 Total air arrivals – ground departure from the proposed airport 106
Figure 9-10 Passenger vehicles entering at the northern airport boundary by mode 107
Figure 9-11 Passenger vehicles exiting at the northern airport boundary by mode 107
Figure 9-12 Passenger vehicles entering at the northern boundary by vehicle type 108
Figure 9-13 Passenger vehicles exiting at the northern boundary by vehicle type 108
Figure 9-14 Passenger vehicles arriving at the terminal and car park entrances 109
Figure 9-15 Passenger vehicles leaving at the terminal and car park exits 109
Figure 9-16 Employee arrival and departure profile - percentage 111
Figure 9-17 Employee arrival and departure profile - volume 111
Figure 9-18 2063 employee mode split by time of day 112
Figure 9-19 Employee arrivals by mode by time of day 113
Figure 9-20 Employee departures by mode by time of day 113
Figure 9-21 2063 employee vehicle arrivals by mode 114
Figure 9-22 2063 employee vehicle departures by mode 114
Figure 9-23 Total arrival trip generation by mode 115
Figure 9-24 Total departure trip generation by mode 115
Figure 9-25 Mode split across the day 116
Figure 9-26 Traffic generation to the main airport entrance by mode 116
Figure 9-27 Traffic generation from the main airport entrance by mode 117
Figure 9-28 Traffic generation to the main airport entrance by vehicle type 117
Figure 9-29 Traffic generation from the main airport entrance by vehicle type 118
Figure 10-1 Vehicle movements originating within SA3 (24 hour) 121

Figure 10-2 2063 AM Peak Traffic Volume Difference plot (2 hour) 123
Figure 10-3 2063 PM Peak Traffic Volume Difference plot (2 hour) 124
Figure 10-4 Location of Tabulated Level of Service output 125
Figure 10-5 2063 AM Peak Volume/Capacity - Do Minimum (Left), with proposed Airport (Right) 127
Figure 10-6 2063 PM Peak Volume/Capacity - Do Minimum (Left), with proposed Airport (Right) 128

Appendices

Appendix A - Traffic Volumes

Appendix B – Crash data

Appendix C – Initial airport development traffic generation

Appendix D – Longer term airport development traffic generation

Glossary and abbreviations

Term	Usage
ABS	Australian Bureau of Statistics
AM	Ante Meridiem
ART	Articulated Vehicles
BTS	Bureau of Transport Statistics
BWSEA	Broader Western Sydney Employment Area
CBD	Central Business District
CCTV	Closed-circuit television
CTMP	Construction Traffic Management Plan
Do Minimum	This is the minimum transport network improvements required to maintain the status quo on the road network around the airport site without the proposed project
EIS	Environmental Impact Statement
HTS	Household Travel Surveys
Interpeak	The time period between the AM and PM peak periods
Kiss ‘n’ Fly	Air passenger trips involving a car dropping or picking up air passengers with minimal stopping time at the airport.
JTW	Journey to Work
LCV	Light Commercial Vehicles
LGA	Local Government Area
Longer term development	A future stage in the development of the proposed airport, where the airport is assumed to comprise parallel runways and is capable of handling approximately 82 million passengers annually. The EIS assumes this occurs in 2063 for assessment purposes.
Mitigation	Reduction in severity
NSW	New South Wales
Park ‘n’ fly	A trip type where one air passenger drives a car to the airport and it is stored in a car park until the passenger returns to the airport
PCU	Passenger Car Unit
PM	Post Meridiem
RAAF	The Royal Australian Air Force
RIG	Rigid Vehicles
RMS (formerly NSW RTA)	NSW Roads and Maritime Services
SALTM	Sydney Airport Land Use Transport Model
Shuttle	A small bus capable of carrying up to 30 passengers direct to the airport from a major centre

Term	Usage
Stage 1 (or initial) development	The initial stage in the development of the proposed airport, including a single runway and the capacity to handle approximately 10 million passengers annually. The EIS assumes for assessment purposes that airport operations commence in 2025 and the number of annual passengers reaches 10 million in 2030.
STM3	The Strategic Sydney Travel Model version 3
SWGC	Southwest Growth Centre
TfNSW	Transport for New South Wales
USA	United States of America
VPD	Vehicles Per Day
WSA	Western Sydney Airport
WSIP	Western Sydney Infrastructure Plan
WSU	Western Sydney Unit

1. Introduction

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the Joint Study on Aviation Capacity in the Sydney Region (Department of Infrastructure and Transport 2012) and A Study of Wilton and RAAF Base Richmond for civil aviation operations (Department of Infrastructure and Transport 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek would be the location of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth between 1986 and 1991. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The airport would service both domestic and international air traffic, with development staged in response to passenger demand. The initial development of the airport would include a single 3.7 km runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million domestic and international passengers per year. In the longer term, approximately 40 years after the airport has commenced operations and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and rail transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a curfew free basis. Consistent with the practice at all federally leased airports; non-aeronautical commercial uses could be permitted on the site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment and approval in accordance with the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015.

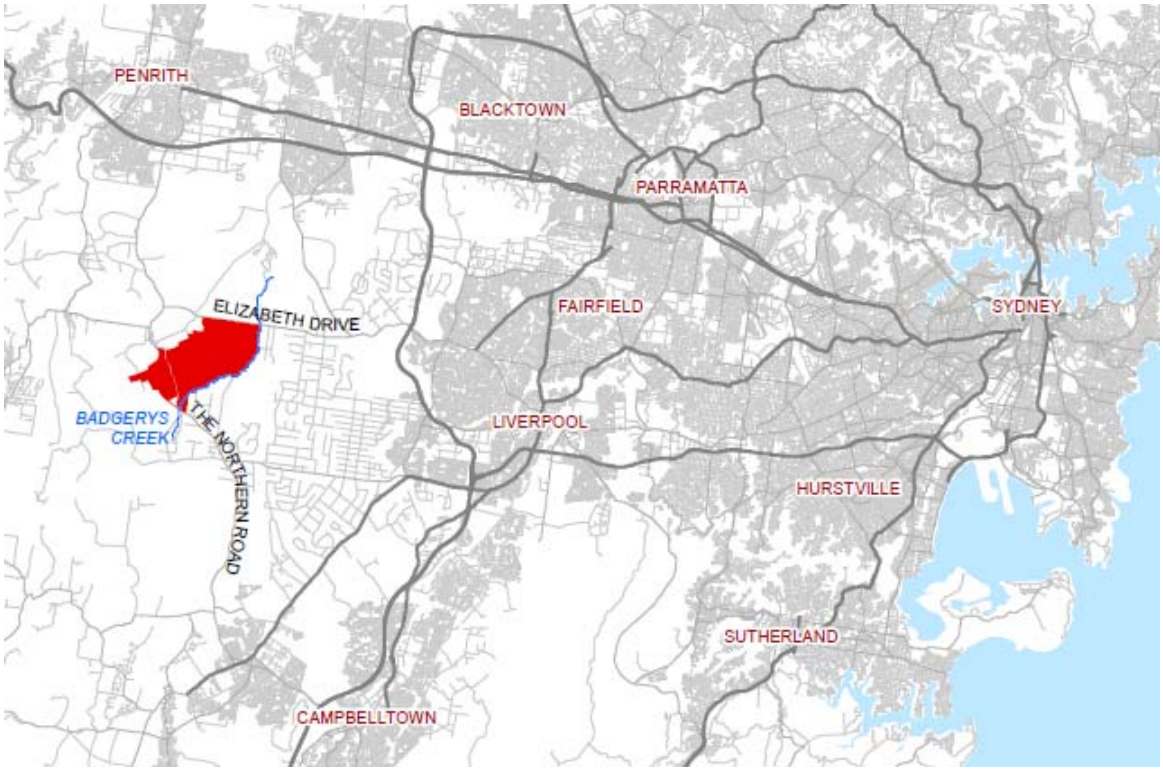
The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the new airport, including the development of an airport plan. The draft airport plan is the primary source of reference for the EIS. The draft airport plan identifies a staged development of the airport. It provides details of the initial development being authorised (referred to as Stage 1) as well as details of potential future stages of the airport's development which enable preliminary consideration of the implications of long term airport operations. Any stages of airport development beyond the initial stage would be managed in accordance with the existing process in the Commonwealth *Airports Act 1996*. This includes a requirement that for major developments (defined in the Airports Act) a major development plan be developed for approval by the Infrastructure Minister following a referral under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

The airport plan will be required to include any conditions notified by the Environment Minister following the EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities under the relevant legislation.

1.2 Study area

The proposed Western Sydney Airport (WSA) is located approximately 56 km from the centre of Sydney and is bounded by Elizabeth Drive to the north, Willowdene Avenue to the south, Luddenham and Adams Road to the west, Badgerys Creek to the east. The Northern Road currently cuts across the south-western side of the site but will be relocated off site to allow the proposed development to proceed. The airport is around 1,700 hectares and its regional location is shown in Figure 1-1.

Figure 1-1 Regional location of the Western Sydney Airport



Source: GHD

1.3 Purpose and structure of this report

This report has been prepared to meet the requirements of the EIS Guidelines (EPBC 2014/7391). In relation to surface transport, the guidelines require assessment of:

(Section 5g): "….changes in traffic movements during construction and operation (associated with both passenger movements and workers)".

The report focuses on the traffic implications of both the initial stage and the longer term development of the proposed airport on the surrounding transport network. This report focuses on the peak periods during these years of assessment and the overall effect on the NSW local and regional road network, public transport and pedestrian and cycling facilities.

The report does not consider in detail the existing internal road network and planned transport network within the proposed airport as this is subject to confirmation as the design is developed.

The remainder of this report is structured as follows:

- **Section 2 - Methodology**: describes the key steps undertaken in the assessment including key data sources, modelling methodology and assumptions.
- **Section 3 - Existing Environment**: this section provides a review of existing road features, adjacent developments, traffic volumes, sight distances and historical crash data.
- **Section 4 - Construction traffic assessment**: this section details the additional traffic generated as a result of construction of the proposal including expected construction traffic access routes. An assessment of the likely impact of construction traffic on the surrounding transport network is provided.

Part A Initial airport development:

- **Section 5 – Key development components and assumed road network conditions**: provides a description of the key Stage 1 airport and transport infrastructure including proposed access arrangements and internal transport infrastructure.
- **Section 6 – Trip generation**: describes the methodology for and presentation of the calculation of the trips generated by the initial development.
- **Section 7 – Operational traffic assessment**: examines the potential traffic and transport impacts associated with the operation of the project in the design year 2031 (approximately five years after opening).

Part B Longer term airport development

- **Section 8 – Key development components and assumed road network conditions**: provides a description of the key longer term airport and transport infrastructure including proposed access arrangements and internal transport infrastructure.
- **Section 9 – Trip generation**: describes the methodology for and presentation of the calculation of the trips generated by the longer term airport development.
- **Section 10 – Operational traffic assessment**: examines the potential traffic and transport impacts associated with the operation of the proposed project in the design year 2063.

2. Methodology

This section outlines the methodology and evaluation criteria used in the assessment of both the initial stage airport development and the longer term development.

2.1 Scope

The scope of this report is to meet the relevant requirements of the *EIS Guidelines – Western Sydney Airport EPBC 2014/7391* dated 22 January 2015. These are to address:

(Section 5g): "….changes in traffic movements during construction and operation (associated with both passenger movements and workers)".

Therefore this report provides an assessment of traffic and transport impacts during the following stages:

- construction – analysed years 2016 – 2026;
- initial stage development – assessment year 2031; and
- longer term development – assessment year 2063.

The construction stage focuses on the traffic implications from haulage of material required by the proposed project along the road network, and the transporting of plant, equipment and vehicular traffic generated by construction employees. The report focuses on the peak construction during this period and the overall effect on the higher order road network.

The analysis year for the proposed initial stage was determined as a midpoint between the current available traffic and transport models for Sydney. These models are developed based on the following years: 2011, 2016, 2021, 2026, 2036, 2041 and 2063. By adopting the year 2031 for assessing the proposed initial stage development, this study differs from other Stage 1 studies conducted to inform the EIS, which are based on the year 2030. The use of traffic demand forecasts for the year 2031 provides a consistent basis for comparing outputs from this assessment with other studies utilising the Sydney Strategic Travel Model (see sections 2.2 and 2.3 below) and does not affect the general conclusions about the proposed airport's impacts on traffic volumes and road capacities compared to a year 2030 scenario.

The analysis of impacts of the proposed longer term airport development is based on the year 2063. There is no published information about Western Sydney's transport system for this time. Therefore the 2063 traffic and transport models developed by the Transport for NSW Bureau of Transport Statistics apply transport demand data based on 2063 land use and population assumptions onto a 2041 transport system.

2.2 Data sources

The investigation and analysis of impacts was undertaken at a desktop level. The desktop assessment included the collection and review of the following relevant information:

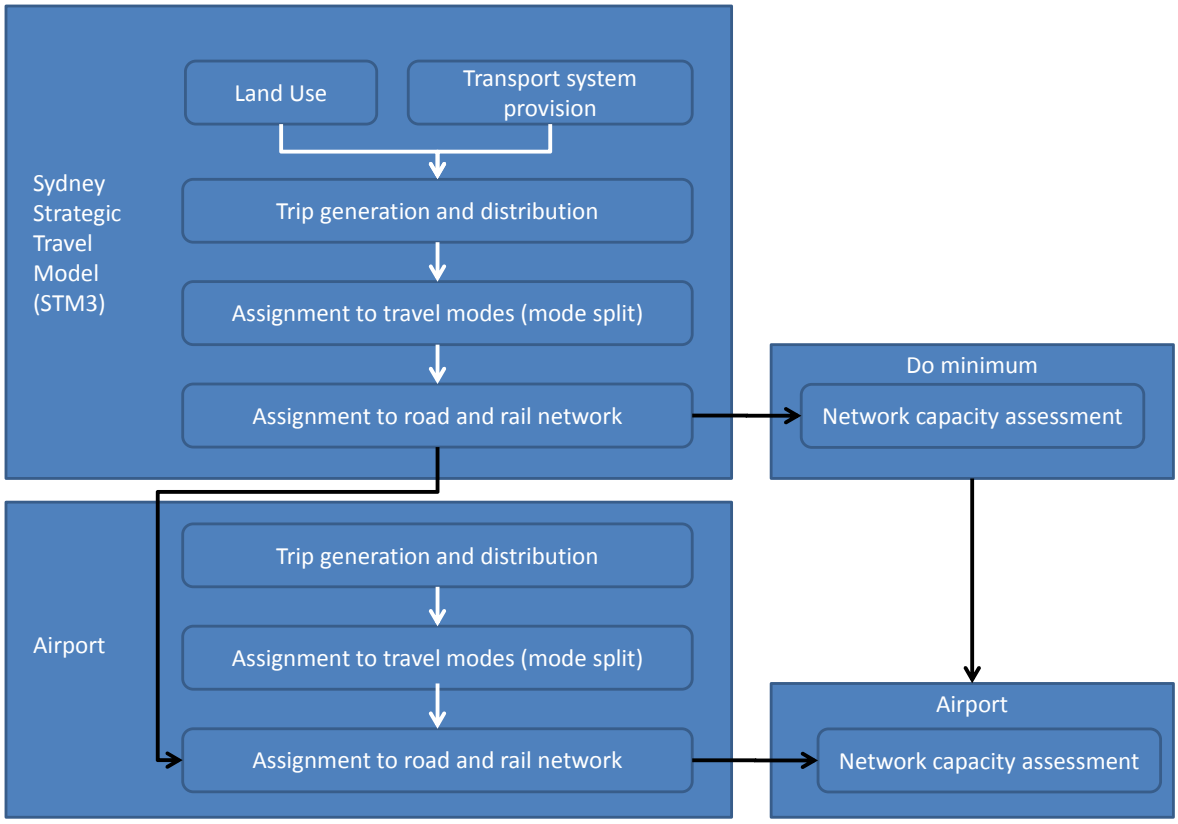
- Aerial photography and other GIS mapping information.
- Traffic count data for the study area (as defined in section 1.2) obtained from the NSW Roads and Maritime Services (Roads and Maritime).
- Roads and Maritime crash data for state and local authority controlled roads in the study area.
- Sydney Airport Land Transport Model (SALTM).
- Airport Cooperative Research Program (Transportation Research Board).

- US Customs and Border Protection clearance time data.
- US Transportation Security Administration security screening clearance times.
- Sydney Strategic Travel Model v3 (STM3), provided by Transport for NSW for a number of forecast years and modelling scenarios:
    - 2011 Standard (no specific adjustment for Western Sydney or Western Sydney Airport).
    - 2021 Standard (no specific adjustment for Western Sydney or Western Sydney Airport).
    - 2026 Western Sydney with Western Sydney Airport (WSAr02).
    - 2036 Western Sydney with Western Sydney Airport (WSAr02).
    - 2063 Western Sydney with Western Sydney Airport (WSAr02).

2.3 Modelling methodology

The method for undertaking the assessment of the proposed airport using the Sydney Strategic Travel Model with the trip generation from Western Sydney Airport is shown in Figure 2-1.

Figure 2-1 Modelling methodology



2.3.1 Sydney Strategic Travel Model overview

The STM (Strategic Travel Model) is a tool developed by the Transport for NSW Bureau of Transport Statistics to project travel patterns in the Sydney Greater Metropolitan Area (GMA).

STM uses land use forecasts in the form of population and employment projections by travel zone combined with a detailed representation of the road and public transport networks in the GMA to assess the impact of growth and trip making behaviour on transport infrastructure and vice versa.

The STM is underpinned by a series of behavioural models, derived from observed data such as the Household Travel Survey (HTS) and Journey to Work (JTW) data,

In common with most strategic travel models globally, there are, broadly speaking, four stages of analyses required to develop travel demand forecasts:

1. Trip generation, or travel frequency – that is, given the demographics and land uses of a given travel zone, how many trips to and from this zone will occur.
2. Trip distribution (where will these trips go).
3. Mode choice (how will they get there - car, bus, rail, ferry or a combination)
4. Assignment (route chosen for each trip, for each mode, between each origin-destination pair). This stage provides the detail for the number of vehicles on each road and people on each public transport service.

The STM3 is the latest iteration of the STM. The STM3 models detailed in section 2.2 have been used as the foundation of the traffic impact assessment.

2.3.2 Traffic impact assessment methodology

The traffic impact assessment has focussed on the 'assignment' stage of the STM outlined above. That is, complete 4-stage model runs have not been undertaken. Instead, revised traffic assignments have been carried out, making best use of the existing information available, while enabling representation of the greater level of detail available to the EIS team regarding the proposed airport and surrounding infrastructure.

The following changes have been made to the models for the specific purpose of this assessment:

- removal of trips destined for proposed airport travel zones in the STM model. This constitutes the demand for the 'Do Minimum' scenarios in 2031 and 2063, used to ascertain the impact of the airport above the other development forecast for Western Sydney;
- use of revised numbers of trips originating in and destined for the airport site for cars, light goods, rigid and articulated vehicles. This represents:
    - construction traffic in 2021 (see section 4.9 for further details)
    - initial stage development operational traffic in 2031 (see section 7.1 for further details)
    - longer term operational traffic in 2063, with and without rail (see section 10.1 for further details);
- additional road infrastructure in the form of the proposed M12 and connections, running generally parallel to Elizabeth Drive and providing direct motorway grade access to the proposed airport (see section 5.5.3 for further details). It is assumed that the proposed M12 will be operational when the proposed airport is operational, so is included in all 'with Airport' model scenarios; and
- implicit within the calculation of vehicle trips coming from and to the proposed airport in the 2063 scenario is the presence of a railway line extension from Leppington in the east, linking the airport with St Marys to the north).

Following the above alterations, the revised road vehicle demand is reassigned to the revised road network. This is conducted in a manner consistent with a standard STM3 assignment, in two stages:

- a separate assignment of heavy vehicle demands is undertaken first, segmented into different mass and length classes (light commercial vehicles, rigid vehicles and articulated vehicles), with the resulting volumes used as a 'preload' onto the road network; and
- an assignment of the car-based demand, segmented into those willing to pay tolls on the motorway network and those that are not willing.

For each model scenario, four two-hour time periods are assigned. These time periods are representative of the AM peak (07:00-09:00), Interpeak (09:00 – 15:00), PM peak (15:00 – 18:00) and Evening peak (18:00 – 07:00). Combining and factoring these volumes allows a 24 hour weekday volume to be calculated.

However, the network exhibits the most capacity constraint in the AM and PM peaks. Analysis of the network capacity in this report has therefore been restricted to these periods. All time periods are used to calculate 18-hour and 24-hour traffic volumes, for use by other disciplines, such as the noise and air quality assessments.

Traffic volumes are presented in passenger car units (pcu). Trip generation calculations are carried out using vehicles. STM3 converts from vehicles to pcu using the following factors:

- light commercial vehicles (LCV) factor equal to 1.2
- rigid vehicles (RIG) factor equal to 2
- articulated vehicles (ART) factor equal to 4 for semi-trailers and 5 for B-Doubles.

Therefore, for example, it is considered that an articulated vehicle takes up the equivalent road space of four cars.

2.3.3 Modelling assumptions

The trip generation and traffic generation for the proposed airport have been synthesised based on the Sydney Airport Land Use Transport Model (SALTM). This model describes the types of trips to Sydney (Kingsford Smith) Airport and is based on surveys completed in 2008.

From this model and recent developments in airport practice, such as self-check-in and bag drop-off and security clearance times, certain assumptions have been made about the initial and longer term operations of the proposed airport.

These assumptions include:

- passenger arrival and departure profiles for landside transportation will compact – i.e. people will arrive at the proposed airport closer to their flight departure time and depart from the airport more quickly;
- the main access road for the proposed airport is limited to three traffic lanes in each direction and one bus lane in each direction. This will act as a capacity constraint over the longer term resulting in a shift away from cars towards public transport.

Strategic traffic modelling has been undertaken to assess the impact of the proposed airport development. STM3 models were provided by Transport for NSW for this task. The models are currently in development by Transport for NSW. However, due to the time constraints for the Western Sydney Airport EIS, GHD has used the latest available versions as the basis for the analysis in this study. GHD has not reviewed or corroborated the models provided beyond consistency checks of outputs.

The road and public transport networks for Do Minimum modelling scenarios is consistent with assumptions made in the STM3 models adopted (see section 2.2). Note that a representation of the M12 was not included in these models.

The M12 motorway is assumed to be present in each 'with Airport' scenario. The assumed form of the M12, in terms of its capacity and connectivity should be considered to be indicative and has not been checked for feasibility or assessed in any other manner. Details of the assumptions pertaining to the M12 are provided in section 5.5.3.

The construction impact has been analysed from 2016 to 2026, the construction profile shows that the year of 2021 has the peak construction movements and therefore this construction modelling has been based on 2021 to capture the worst case scenario.

2.4 Assessment criteria

This traffic and transport assessment has been undertaken with reference to the *Guide to Traffic Generating Developments* (NSW RTA 2002) in lieu of any specific relevant Australian Government guidelines. This guideline suggests a process and methodology to undertake the assessment which is familiar to NSW stakeholders and the community. The operational traffic assessment process outlined in the guidelines stipulates that the operating characteristics need to be compared with agreed performance criteria.

The assessment criteria adopted for this report are outlined in the following sections.

2.4.1 Midblock capacity

The capacity of urban roads is generally determined by the capacity of the intersections. However based on Austroads *Guide to Traffic Management Part 3 Table 5.1*, typical one-way midblock capacities for a median or inner lane on urban arterial roads under interrupted flow conditions are 900 vehicles per hour per lane (undivided road) or 1,000 vehicles per hour per lane (divided road). The capacity falls to 600 vehicles per hour per lane for a kerbside lane with occasional parked vehicles. These capacities at times may increase under ideal conditions to 1,200 – 1,400 vehicles per hour per lane. Based on this, the mid-block capacities for roads can be estimated and compared to the existing traffic volumes in terms of volume to capacity ratios.

The STM3 has inbuilt assumptions of link capacities, which are more detailed than the Austroads assumptions. A mid-block volume/capacity analysis derived from STM3 has been used for this study.

The volume/capacity measure for each link (VCR) is a measure of the amount of traffic carried by a link compared to its nominal capacity. As volume/capacity nears 1, the speed on the link decreases and both the likelihood and the duration of flow breakdowns increase.

The Austroads *Guide to Traffic Management – Part 3: Traffic Studies and Analysis (2009)* outlines Level of Service criteria for mid-block sections of road based on the VCR. A summary of these Levels of Service is presented below in Table 2-1.

Table 2-1 Level of service descriptions for roads

Level of Service	Uninterrupted Flow Facilities (Motorways)	Interrupted Flow Facilities (Arterial and Collector Roads)	VCR Range
A	Free flow conditions in which individual drivers are unaffected by the presence of others in the traffic stream. Freedom to select desired speeds and to manoeuvre within the traffic stream is extremely high, and the general level of comfort and convenience provided is excellent.	Primarily free flow operations at average travel speeds, usually about 90% of the FFS (free flow speed) for the given street class. Vehicles are completely unimpeded in their ability to manoeuvre within the traffic stream. Control delay at signalised intersections is minimal.	0.00 to 0.34
B	Zone of stable flow and drivers still have reasonable freedom to select their desired speed and to manoeuvre within the traffic stream, although the general level of comfort and convenience is less than with LoS A.	Reasonably unimpeded operations at average travel speeds, usually about 70% of the FFS for the street class. The ability to manoeuvre within the traffic stream is only slightly restricted and control delays at signalised intersections are not significant.	0.35 to 0.50
C	Also in the zone of stable flow, but most drivers are restricted to some extent in their freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort and convenience declines noticeably at this level.	Stable operations; however ability to manoeuvre and change lanes in mid-block locations may be more restricted than at LoS B, and longer queues, adverse signal coordination or both may contribute to lower average travel speeds of about 50% of the FFS for the street class.	0.51 to 0.74
D	Close to the limit of stable flow and is approaching unstable flow. All drivers are severely restricted in their freedom to select their desired speed and to manoeuvre within the traffic stream. The general level of comfort and convenience is poor, and small increases in traffic flow will generally cause operational problems.	A range in which small increases in flow may cause substantial increases in delay and decreases in travel speed. LoS D may be due to adverse signal progression, inappropriate signal timing, high volumes or a combination of these factors. Average travel speeds are about 40% of FFS.	0.75 to 0.89
E	Occurs when traffic volumes are at or close to capacity, and there is virtually no freedom to select desired speeds or to manoeuvre within the traffic stream. Flow is unstable and minor disturbances within the traffic stream will cause breakdown.	Characterised by significant delays and average travel speeds of 33% of the FFS or less. Such operations are caused by a combination of adverse progression, high signal density, high volumes, extensive delays at critical intersections and inappropriate signal timing.	0.90 to 0.99
F	In the zone of forced flow. With LoS F, the amount of traffic approaching the point under consideration exceeds that which can pass it. Flow breakdown occurs and queuing and delays result.	Characterised by urban street flow at extremely low speeds, typically 25% to 33% of the FFS. Intersection congestion is likely at critical signalised locations, with high delays, high volumes and extensive queuing.	1.0 or greater.

Source: Adapted from Austroads Guide to Traffic Management - Part 3: Traffic Studies and Analysis.

3. Existing environment

This section outlines the existing traffic and transport environment in the vicinity of the airport site including traffic conditions on The Northern Road, Elizabeth Drive, Badgerys Creek Road, Bringelly Road, Adams Road and the M7 Motorway. This includes a profile of the existing development, the existing transport and accessibility conditions and the existing road network performance.

3.1 Existing road network characteristics

3.1.1 Functional road hierarchy

Roads are classified according to the functions that they perform. The main purpose of defining a road's functional class is to provide a basis for establishing the policies which guide the management of the road according to its intended service or qualities. Functional road classification involves the relative balance of the mobility and access functions.

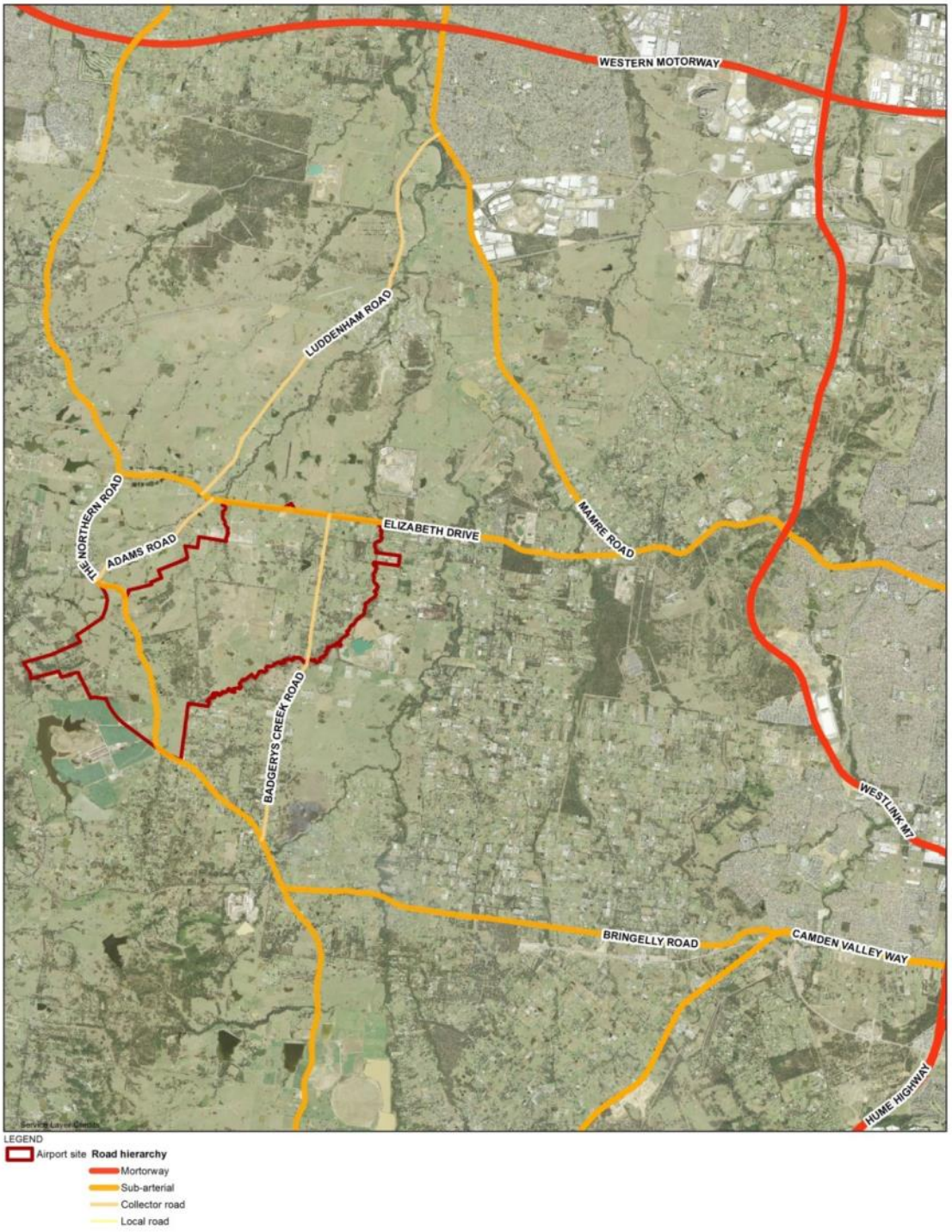
In terms of functional road classification, State roads are strategically important as they form the primary network used for the movement of people and goods between regions within Sydney, and throughout the State. State roads are the responsibility of the Roads and Maritime to fund, prioritise and carry out works. State roads generally include roads classified as Freeways, State Highways, and Main Roads under the NSW *Roads Act 1993*. The regulation to manage the road system is stated in the Australian Road Rules (1999).

Roads and Maritime define four levels in a typical functional road hierarchy, ranking from high mobility and low accessibility, to high accessibility and low mobility. These road classes are:

- **Arterial Roads** – controlled by Roads and Maritime, they typically exhibit no limit in flow and are designed to carry vehicles long distances between regional centres.
- **Sub-Arterial Roads** – can be managed by either council or Roads and Maritime under a joint agreement. Typically, their operating capacity ranges between 10,000 and 20,000 vehicles per day, and their aim is to carry through-traffic between specific areas in a sub region, or provide connectivity from arterial road routes (regional links).
- **Collector Roads** – provide connectivity between local sites and the arterial road network, and typically carry between 2,000 and 10,000 vehicles per day.
- **Local Roads** – provide direct access to properties and the collector road system and typically carry between 500 and 4,000 vehicles per day.

The road network around the Western Sydney Airport site is shown in Figure 3-1 and described in the following sections.

Figure 3-1 Major road network around Western Sydney Airport



3.1.2 Westlink M7 Motorway (M7)

The M7 is an arterial road which connects western Sydney by providing an uninterrupted journey between the M2, M4 and M5 motorways. It is a fully electronic toll road with no toll booths and uses a distance based tolling system.

In the vicinity of Elizabeth Drive, the M7 has two lanes in each direction separated by a grass median around 14 metres wide. The M7 provides for travel at variable speeds up to 100 km/h. An off-road shared cycle / pedestrian pathway traverses the motorway and connects with the Sydney Cycleway network.

3.1.3 The Northern Road

The Northern Road is an arterial road that connects Narellan in the south west to the Great Western Highway in Penrith. In the vicinity of Luddenham, The Northern Road has an undivided carriageway with one lane in each direction and a sign posted speed limit of 80 km/h.

3.1.4 Elizabeth Drive

Elizabeth Drive is an arterial road which connects The Northern Road at its western end, and the M7 to the Hume Highway at Liverpool. Between The Northern Road and the Mamre Road roundabout, Elizabeth Drive has an undivided carriageway with one lane in each direction and has a sign posted speed limit of 80 km/h. Elizabeth Drive between Mamre Road and the M7 has two eastbound lanes and one westbound lane. In the vicinity of Wallgrove Road, Elizabeth Drive carries around 26,000 vehicles per day.

3.1.5 Bringelly Road

Bringelly Road is a collector road which connects The Northern Road at Bringelly to Camden Valley Way at Horningsea Park. Bringelly Road is around 10 kilometres in length and has an undivided carriageway with one lane in each direction, unsealed shoulders and a sign posted speed limit of 80 km/h for the majority of its length.

3.1.6 Badgerys Creek Road

Badgerys Creek Road is a collector road in a rural environment which connects The Northern Road at a roundabout to the north of Bringelly to Elizabeth Drive, around seven kilometres in length. The carriageway is undivided with one lane in each direction, unsealed shoulders and a sign posted speed limit of 80 km/h.

3.1.7 Adams Road

Adams Road is a collector road in a rural environment connecting The Northern Road at Luddenham to Elizabeth Drive. The carriageway is undivided with one lane in each direction and a sign posted speed limit of 70 km/h.

3.1.8 Mamre Road

Mamre Road is an arterial road which connects The Great Western Highway in St Marys to Elizabeth Drive. Mamre Road has an undivided carriageway with one lane in each direction and has a sign posted speed limit of 80 km/h.

3.1.9 Luddenham Road

Luddenham Road is a collector road in a rural environment connecting Elizabeth Drive at Luddenham to Mamre Road. The carriageway is undivided with one lane in each direction and a sign posted speed limit of 80 km/h.

Local roads within the airport site

A number of roads pass through the airport site. Figure 3-2 shows their geographic locations. With the exception of The Northern Road, all other roads were compulsorily acquired by the Australian Government in July 1991. These roads are currently maintained by Liverpool City Council under an agreement with the Australian Government.

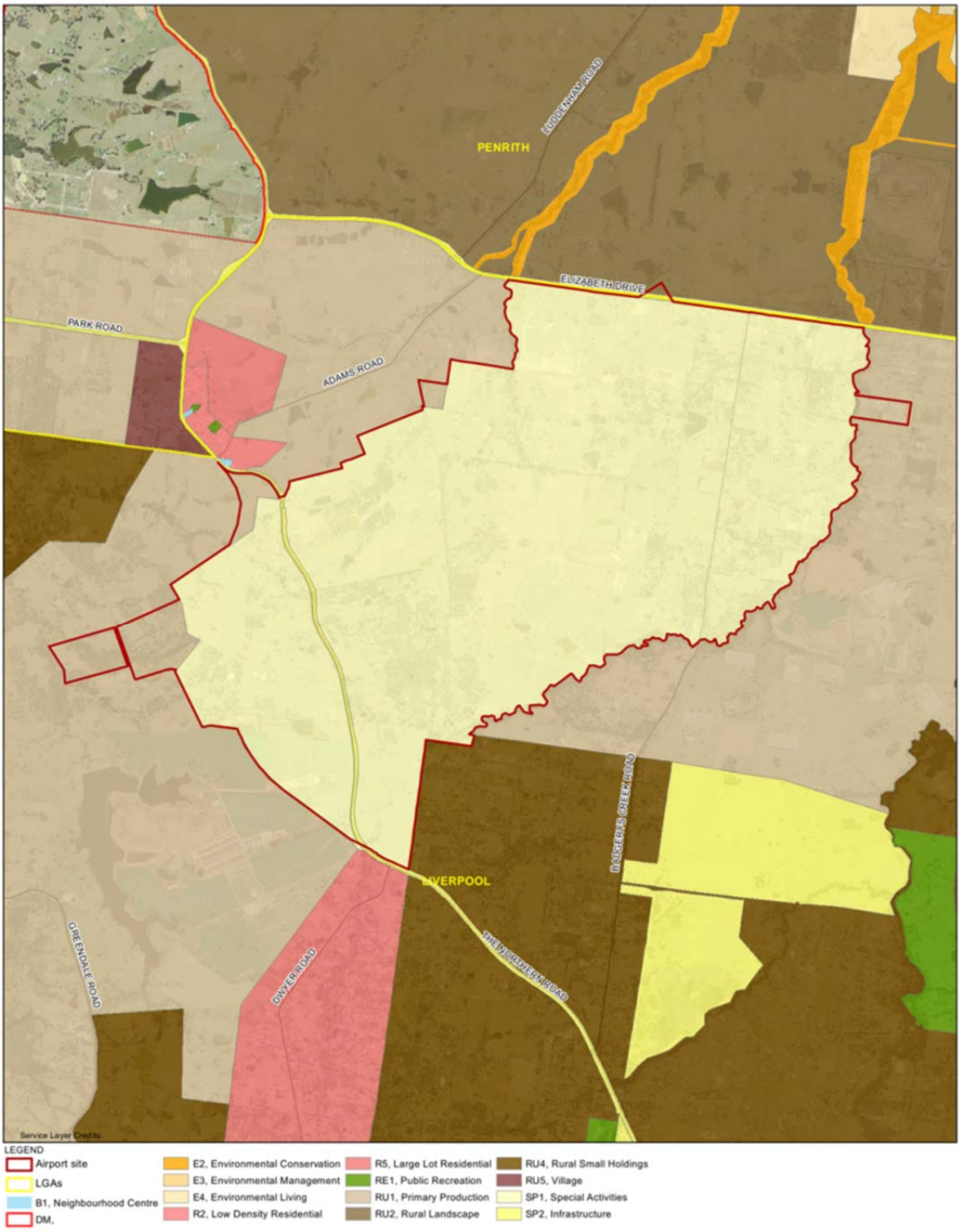
Figure 3-2 Map of existing roads in and around the airport site



Source: GHD

Existing land uses in the vicinity of the study area are shown in Figure 3-3. The areas surrounding the airport site are mostly rural properties with a few residential areas adjacent to The Northern Road and Park Road intersection and further south of The Northern Road.

Figure 3-3 Map of land use surrounding the airport development site



Source: NSW LPMA 2012 adapted by GHD

3.2 Existing daily traffic volumes

Roads and Maritime have provided daily traffic volumes within the study area. The data provided in Table 3-1 are from 2005 and is a combination of vehicle counts and axle pair counts. These count locations are no longer counted by Roads and Maritime, therefore the most recent data available without undertaking traffic surveys is from 2005. Data provided are in Appendix A.

Table 3-1 Historical two-way daily traffic volumes - 2005

Location	Annual Average Daily Traffic (AADT)	Vehicle count or axle pairs	Road classification
The Northern Road north of Bringelly Road	16,944	vehicle	arterial
The Northern Road north of Elizabeth Drive	16,654	vehicle	arterial
Elizabeth Drive east of The Northern Road	7,311	axle pairs	collector
Mamre Road south of Erskine Park Road	13,793	vehicle	sub-arterial
Bringelly Road west of Camden Valley Way	8,900	axle pairs	collector
Bringelly Road east of The Northern Road	6,212	axle pairs	collector

Roads and Maritime have permanent counting stations on Elizabeth Drive at Cecil Hills and Bonnyrigg. Historical data has been analysed to gain an understanding of traffic growth in the surrounding area, with the time series data shown in Table 3-2 and growth rate calculation shown in Table 3-3.

Table 3-2 Elizabeth Drive – historical traffic volumes (AADT)

Location	Direction	2008	2009	2010	2011	2012	2013	2014
Elizabeth Drive at Cecil Hills	Westbound	10,927	10,980	11,835	12,061	12,129	12,636	12,923
	Eastbound	11,596	11,715	12,552	12,818	13,075	13,448	13,675
Elizabeth Drive at Bonnyrigg	Westbound	16,726	16,685	17,585	17,760	17,750	17,898	17,989
	Eastbound	18,874	20,201	18,697	18,818	19,358	20,140	20,132

Table 3-3 Elizabeth Drive - historical traffic growth rate (AADT)

Location	Direction	2008	2008 combined	2014	2014 combined	% growth per annum compounding
Elizabeth Drive at Cecil Hills	Westbound	10,927	22,523	12,923	26,598	2.8%
	Eastbound	11,596		13,675		
Elizabeth Drive at Bonnyrigg	Westbound	16,726	35,600	17,989	38,121	1.2%
	Eastbound	18,874		20,132		

3.3 Daily traffic profiles

Traffic surveys were undertaken by Roads and Maritime as part of The Northern Road Upgrade Stage 2B project between 16 June and 22 June 2015 at the following locations:

- The Northern Road, north of Bringelly Road;
- The Northern Road south of Bringelly Road; and
- Bringelly Road, east of The Northern Road.

Table 3-4 provides a summary of the 2015 counts and Figure 3-4 to Figure 3-6 present the 24-hour traffic profile for each site during both weekday and weekend periods.

Table 3-4 Existing daily traffic volumes - 2015

Location	Vehicles per day(vpd) Weekday	Vehicles per day(vpd) Weekend	Vehicles per day(vpd) 7 day average
The Northern Road north of Bringelly Road	16,916	12,286	15,593
The Northern Road south of Bringelly Road	14,745	11,100	13,704
Bringelly Road east of The Northern Road	6,462	4,908	6,018

Figure 3-4 Traffic profile at The Northern Road north of Bringelly Road

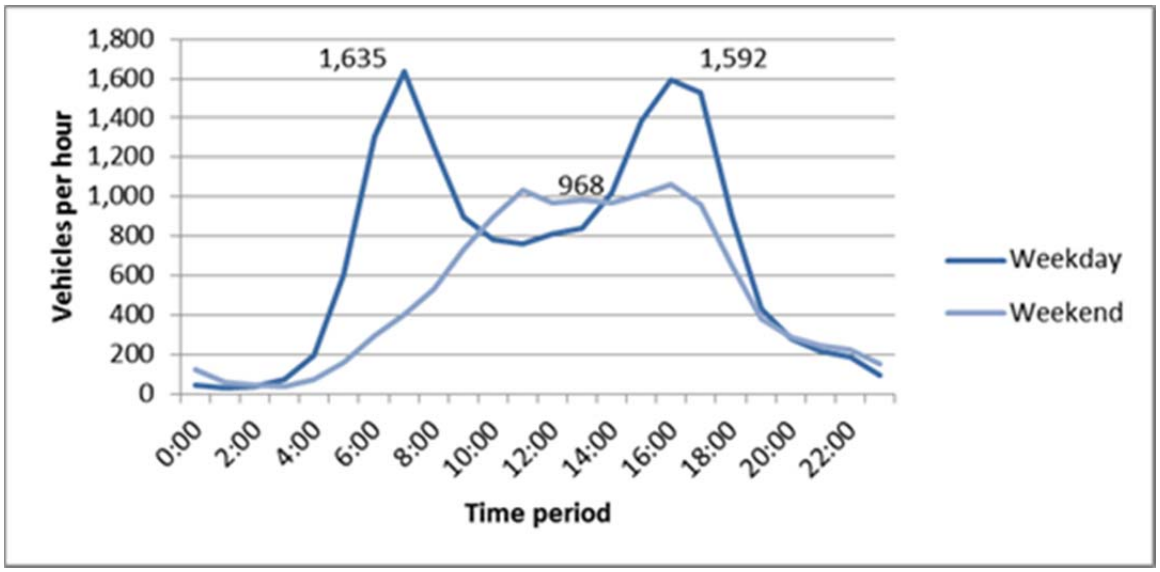


Figure 3-5 Traffic profile at The Northern Road south of Bringelly Road

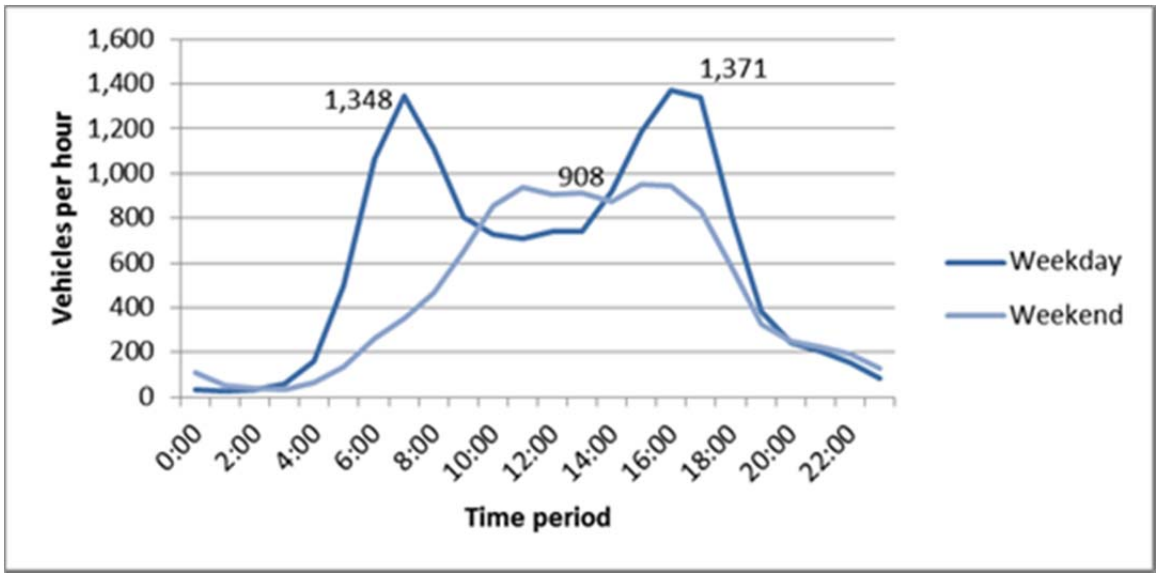
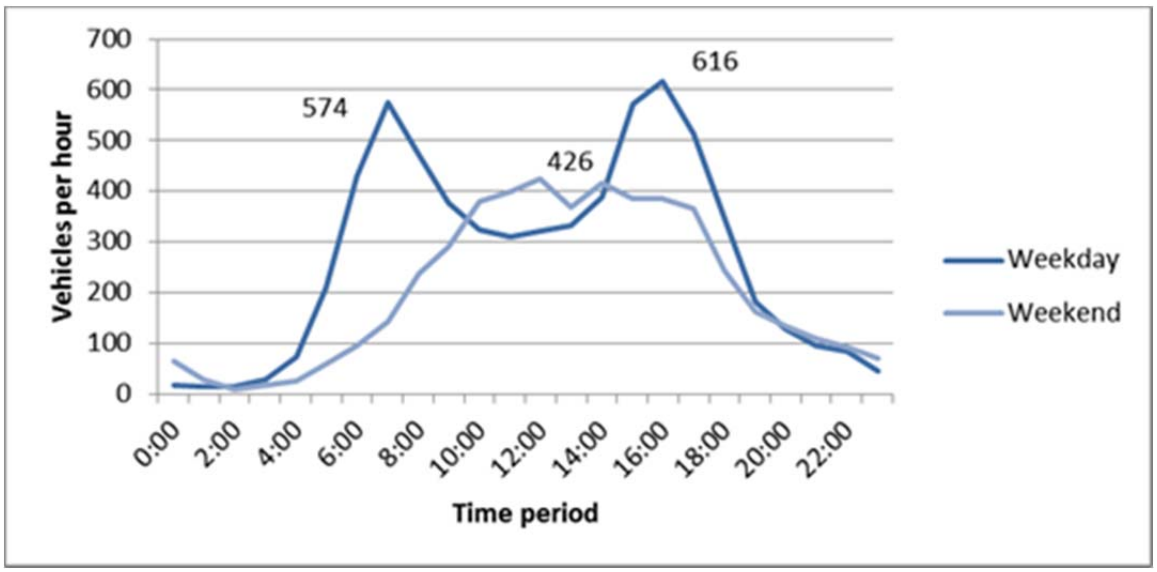


Figure 3-6 Traffic profile at Bringelly Road east of The Northern Road



3.4 Existing network peak period performance

The Sydney Strategic Travel Model, version 3 (STM3) provides a tool to assess the impact of land use and transport infrastructure changes. In order to provide an understanding of the current transport system, the 2011 base year model has been analysed to provide an insight into the prevailing peak period performance in the area surrounding the proposed airport site. No changes were made to the 2011 model for this analysis.

The model forecasts the traffic volumes on major roads in New South Wales in peak periods. From this, an assessment of the forecast volume/capacity and average speed of each link in the network can be made. It should be noted that this analysis is based on mid-block capacities on the road network and does not explicitly model behaviour at intersections, although some allowance is made for the delays incurred. More details on the volume/capacity assessment and the relationship between volume/capacity and Level of Service (LoS) is provided in section 2.4 and Table 2-1.

The Level of Service for each modelled road in the study area is shown in Figure 3-8 and Figure 3-9. The results from certain critical links have been provided in Table 3-5 (refer to Table 2-1 for an explanation of Level of Service).

Table 3-5 Level of Service for 2011 Existing Network

Id	Road	Location	AM Peak		PM Peak	
			Nbd/Ebd	Sbd/Wbd	Nbd/Ebd	Sbd/Wbd
1	The Northern Road	North of Elizabeth Dr	C	D	C	C
2	The Northern Road	South of M4	D	B	B	C
3	The Northern Road	South of Bringelly Rd	B	B	B	B
4	M4	West of Mamre Road	D	C	C	C
5	M4	West of M7	F	C	C	D
6	M7	South of M4	E	D	D	D
7	M7	South of Elizabeth Drive	D	C	C	C
8	M5	East of M7	F	D	D	E
9	M31	South of Campbelltown Road	D	C	C	C
10	Narellan Road	North of Tramway Dr	C	D	C	C
11	Bringelly Road	West of Cowpasture Road	B	A	A	B
12	Cowpasture Road	At M7	C	C	C	C
13	Elizabeth Dr	East of M7	C	C	C	C
14	Elizabeth Dr	West of M7	D	C	C	D
15	Elizabeth Dr	West of Mamre Road	C	B	A	C
16	Elizabeth Dr	East of the Northern Road	C	A	A	B
17	Mamre Road	North of Elizabeth Dr	C	C	B	C
18	Mamre Road	South of M4	D	C	C	C
19	Luddenham Dr	West of Mamre Road	B	A	A	B
20	Lawson Rd	South of Elizabeth Dr	A	A	A	A
21	Western Rd	South of Elizabeth Dr	A	A	A	A
22	Fifteenth Ave	West of Cowpasture Rd	B	A	A	B

Figure 3-7 Location of Tabulated Level of Service output

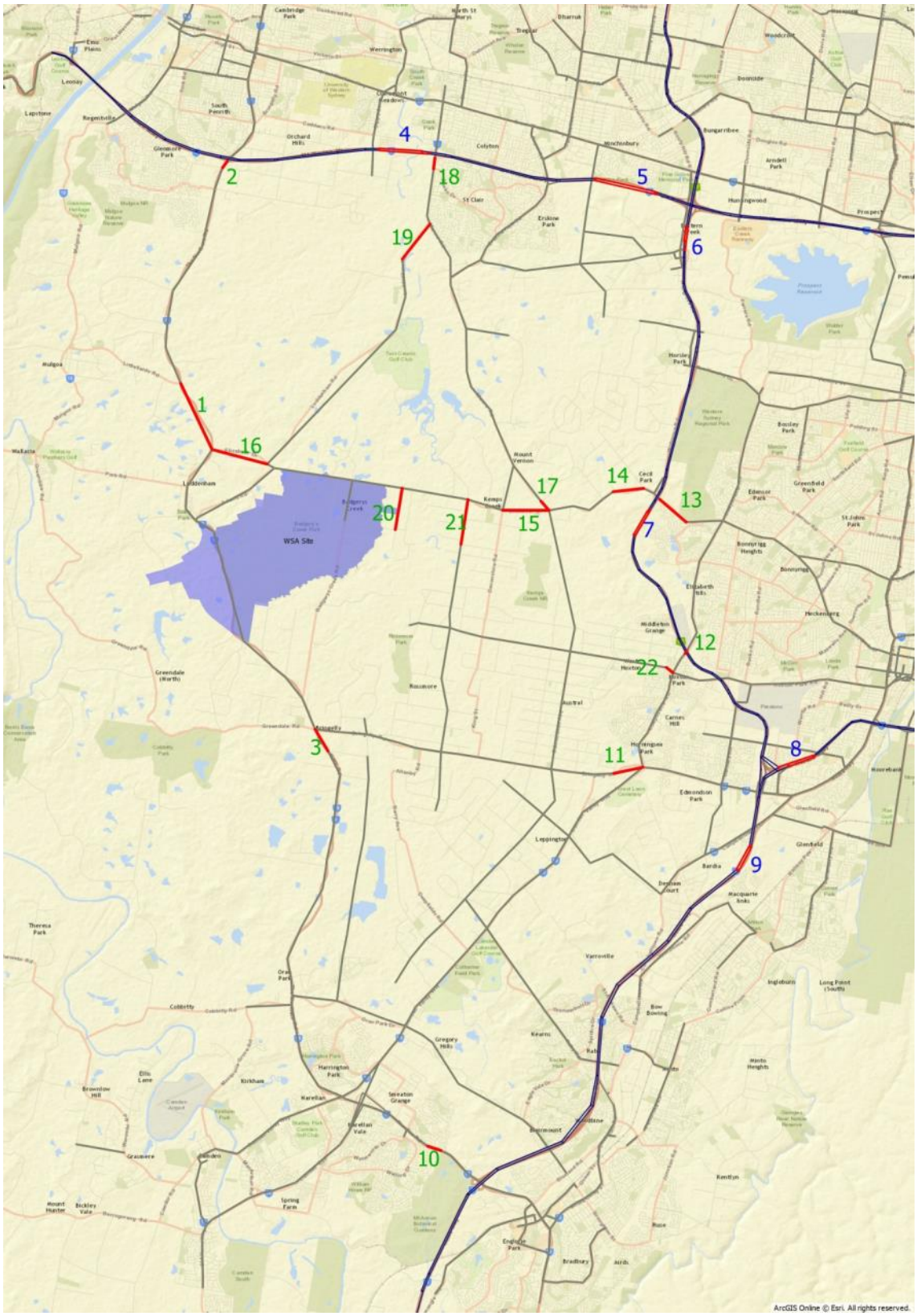
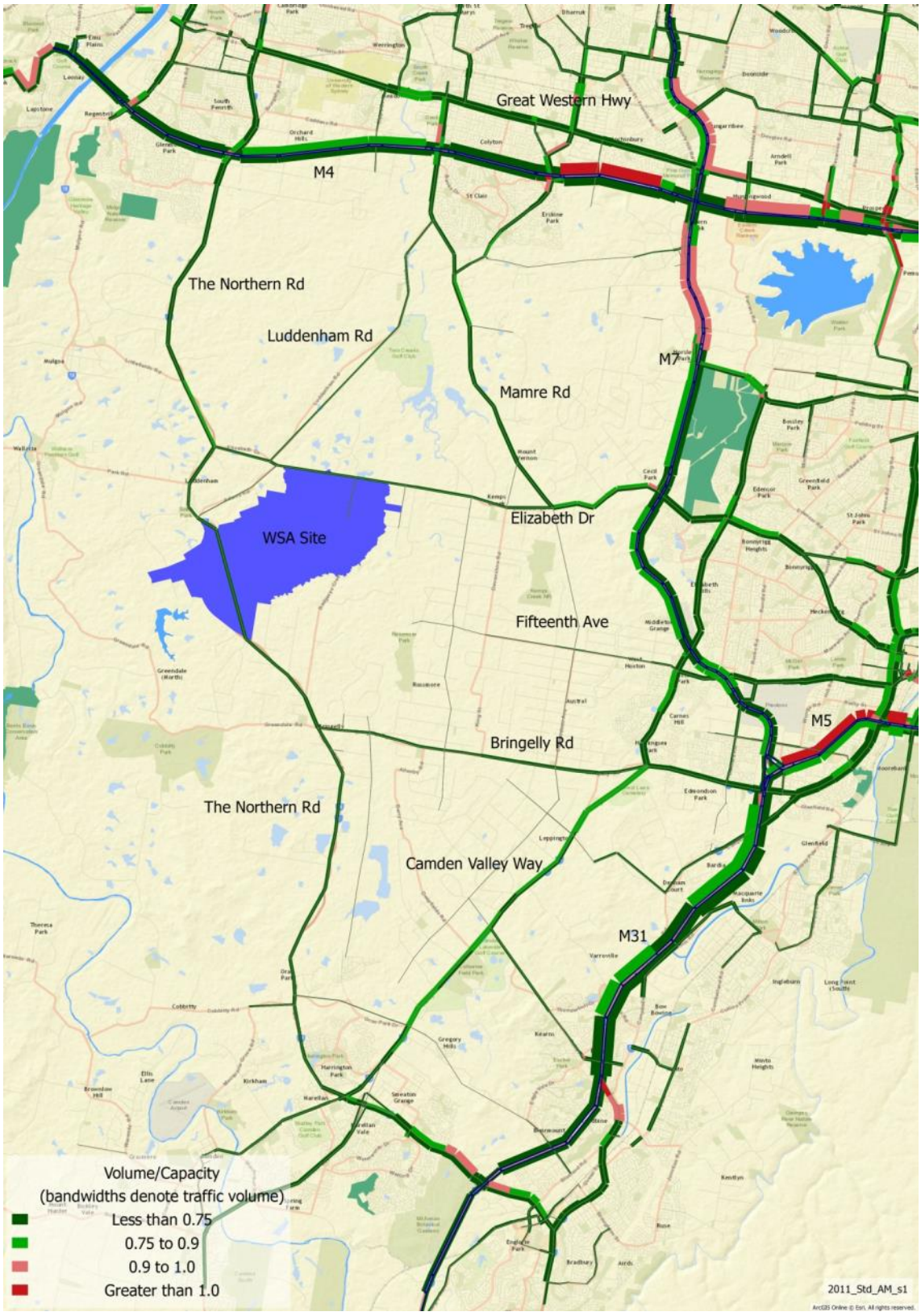


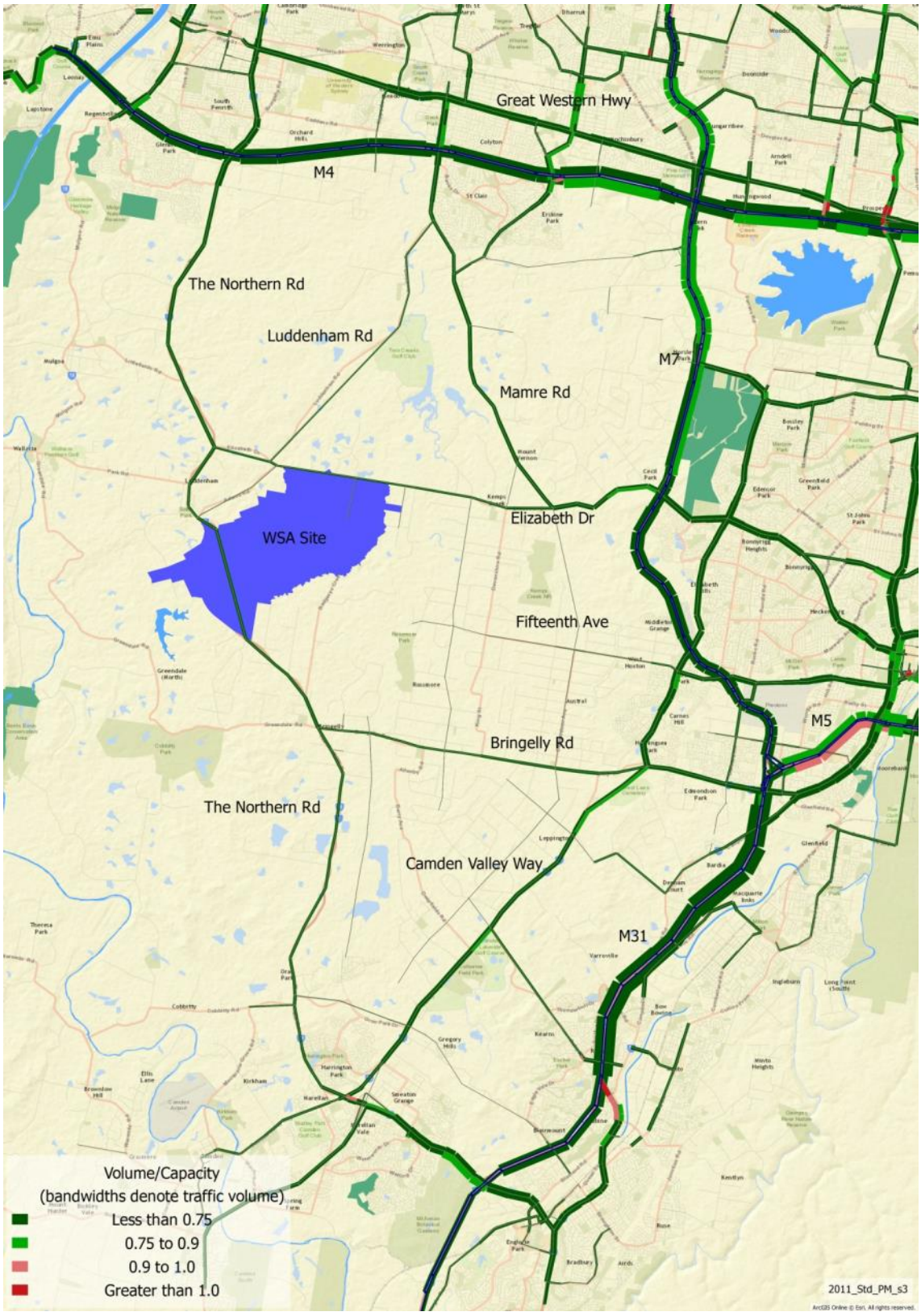
Figure 3-8 and Figure 3-9 show the modelled volume/capacity ratios for the 2011 base year model. The bandwidths in the figures are proportional to the total traffic volume, so the wider the bandwidth, the more traffic is using the link. The colour coding relates to the LoS criteria shown in Table 2-1, with grey, yellow, pink and red representing LoS A to C, D, E and F respectively.

Figure 3-8 2011 AM Peak Volume/Capacity - existing conditions



Source: STM3 2011 Standard Model, AM Peak

Figure 3-9 2011 PM Peak Volume/Capacity - existing conditions



Source: STM3 2011 Standard Model, PM Peak

The 2011 base model, as represented by Table 3-5, Figure 3-8 and Figure 3-9, shows that the roads in the vicinity of the airport site are relatively uncongested in 2011, with only sections of Narellan Road and Camden Valley Way showing a LoS equal to or greater than D in either peak period. It should be noted that since 2011 there has been development in the area, for example in the Broader Western Sydney Employment Area (BWSEA) and South West Priority Growth Area, but there remains spare capacity on much of the network near the airport site.

In the AM peak, the model shows capacity constraint on:

- The M4
  - LoS F eastbound to the west of the M7
  - LoS E eastbound to the east of the M7
- The M7
  - LoS E in both directions south of the M4
  - LoS E southbound to the north of the M4
- The M5
  - LoS F eastbound, east of the M7
- Narellan Road
  - LoS E southeast-bound towards the M31

In the PM peak, overall the capacity constraint is less acute, however the model still shows constraint on:

- The M5
  - LoS E, westbound, east of the M7
- The M4
  - LoS D, westbound along much of the length of the motorway
- The M7
  - LoS D in both directions, particularly close to the M4 intersection.

Therefore, although the immediate area around the airport site does not exhibit significant congestion, there are existing constraints on the strategic motorway network.

3.5 Public transport

3.5.1 Bus services

There are currently four bus services within the study area:

- Route 789 Penrith Interchange to Luddenham.
- Route 801 Liverpool Interchange to Badgerys Creek Road.
- Route 855 Austral to Liverpool via Prestons and Churchill Gardens.
- Route 856 Bringelly to Liverpool via Prestons and Churchill Gardens.

Route 789 Penrith Interchange to Luddenham

Route 789 provides a bus service between Penrith Interchange and Luddenham via The Northern Road. This service operates two times a day as follows:

- two services depart Penrith Interchange per day at 7:00 am and 3:45 pm.
- two services depart Luddenham per day at 7:34 am and 3:45 pm.

Route 801 Liverpool Interchange to Badgerys Creek

Route 801 provides a bus service between Badgerys Creek and Liverpool via Kemps Creek, Cecil Park and Bonnyrigg. This service operates three times a day as follows:

- three services depart Badgerys Creek per day at 7:15 am; 8:50 am and 4:42 pm.
- three services depart Liverpool Interchange per day at 3:08 pm; 3:50 pm and 5:53 pm.

Route 855 Austral to Liverpool via Prestons and Churchill Gardens.

Route 855 provides a bus service between Austral and Liverpool via Prestons and Churchill Gardens. This service operates around ten times a day as follows:

- AM services depart Austral between 5:17 am and 9:44 am with PM services operating at 12:04 pm; 3:18 pm and 5:16 pm.
- AM services depart Liverpool at 8:38 am and 11:08 am with PM services operating at 1:38 pm; 4 pm; 5 pm and 6:30 pm.

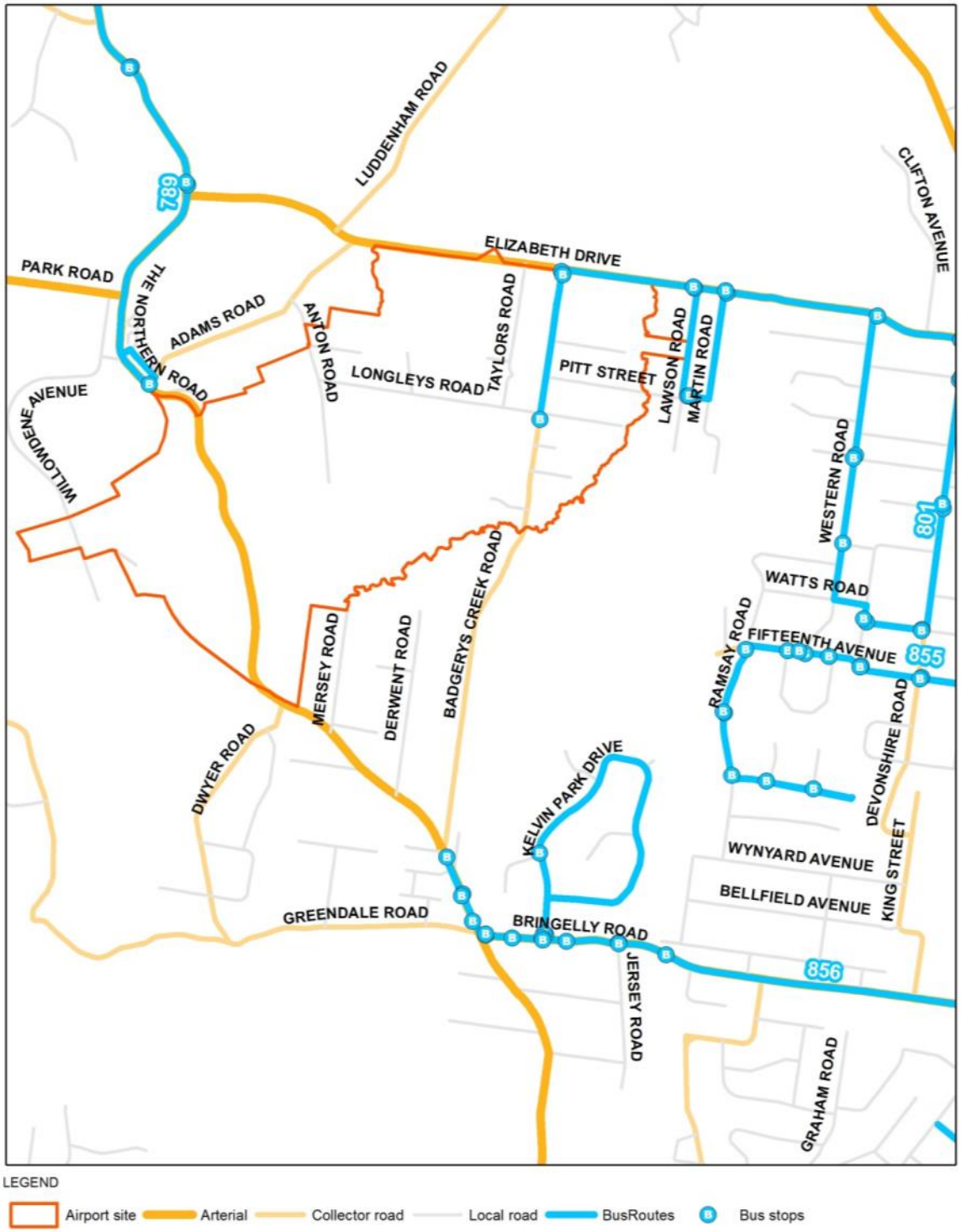
Route 856 Bringelly to Liverpool via Prestons and Churchill Gardens.

Route 855 provides a bus service between Bringelly and Liverpool via Prestons and Churchill Gardens. This service operates around seven times a day as follows:

- five AM services depart Bringelly between 5:38 am and 11:07 am with PM services operating at 4:15 pm and 5:49 pm.
- AM services depart Liverpool at 7:37 am and 10:08 am with PM services operating at 1:08 pm; 4:40 pm and 6 pm.

Figure 3-10 shows the bus services within the study area.

Figure 3-10 Bus services within study area



Source: Transport for NSW modified by GHD

3.5.2 Train services

The following train interchanges are currently the closest to the site:

- T1 Western Line – Penrith Interchange.
- T2 Inner West and South Line – Liverpool Interchange.
- South West Rail Link – Leppington.

Penrith and Leppington stations are around 15 kilometres from the site and Liverpool is around 21 kilometres.

3.6 Pedestrian and cycle facilities

3.6.1 Camden

According to Liverpool City Council Bike Plan (2009), there are currently limited bicycle links within Camden LGA. Roads and Maritime has proposed a regional cycle way along the length of Camden Valley Way within the Liverpool LGA as part of the upgrade works of this road. This will form the principal cycle link with Camden LGA for the foreseeable future.

As the growth centres lands develop additional cycleway links are to be enhanced and integrated within the Liverpool cycleway network. By 2018, the expected Bringelly Road Stage 1 and Stage 2 upgrades described in the Western Sydney Infrastructure Plan will deliver more than 10 km of shared pedestrian and cyclist paths between Leppington and The Northern Road.

Also, according to the Western Sydney Infrastructure Plan, The Northern Road is expected to have shared pedestrian and cyclist paths between Narellan area and the M4 Motorway by 2019.

3.6.2 Liverpool

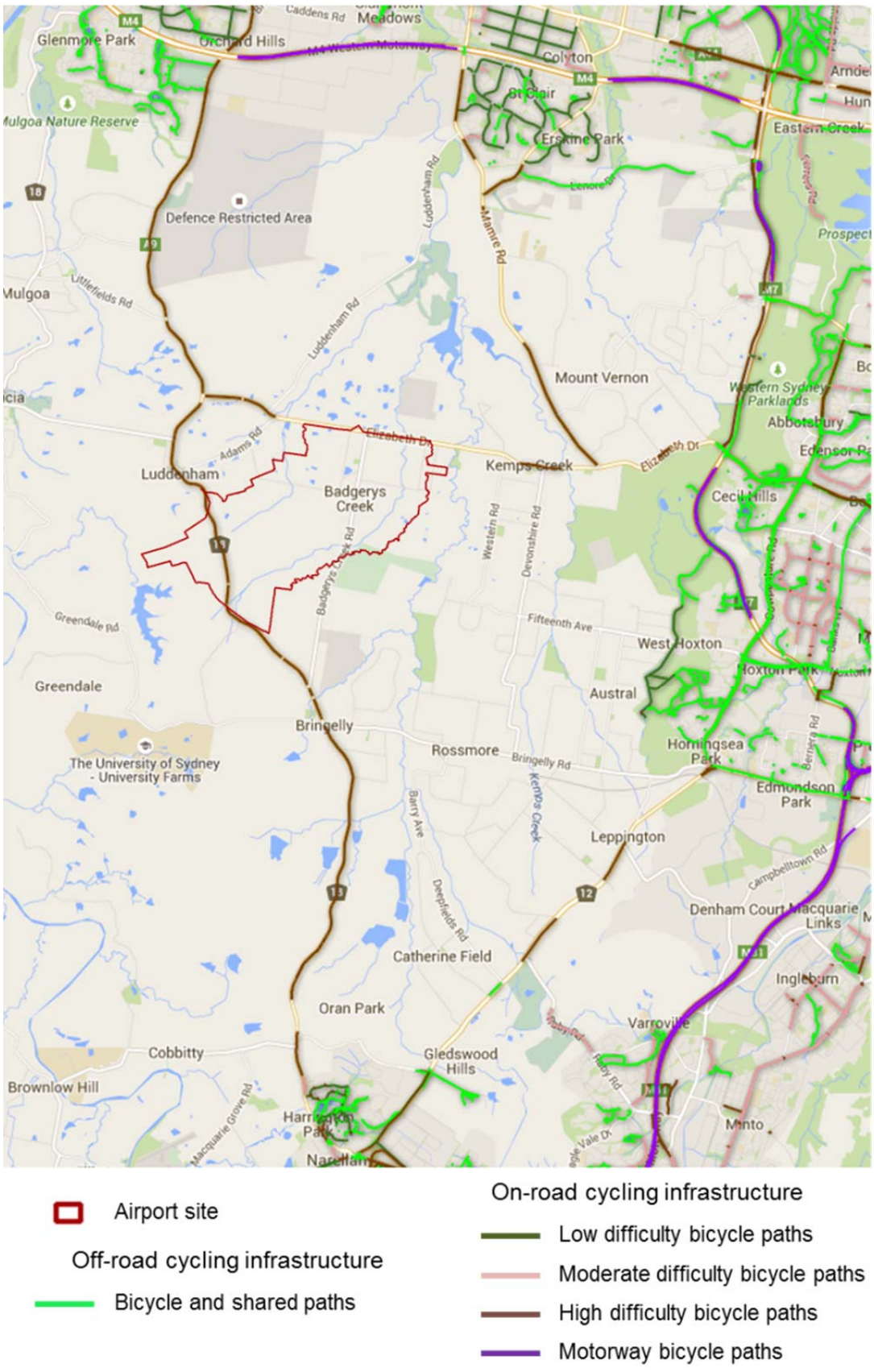
Local bike routes within Liverpool generally consist of recreational routes, such as the Wattle Grove cycle ways, Green Valley Road and the Chipping Norton Lakes cycle way. Other local routes that exist at present include the Cartwright Avenue route and the Memorial Avenue route. There are also some cyclist loops around existing recreational areas in Hinchinbrook, and other western areas.

3.6.3 Penrith

Besides Glenmore Park, St Clair and Erskine Park areas, there is no additional cycling infrastructure up to Penrith's LGA border with Liverpool due to the predominance of mostly rural and residential land use in these areas at present. In the future when the growth centres areas within Liverpool reach this border, some local pathway crossings will most likely be required, potentially with links down Elizabeth Drive, The Northern Road, Bringelly Road, Badgerys Creek Road and Devonshire Road.

Cycling infrastructure in the study area is shown in Figure 3-11.

Figure 3-11 Cycling infrastructure within study area



Source: http://www.rms.nsw.gov.au/roads/using-roads/bicycles/cyclewayfinder/index.html

3.7 Crash statistics

The Roads and Maritime Crash Analysis Department supplied crash statistics for a five-year period from January 2009 to December 2013 as seen in Figure 3-12 for The Northern Road – between Maxwell Street and Mersey Street and for a five-year period from July 2009 to June 2014 for the following locations:

- The Northern Road – between Badgerys Creek Road and Mersey Street.
- Bringelly Road – between The Northern Road and Camden Valley Way.
- Elizabeth Drive – between The Northern Road and Westlink M7.
- Mamre Road - between Elizabeth Drive and the M4 Motorway.
- Badgerys Creek Road – between Elizabeth Drive and The Northern Road.
- Adams Road – between Elizabeth Drive and The Northern Road.

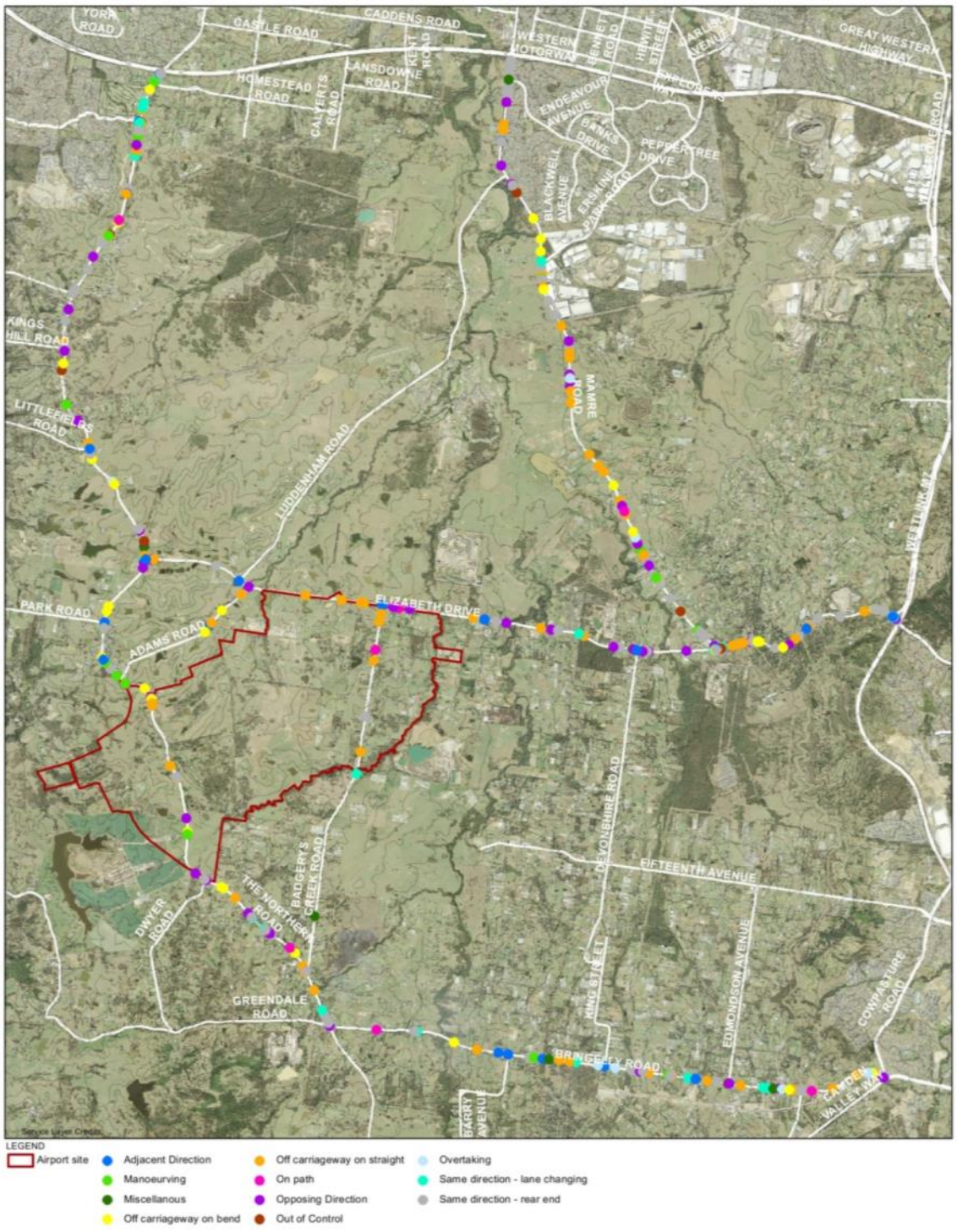
3.7.1 The Northern Road

The Northern Road – between Maxwell Street and Mersey Street

In total, 304 crashes occurred over this five year period. Of these recorded crashes:

- four crashes (1%) resulted in fatalities; three of these fatal crashes involved a head on with opposing traffic.
- 130 crashes (43%) resulted in 190 injuries.
- 157 (52%) occurred at intersections.
- 141 (46%) were rear-end crashes.
- 28 (9%) were opposing vehicles turning.
- 24 (8%) crashes resulted in vehicles leaving the carriageway on a straight section of road.
- speed was a contributing factor in 32 (11%) of the crashes.
- 21 (7%) crashes involved heavy vehicles including articulated trucks and buses.
- crashes were evenly spread throughout the day and not concentrated in a particular time period.
- crashes occurring in wet or dark conditions were not over represented.

Figure 3-12 Location of crashes (last five years)



Source: NSW Centre for Road Safety modified by GHD

The crash statistics for each location are summarised below and detailed crash reports are provided in Appendix B.

The Northern Road – between Badgerys Creek Road and Mersey Street

In total, 16 crashes occurred over this five year period. Of these recorded crashes:

- one crash (6%) resulted in a fatality; this crash involved a head on with opposing traffic.
- six crashes (38%) resulted in eight injuries.
- four (25%) were rear-end crashes.
- three crashes (19%) resulted in vehicles leaving the carriageway on a straight section of road.
- three crashes (19%) resulted in vehicles leaving the carriageway on a curved section of road.
- two (13%) were head-on crashes (not overtaking).
- fatigue was a contributing factor in five (31%) of the crashes.
- speed was a contributing factor in four (25%) of the crashes.

3.7.2 Bringelly Road - The Northern Road and Camden Valley Way

In total, 113 crashes occurred over this five year period. Of these recorded crashes:

- two crashes (2%) resulted in a fatality; these two crashes involved adjacent approaches at the intersection of Bringelly Road and Camden Valley Way.
- 61 crashes (54%) resulted in 92 injuries.
- 72 (64%) occurred at intersections.
- 29 (26%) were rear-end crashes.
- 15 crashes (12%) resulted in vehicles leaving the carriageway on a straight section of road.
- seven (6%) were opposing vehicles turning.
- 10 crashes (9%) involved heavy vehicles including articulated trucks and buses.
- speed was a contributing factor in eight (7%) of the crashes.
- fatigue was a contributing factor in seven (6%) of the crashes.
- crashes occurring in wet or dark conditions were not over represented.

3.7.3 Elizabeth Drive - The Northern Road and Westlink M7

In total, 157 crashes occurred over this five year period. Of these recorded crashes:

- two crashes (1%) resulted in a fatality.
- 75 crashes (48%) resulted in 99 injuries.
- 86 (55%) occurred at intersections.
- 50 (32%) were rear-end crashes.
- 23 (15%) crashes resulted in vehicles leaving the carriageway on a straight section of road.
- 12 (8%) were head-on crashes (not overtaking).
- 11 (7%) were as a result of lane changing.
- 24 (15%) crashes involved heavy vehicles including articulated trucks.

- speed was a contributing factor in 21 (13%) of the crashes.
- fatigue was a contributing factor in 14 (9%) of the crashes.
- crashes were evenly spread throughout the day and not concentrated in a particular time period.
- crashes occurring in wet or dark conditions were not over represented.

3.7.4 Mamre Road - Elizabeth Drive and M4 Motorway

In total, 159 crashes occurred over this five year period. Of these recorded crashes:

- one crash (1%) resulted in a fatality.
- 79 crashes (50%) resulted in 105 injuries.
- 67 (42%) occurred at intersections.
- 50 (31%) were rear-end crashes.
- 26 crashes (16%) resulted in vehicles leaving the carriageway on a straight section of road.
- 11 (7%) were head-on crashes (not overtaking).
- 10 (6%) were as a result of opposing vehicles turning.
- 22 crashes (14%) involved heavy vehicles including articulated trucks.
- speed was a contributing factor in 14 (9%) of the crashes.
- fatigue was a contributing factor in 14 (9%) of the crashes.
- crashes were evenly spread throughout the day and not concentrated in a particular time period.
- crashes occurring in wet or dark conditions were not over represented.

3.7.5 Badgerys Creek Road - Elizabeth Drive and The Northern Road

In total, 24 crashes occurred over this five year period. Of these recorded crashes:

- nine crashes (38%) resulted in 12 injuries.
- 17 (71%) occurred at intersections.
- five crashes (21%) resulted in vehicles leaving the carriageway on a straight section of road.
- two (8%) were rear end crashes.
- speed was a contributing factor in six (25%) of the crashes.
- fatigue was a contributing factor in three (13%) of the crashes.
- crashes were evenly spread throughout the day and not concentrated in a particular time period.
- crashes occurring in wet or dark conditions were not over represented.

3.7.6 Adams Road - Elizabeth Drive and The Northern Road

In total, six crashes occurred over this five year period. Of these recorded crashes:

- four crashes (67%) resulted in six injuries.
- only one crash (17%) occurred at an intersection.
- two crashes (33%) resulted in vehicles leaving the carriageway on a straight section of road.
- speed was a contributing factor in four (67%) of the crashes.
- fatigue was a contributing factor in one (17%) of the crashes.
- crashes were evenly spread throughout the day and not concentrated in a particular time period.
- crashes occurring in wet or dark conditions were not over represented.

3.8 Key findings

The existing land use in the vicinity of the airport site is generally rural /agricultural, consisting mainly of farming land and residential properties.

As identified in section 3.1, the existing traffic volumes on the surrounding road network are within the expected functional classification for arterial roads outlined by Roads and Maritime Services.

Bus routes 789 and 801 currently service the area in the vicinity of the airport site.

Pedestrian and cycling infrastructure is provided within the study area but is currently very limited due to the rural nature of the existing environment.

The 2011 STM3 model for existing conditions shows capacity constraints on the M4 and M5 eastbound and in both directions on the M7 during the AM peak and in the PM peak, the westbound direction on the M4 and M5, as well as both directions on the M7. Therefore, although the immediate area around the airport site does not exhibit significant congestion, there are constraints on the strategic motorway network.

The number of crashes is not out of character for these high volume roads. The following stands out in the analysis:

- there is a high representation of speed and fatigue in the roads analysed;
- there is a high number of rear end crashes on The Northern Road; and
- there have been two fatalities at the intersection of Bringelly Road and Camden Valley Way.

The identified common crash types and themes should be considered in future proposed works associated with the Western Sydney Infrastructure Plan. The Western Sydney Infrastructure Plan is discussed in section 5.5.

4. Construction traffic assessment

4.1 Overview

The proposed WSA would be a multidisciplinary civil engineering and building construction project that would require diverse technical skills to complete.

Construction of the initial development of the airport has been assumed to occur in two distinct packages for this assessment:

- site preparation including bulk earthworks within the Stage 1 construction footprint; and
- aviation infrastructure works.

These works will be approved through the Airport Plan.

Any subsequent construction beyond Stage 1, including the longer term airport development, would be subject to separate approvals in accordance with the *Airports Act 1996*.

4.2 Construction methodology

The indicative construction methodology is outlined in Chapter 6 of the EIS and the following is a summary from that document.

4.2.1 Site preparation works

Broadly, the site preparation works package would include:

- establishment of temporary site facilities and access
- identify limits of construction disturbance areas
- sewage disposal offsite
- construction of site perimeter fencing
- contaminated materials treatment and disposal
- clearing and grubbing and removal of decommissioned services including TransGrid 330 kV transmission line and The Northern Road within the airport site
- topsoil stripping and stockpiling
- bulk earthworks
- installation of drainage including culverts and open drains / swales including sedimentation facilities
- construction of the site perimeter access road
- providing site services to site boundary
- rehabilitation (topsoiling and grassing).

4.2.2 Aviation infrastructure works

Broadly, the aviation infrastructure works package would include:

- establishment of site facilities
- sewage disposal offsite
- establishment of an asphalt batch plant
- establishment of a concrete batch plant

- pavement excavation and subgrade preparation
- select fill placement
- asphalt placement
- concrete placement
- electrical and communications conduits
- aerodrome ground lighting
- provision of all services within the site
- buildings.

Other works related to the project but subject to separate planning approvals processes and not directly addressed by this report include the construction of replacement sections of The Northern Road and Elizabeth Drive to provide a diversion around the northern triangle. Both projects are being progressed in parallel with this EIS by Roads and Maritime.

The construction impact has been analysed from 2016 to 2026, the construction profile shows that the year of 2021 has the peak construction movements and therefore this construction modelling has been based on 2021 to capture the worst case scenario.

4.3 Construction programme

An indicative construction programme has been developed (GHD, 2015). Key dates in the programme are:

- site preparation works would commence mid-2016 and be completed by early 2023 with handover of parts of the site to the aviation infrastructure works contractor in parallel
- aviation infrastructure works would commence mid-2019 and be completed by mid--2024
- commissioning and operational readiness would be undertaken in 2024 allowing for first passengers in 2025.

4.4 Estimated workforce

The proposed airport would create employment opportunities for construction workers and support staff. Estimated peak worker numbers for the site preparation and aviation infrastructure works are shown in Table 4-1.

Table 4-1 Peak on site construction personnel

Package	Peak personnel onsite
Site preparation works	233
Aviation infrastructure works	704
Construction peak (concurrent site preparation and aviation infrastructure works)	809

It is anticipated that the majority of the workforce, both labour and supervisory and professional, would be sourced from the Western Sydney region. No onsite accommodation would be necessary with personnel housed within existing and local communities.

4.5 Hours of work

During the site preparation works, it is expected that the onsite works would be undertaken 6 am to 6 pm, Monday to Saturday.

During the aviation infrastructure works, the site would generally work 6 am to 6 pm, Monday to Saturday, however due to the scale of the pavement works, it is anticipated that pavement materials would need to be delivered to site 24 hours per day for extended periods.

Other works that may potentially need to be undertaken at night during both phases of Stage 1 construction include:

- works to existing services, if requiring shut downs;
- works on or adjacent to existing roads (specifically Elizabeth Drive and The Northern Road); due to lane closure requirements
- deliveries of oversize loads; and
- large, continuous work processes including concrete pours, paving, etc.

4.6 Key access routes to/from site

The site is approximately 10 km from the M7 and the majority of deliveries are expected to arrive via the M7 and Elizabeth Drive. The M7 has good connectivity to the south via the M31, Sydney City via the M5 and M4 and the north via the M2. Figure 4-1 shows the indicative key routes which are expected to be used by construction vehicles to access the airport site.

The M7 and Elizabeth Drive are the most likely key access routes for heavy vehicles due to the shorter travel distance to the site and regular congestion that occurs on Narrellan Road and The Northern Road around Campbelltown and Narrellan.

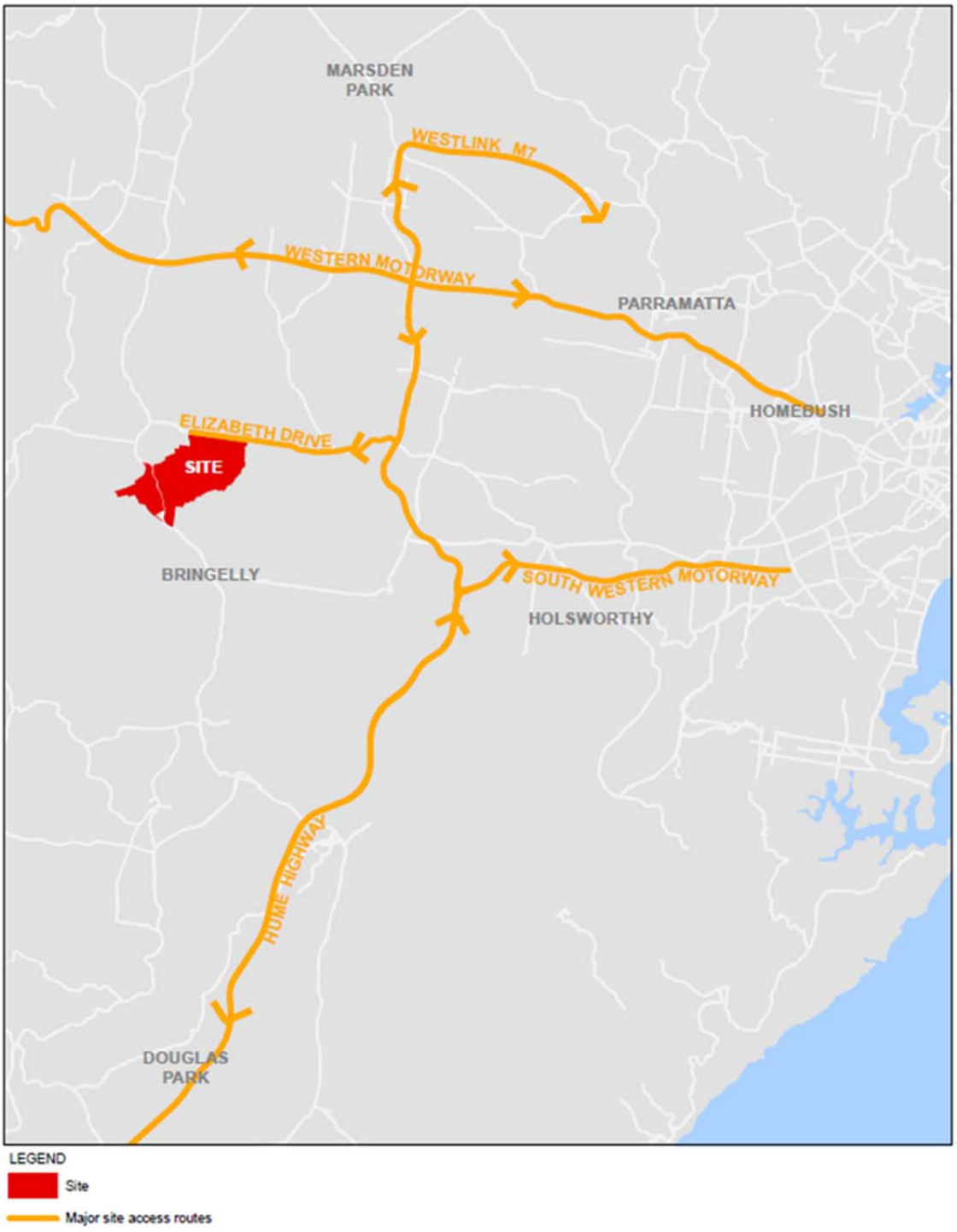
A number of site access gates would be established at the commencement of site preparatory works with provision for access by heavy and light vehicles. Seven gates would be established as detailed in Table 4-2.

Table 4-2 Access gates to airport site

Gate Number	Road	Access to	Vehicles
1	Elizabeth Drive	Site office	Light only
2	Elizabeth Drive	Airport site (east)	Heavy only
3	Elizabeth Drive	Fuel farm, maintenance facility and laydown area	Light and heavy
4	Anton Road	Satellite Office 1	Light only
5	The Northern Road	Satellite Office 2	Light only
6	The Northern Road	Airport site (west)	Light and heavy
7	Badgerys Creek Road	Airport site (east)	Light only

Upgrades to Elizabeth Drive and The Northern Road at the access points are expected to include deceleration and acceleration lanes and right-turn lanes as required to accommodate heavy vehicle movements associated with the construction programme. Other roads in the vicinity may also require upgrades and traffic control measures to accommodate additional vehicle movements. The access points would have lockable temporary gates in the permanent boundary fence. Internal egress through the site would initially be provided by the existing roads. As the site develops and the earthworks progress, new site access roads would be constructed. The site access roads would be constructed with imported gravels and maintained by graders and water carts, as required.

Figure 4-1 Key site access routes



Source: GHD

4.6.1 Potential source quarries

It is expected that gravel will be imported onto site from an established quarry.

The potential source quarries are:

- Gunlake Marulan Quarry
- Holcim Lynwood Quarry
- Boral Peppertree Quarry

All of these quarries are located in the Southern highlands.

4.7 Construction traffic impacts

4.7.1 Construction traffic generation

The EIS provides a detailed estimate of the total number of light and heavy vehicles accessing the site throughout the construction period.

Daily light vehicle numbers have been estimated based on the assumption that 80% of construction personnel drive to/from the site on a given day. The remainder would either utilise public transport or car-pooling. It is estimated that 440 light vehicles (cars/utes) would access the site each day including arrivals and departures.

The EIS identifies that bulk concrete and asphalt batching will take place on site.

For heavy vehicles, the following construction traffic generation assumptions have been adopted based on preliminary construction planning:

- heavy vehicles would operate to and from the site 24 hours per day during aviation infrastructure works.
- heavy vehicles would consist of:
  - 40 B-Doubles (night time - modelled in the evening period)
  - 122 B-Doubles (articulated vehicle class)
  - three truck and dog (articulated vehicle class)
  - 22 semi-trailers

Table 4-3 Peak construction vehicle generation

Vehicles		AM Peak	Inter-peak	PM Peak	Evening	Total (vtpd)*
Light vehicles	In	264	88	0	88	440
	Out	0	66	220	154	440
Semi-trailers	In	4	11	5	2	22
	Out	4	11	5	2	22
B-Double and Truck and Dog	In	21	63	31	50	165
	Out	21	63	31	50	165
Total		**314**	**302**	**292**	**346**	**1,254**

Note: * (vtpd) = vehicle trips per day

The time periods in Table 4-3are defined as follows:

- AM Peak (07:00 – 09:00)
- inter-peak (09:00 – 15:00)
- PM Peak (15:00 – 18:00)
- evening (18:00 – 07:00)

The time periods detailed above are those required by the STM3 model. The detailed profiles of arrival and departure times have been allocated to the appropriate STM3 time periods for assignment in the traffic model.

4.7.2 Expected traffic distribution

The peak hour temporal distribution in Table 4-3 has been based on the following assumptions:

- an arrival and departure profile for light vehicles from 5 am to 7 pm
- regular arrivals/departures throughout the day and night of B-Doubles and regular arrivals/departures throughout the day of semi-trailers and truck-and-dog

The geographic distribution for light vehicles has been assumed to be consistent with the distribution of light vehicle arrivals and departures from this area in the existing 2021 STM3 model.

As detailed information on a probable distribution for heavy vehicles is not available, the following assumptions have been made:

- 50% to/from the M31 (Hume Highway)
- 20% to/from the M5
- 10% to/from the M4 east
- 10% to/from the M4 west
- 10% to/from the M7 north.

As the compound locations within the site are currently unknown, it is assumed that all vehicles access the construction site via Elizabeth Drive to the north of the site.

4.8 Road network performance

The STM3 2021 Standard model has been used as the basis for the construction traffic analysis. The 2021 Standard model uses land use forecasts for the GMA in 2021 to calculate the expected background traffic growth to 2021.

The additional trips generated by the construction activity have been added to the network and the effect on traffic levels on the road network recalculated through a reassignment of all trips and applied to the road network within the model to determine the potential impacts of construction.

Table 4-4 provides a summary of the level of service both with and without construction traffic for a series of critical links in the study area. The location of these links is shown in Figure 3-7.

Figure 4-2 and Figure 4-3 show the volume/capacity ratios when construction traffic is added on top of the projected 2021 background traffic volumes.

Table 4-4 Level of Service for 2021 With and Without Construction Traffic

Id	Road	Location	Baseline (Without Construction Traffic)				With Construction Traffic			
			AM Peak		PM Peak		AM Peak		PM Peak	
			Nbd/Ebd	Sbd/Wbd	Nbd/Ebd	Sbd/Wbd	Nbd/Ebd	Sbd/Wbd	Nbd/Ebd	Sbd/Wbd
1	The Northern Road	North of Elizabeth Dr	C	F	E	D	C	F	E	D
2	The Northern Road	South of M4	E	C	C	E	E	C	C	E
3	The Northern Road	South of Bringelly Rd	C	A	B	C	C	A	B	C
4	M4	West of Mamre Road	F	C	C	F	F	C	C	F
5	M4	West of M7	F	C	D	F	F	C	D	F
6	M7	South of M4	D	E	F	E	D	E	F	E
7	M7	South of Elizabeth Drive	D	C	D	D	D	C	D	D
8	M5	East of M7	F	D	D	F	F	D	D	F
9	M31	South of Campbelltown Road	D	D	D	F	D	D	D	F
10	Narellen Road	North of Tramway Dr	C	E	D	D	C	E	D	D
11	Bringelly Road	West of Cowpasture Road	B	B	B	B	B	B	B	B
12	Cowpasture Road	At M7	D	C	C	E	D	C	**D**	E
13	Elizabeth Dr	East of M7	C	C	C	C	C	C	C	C
14	Elizabeth Dr	West of M7	E	C	C	E	E	C	C	E
15	Elizabeth Dr	West of Mamre Road	D	C	C	D	D	C	C	D
16	Elizabeth Dr	East of the Northern Road	C	A	A	C	C	A	A	C
17	Mamre Road	North of Elizabeth Dr	C	C	C	C	C	C	C	C
18	Mamre Road	South of M4	D	D	D	D	D	D	D	D
19	Luddenham Dr	West of Mamre Road	C	B	B	C	C	B	C	C
20	Lawson Rd	South of Elizabeth Dr	A	A	A	A	A	A	A	A
21	Western Rd	South of Elizabeth Dr	A	A	A	A	A	A	A	A
22	Fifteenth Ave	West of Cowpasture Rd	B	A	A	B	B	A	A	B

Note: Bold text has been used to identify a change in LoS from the base case – whether this is an improvement or a deterioration.

Figure 4-2 Volume/Capacity (AM Peak) in 2021 without (left) and with construction traffic (right)

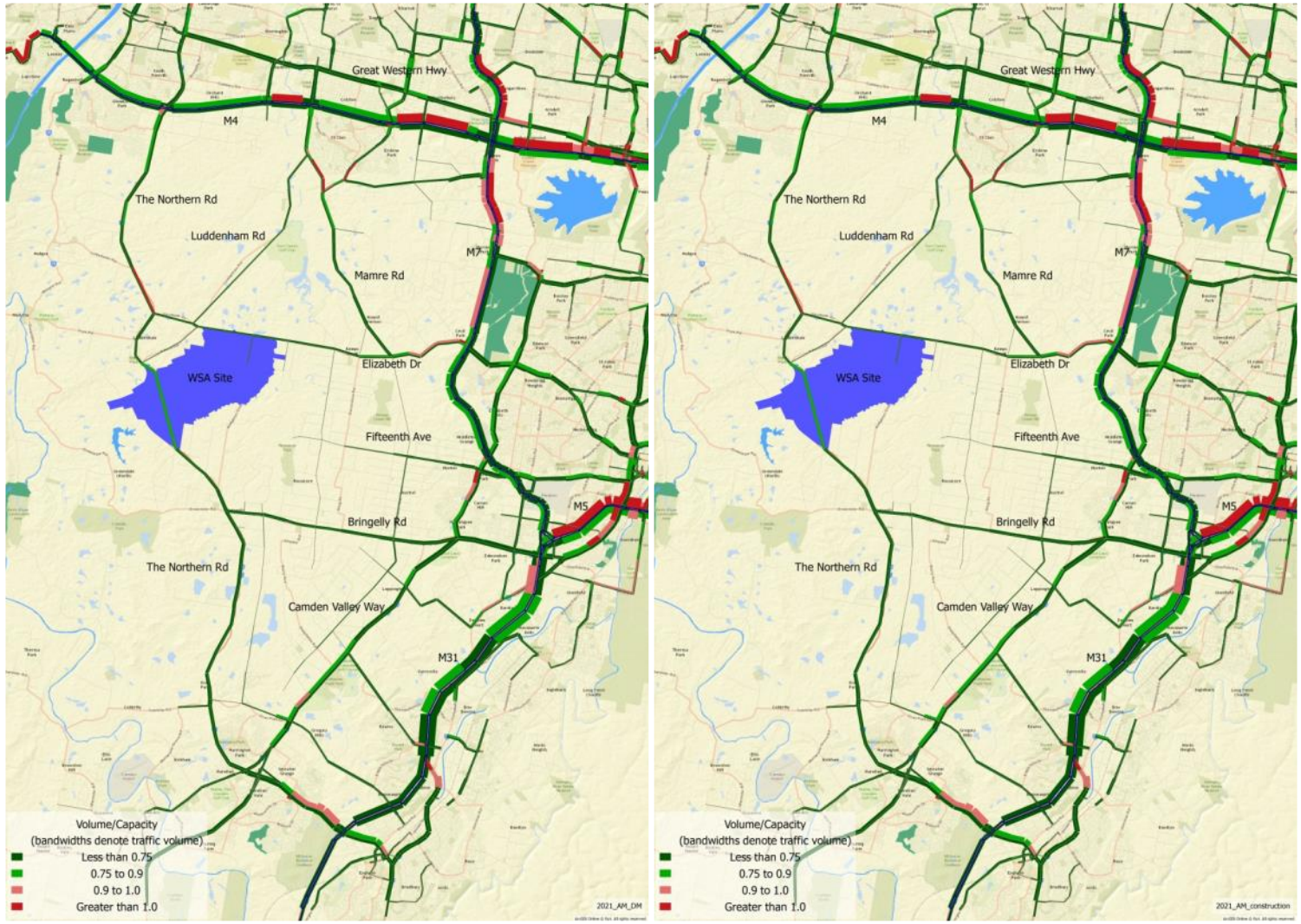
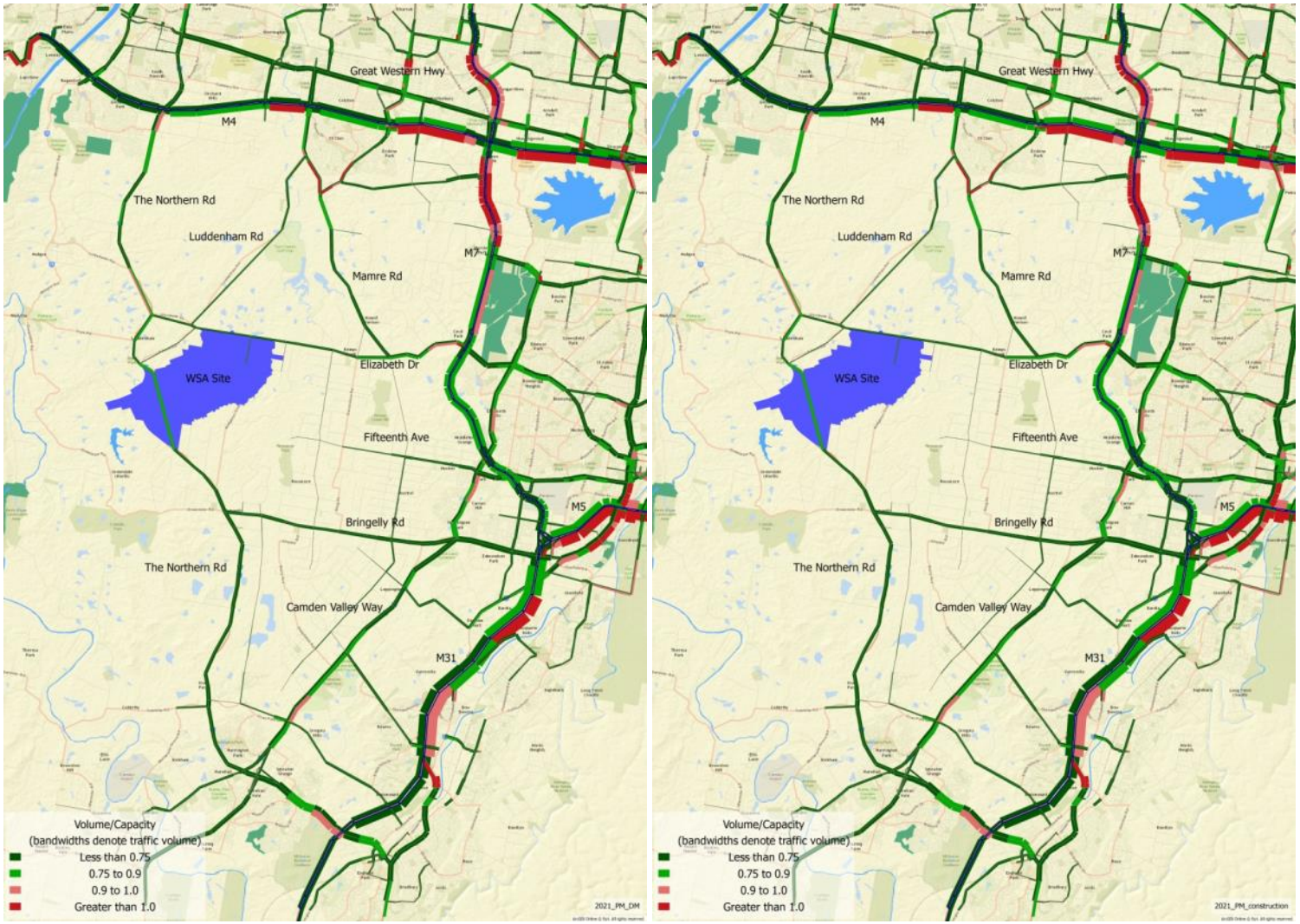


Figure 4-3 Volume/Capacity (PM Peak) in 2021 without (left) and with construction traffic (right)



The calculation of construction traffic volumes suggest an additional ~160 to ~150 vehicles per hour (two directions) on Elizabeth Drive in the AM and PM peaks respectively. This level of additional traffic volume does not increase the LoS above C on Elizabeth Drive in the vicinity of the site.

In the wider area there are capacity constraints, principally on the M4, M5 and M7, however:

- these constraints exist both with and without the construction traffic;
- the LoS does not deteriorate when construction traffic is included with the exception of a minor increase from C to D on Cowpasture Road; and
- the proportion of construction traffic compared to overall traffic reduces with distance from the WSA site, meaning that the impact of construction is reduced with distance from the site.

Therefore the analysis concludes that the construction traffic would not have a significant impact on the operation of the road network.

4.9 Construction mitigation measures

An important measure relating to construction traffic impacts is the implementation of a community information awareness programme. This programme should be initiated prior to construction commencing and continue throughout the entire construction period to ensure that local residents are aware of the construction activities, with particular regard to construction traffic and safety issues, such as diversions, temporary road closures, traffic signalling and speed limits.

Ahead of developing the Construction Traffic Management Plan (CTMP) for the proposed WSA, potential construction period impacts on local roads (on-site and in the local area), will require further assessment in consultation with local councils, NSW Roads and Maritime Services and Transport for New South Wales, identifying:

- any roads to be closed outright
- roads to be temporarily closed and the period of closure, including alternative arrangements
- closure points and the closure process
- accessibility to the temporarily closed roads e.g. public transport and emergency vehicles
- alternative routes that may be available or considered for through traffic and the potential impacts for people living along those routes.

Other important matters that would be considered as part of the CTMP include:

- development of a plan of management for the temporary and permanent closures of roads within the site;
- a specialised community engagement strategy to communicate potential construction traffic impacts to the public;
- ongoing consultation and governance arrangements with Roads and Maritime, Liverpool City Council, Penrith City Council and Emergency Services;
- Coordination with Roads and Maritime regarding safe heavy vehicle access to the site from Elizabeth Drive and The Northern Road;
- traffic control measures to be implemented at access/interaction points;

- potential road upgrades that may be required and the impacts on those roads during and post construction;
- approvals that may be required;
- haulage routes for trucks travelling to and from the site;
- mitigation measures to minimise impact on the community (e.g. avoidance of school zones during school hours, exam times etc.);
- induction for drivers working on the project to cover safety measures particularly for night works;
- reviewing speed environments along transport corridors;
- restriction of construction related traffic within the AM and PM peak periods;
- management of the transportation of construction materials to maximise vehicle loads in order to minimise vehicle movements;
- traffic control to manage and regulate traffic movements during construction;
- disruption to road users;
- use of arterial roads by construction and delivery vehicles entering or leaving the site compounds and/or stockpile sites. These movements would be restricted to a reduced number in the peak periods;
- parking facilities provided on the site for construction workers.

A CTMP would be developed prior to the commencement of construction. The CTMP would be a subplan to the Construction Enivormental Management Plan (CEMP) and provide the overall plan and staging for managing traffic through and around each work site. This would be in accordance with the *RMS Road Design Guide*, the *RMS Traffic Control at Work Sites* manual and *AS1742.3 Manual of Uniform Traffic Control Devices – Traffic control for works on roads*, and any other relevant standard, guide or manual. The draft CTMP would be prepared in consultation with relevant stakeholders.

4.10 Key findings

Construction of the proposed airport would generate an estimated additional 1,254 vehicle movements per day on the surrounding road network during the construction period. This equates to around 314 peak hour vehicle movements which would occur during the AM peak period.

The types of vehicle movements associated with the construction stages for the proposed airport would not impact significantly on the surrounding transport system with the exception of potential oversized vehicle movements for the earthworks. These movements may require temporary road closures or police escorts.

A CTMP would be developed in consultation with relevant stakeholders prior to the commencement of construction. The CTMP would provide the overall plan and staging for managing traffic through and around each work site.

An important measure relating to construction traffic impacts is the implementation of a community information awareness programme. This programme should be initiated prior to construction commencing and throughout the entire construction period to ensure that local residents are aware of the construction traffic issues, with particular regard to diversions, temporary road closures, traffic signalling and speed limits.

Part A – Assessment of the initial airport development

5. Airport facilities and road network conditions

Key details of the proposed initial stage of airport development are provided in section 1.1 and more comprehensively in the project description section of the Volume 1 of the EIS. A principal component of the initial (Stage 1) development would involve construction of a single 3.7 km runway in the northern part of the site and related airside and landside facilities sufficient to service up to an estimated 10 million passengers per year. This assessment assumes 2031 as the appropriate year to analyse the potential impacts of the proposed initial airport development on traffic and transport conditions (see section 2.1).

5.1 Airport access

5.1.1 Main access roadway

The main public access to the proposed airport would be from the north via the new M12 Motorway (being planned by Roads and Maritime and therefore not part of this EIS) that is expected to run generally parallel to Elizabeth Drive. It is expected to include a grade separated interchange for the airport access road. The proposed access corridor within the airport site is 100 metres wide, with capacity for six traffic lanes, two bus lanes and a 40 metre rail reserve in which a future rail link could be constructed.

Additional accesses to proposed commercial development areas on either side of the main access roadway could be via Elizabeth Drive and Badgerys Creek Road. These additional roads would be developed in parallel with the commercial areas when needed.

Access to the proposed airport from the south-west would be via The Northern Road, which would be relocated and upgraded by Roads and Maritime prior to the commencement of airport operations. This access point is anticipated as being primarily for secure access to operational areas of the site, including for cargo and maintenance. This access road is expected to consist of a 50 metre wide corridor allowing four trafficable lanes.

5.1.2 Off-Airport secondary roadways

Anton Road and Adams Road connect to Elizabeth Drive and would provide a secure access to the proposed airport from the north-west to such areas as the fuel farm and Airport Rescue and Firefighting Services. These are currently local roads which would be upgraded as necessary to support the desired airport functions.

It is expected that Badgerys Creek Road would be maintained as a secure alternate access to the airport. It is not envisaged that this access would be used for freight or public access in the longer term. It may form an interim secondary public access prior to the construction of the second runway.

5.2 Airport parking

The proposed airport would include dedicated car parking facilities that may include:

- parking for a minimum of 11,500 vehicles (but up to 12,500 vehicles);
- short and long stay parking;
- employee and operational parking;
- commercial vehicle parking and storage;

- parking for rental cars; and
- emergency services vehicle parking.

The majority of car parking for the initial stage development may be at ground level, with approximately 20 per cent as premium parking (1,680 bays). Multi-level parking may be provided, but as a minimum any car parking facility would include covered parking and covered pedestrian access from the parking area to the terminal. Any car parking facilities would comply with appropriate standards.

Estimated kerbside length requirements (or equivalent vehicle set down/pick up capacity) are provided in Table 5-1:

Table 5-1 Estimated parking capacity requirements

Kerbside length (metres)	Initial stage (10 MAP)		Longer term (82 MAP)	
	Departure	Arrival	Departure	Arrival
	185	191	738	732

MAP - Million Annual Passengers

Source: Western Sydney Airport Concept Development Report

The internal road system and car parking has not been assessed as part of the EIS and is included for reference only as the EIS only considers the impacts on the external transport system.

5.3 Pedestrian and cycling facilities

Pedestrian and cycle access would be included in the proposed airport terminal and ground transport precincts and parking areas, and pedestrian and cycle routes likely provided throughout the site including:

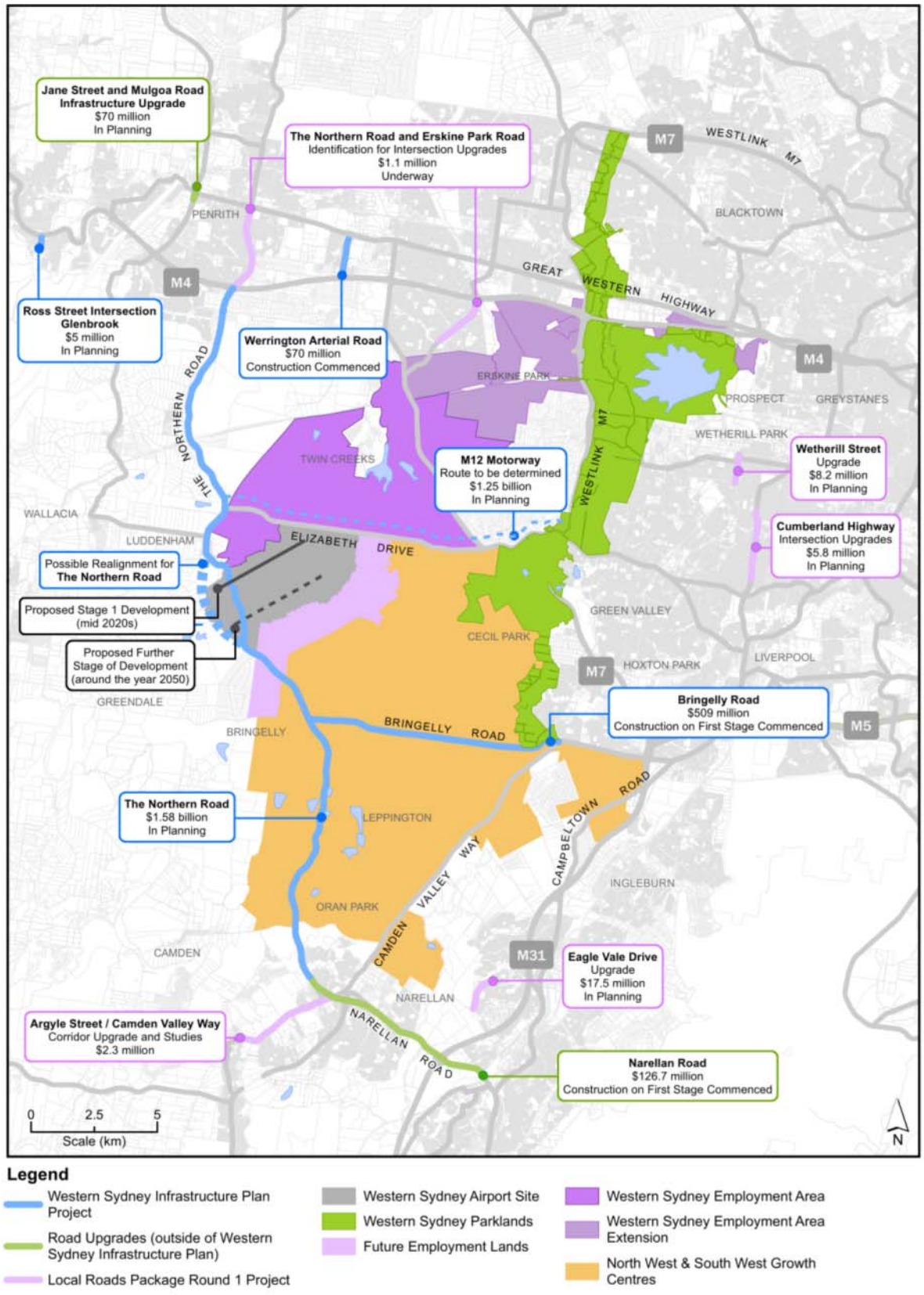
- pedestrian graded ramps for level changes for passengers arriving/departing with baggage;
- cycle parking with storage cages and storage sheds will be provided within the dedicated car park area; and
- grade separated, safe, undercover pedestrian movement between premium parking, pick up/drop-off areas and the terminal.

All ground transport connections would comply with the Commonwealth *Disability Discrimination Act 1992*.

5.4 Future road network conditions

The Commonwealth and New South Wales governments have committed $3.6 billion over 10 years in major road infrastructure upgrades in Western Sydney. These upgrades will relieve pressure on existing infrastructure and provide connectivity to the new airport and surrounding areas before inauguration of services at the proposed airport. The projects which comprise the Western Sydney Infrastructure Plan (WSIP) are shown in Figure 5-1.

Figure 5-1 Western Sydney Infrastructure Plan



Source: https://infrastructure.gov.au/infrastructure/western_sydney/index.aspx

Based on information provided by Transport for NSW a summary of the future road network projects that would be implemented by the 2031 assessment year is provided in Table 5-2. Further details of these projects are provided in section 5.5**.**

Table 5-2 Future road network changes by 2031

Project	Comments
Western Sydney Infrastructure Plan	Upgrade of The Northern Road to a minimum of four lanes from Narellan to the M4 Motorway; Elizabeth Drive upgrade between M7 Motorway and the Northern Road (Including the M7 Interchange); Construction of a new four-lane motorway between the M7 Motorway and The Northern Road; Upgrade of Bringelly Road to a minimum of four lanes from Camden Valley Way to The Northern Road; Moorebank Precinct; Werrington Arterial Road; Improve interchanges connecting Northern Road and new motorway with arterial roads; A $200 million local roads package.
Western Sydney Employment hub roads	Proposed road network to support the Growth Centre, as identified in the Broader Western Sydney Employment Area Structure Plan.
Great Western Highway, Blue Mountains	Widening from 1 to 2 lanes
NorthConnex	Due for completion by 2019.
WestConnex (stages 1, 2 and 3)	All three stages of WestConnex are targeted for completion by 2023. Includes: • M4 widening Church Street to Strathfield and M4 East (stage 1); • new M5 tunnel and St Peters interchange (stage 2); • M4 to M5 link including CityWest Link/Victoria Road and Camperdown interchanges, Airport Gateway and Southern Connector to President Ave, Monterey (stage 3)
Western Harbour Tunnel	Final business case for the Western Harbour Tunnel expected by the end of 2015, with the aim of delivering the project immediately after WestConnex Stage 3.
North West Growth Centre Roads	Proposed road network to support the Growth Centre, as identified in the North West Growth Structure Plan.
South West Priority Growth Area Roads	Proposed road network to support the Priority Growth Area, as identified in the South West Growth Structure Plan.
M4 Widening, Church Street to Mamre Road	
M7 Widening (M4 to M5)	Widening from 2 to 3 lanes between the M4 and M5 Motorways

Source: TfNSW Western Sydney Strategic Modelling Assumptions Book v1

Section 5.5 below provides an indicative description of the key projects identified in Table 5-2. The descriptions are subject to change as decision-making and detailed design for the projects progress.

5.5 Local road network improvements

5.5.1 The Northern Road

The Northern Road will be realigned outside the area required for the operation of the proposed airport by Roads and Maritime prior to the commencement of operations at the airport. Concurrently, utilities in easements along The Northern Road alignment are expected to be relocated.

A connection to The Northern Road would be constructed to the airport site boundary by Roads and Maritime as part of the construction of The Northern Road realignment. The access road to freight and maintenance precincts would include a minimum of two trafficable lanes for each carriageway on the main carriageways, and have a maximum design speed of 90 km/h and maximum posted speed of 80 km/h for the main carriageways.

The Northern Road realignment may occur partly on the airport site. Any realignment will be subject to separate approval processes being conducted by Roads and Maritime.

The Northern Road will be formed with two traffic lanes and one shoulder bus lane in each direction, with provision for walking and cycling through shared paths along its route. The corridor will have additional width to allow for three lanes in each direction to be retrofitted at a later date.

5.5.2 Bringelly Road

Bringelly Road is being upgraded between Camden Valley Way and The Northern Road to support the development of growth centres, employment and the proposed airport. The project consists of upgrading the two-lane segment between the eastern side of Upper Canal Bridge and the western side of the Eastwood Road intersection, through the forthcoming Leppington Town Centre, into a six lane divided road by 2018. Furthermore, the remaining sections of Bringelly Road will also be upgraded from two lanes to a four-lane divided road with a central median which will cater for future extra capacity by widening Bringelly Road into six lanes if needed.

5.5.3 M12 Motorway

This new motorway is proposed to connect the M7 near Cecil Park to The Northern Road near Luddenham in part, parallel to Elizabeth Drive to provide access and traffic capacity for the proposed airport. The future M12 is likely to be built as a four lane road with capacity for six lanes in the future.

The primary public access road to the airport site would be from the future M12. Roads and Maritime will construct the connection from the M12 to the airport site boundary.

The main public access road (from the Elizabeth Drive connection with the future M12) will include:

- a maximum design speed of 90 km/h and maximum posted speed of 80 km/h for the main carriageways including the connections to the M12 Motorway, decreasing to safe speeds in the vicinity of the terminal forecourt and Ground Transportation Centre (maximum design speed of 40 km/h).
- a minimum of two, and up to three, trafficable lanes for each carriageway on the main carriageways with provision for bus lanes in the shoulder.
- connection to allow efficient and safe vehicle movement around the ground transport hub within the terminal forecourt, including access to the commercial precinct, support areas and airport parking.

5.5.4 Badgerys Creek Road

Badgerys Creek Road is a local road under the control of Liverpool City Council. It is expected to remain a public road to the boundary of the airport site. Similarly it is expected at this stage that Badgerys Creek Road would remain open to public transport and private vehicles on the airport site prior to the construction of the second (southern) runway, depending on the requirements for additional access to landside facilities and the location of the airport security fence.

5.5.5 Other external roads

Other roads which would be upgraded (by others) to meet the requirements of the proposed initial airport development stage include:

- Elizabeth Drive would be deviated to the northeast and upgraded, approximately between its current intersection with Badgerys Creek and Adams Road to accommodate exclusion zones for the northern runway.
- Adams Road which would be upgraded from Elizabeth Road at least to Anton Road to meet the needs of construction and support traffic for the proposed airport, including B-Double traffic.
- Anton Road which would be upgraded from Adams Road to meet the need for construction traffic and secondary access to non–public facilities for the proposed airport located along the northern site boundary, including B-Double traffic.
- a perimeter road would provide access to support infrastructure and navigational aids. This two-lane roadway will also be used to monitor the airport security and perform any maintenance of the security fencing, perimeter lighting, and CCTV system.

5.6 Public transport

In the short term, public transport access to the proposed airport could be provided through road upgrades, park and ride facilities and new bus services directly linking to major centres in Western Sydney.

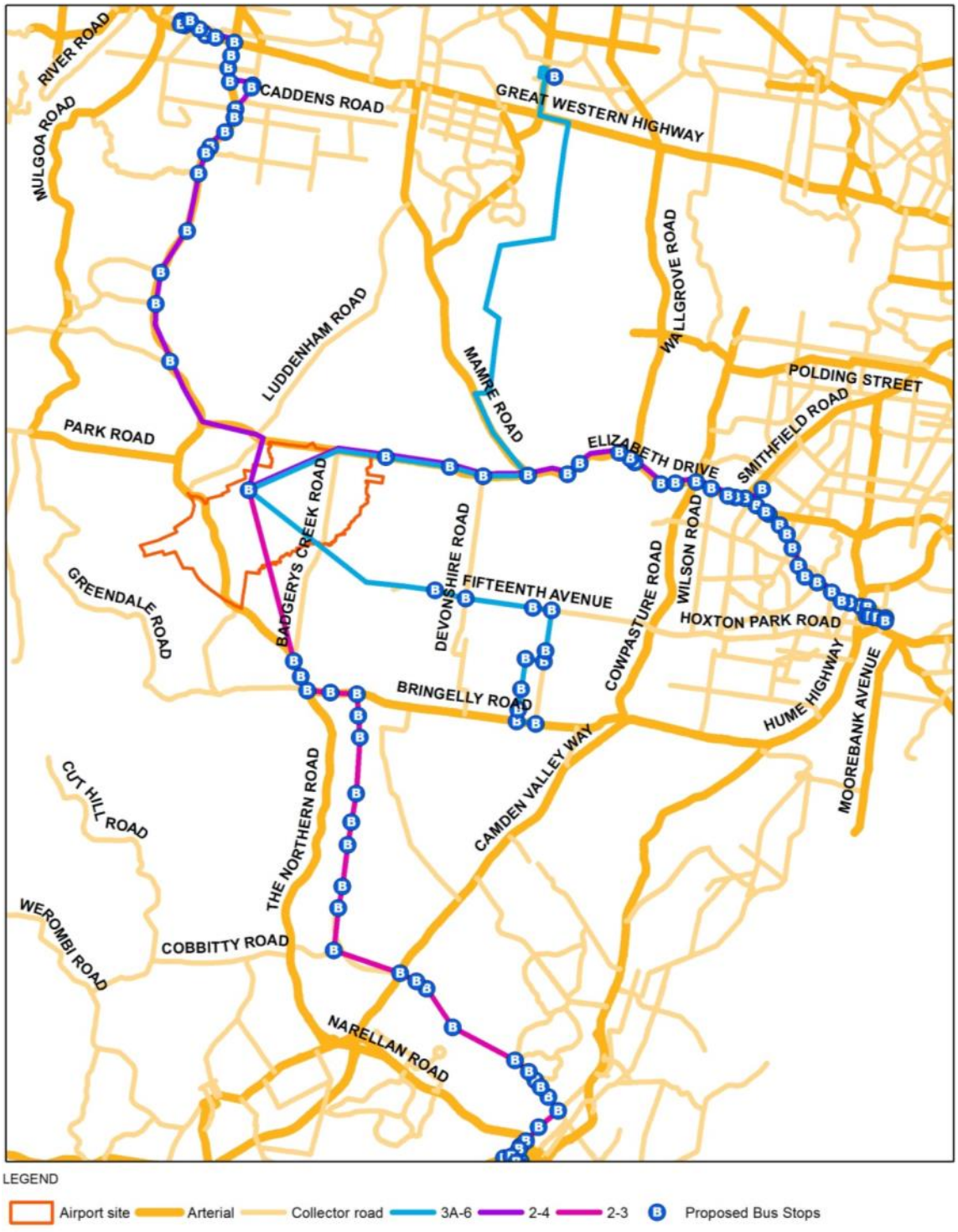
There are three additional bus routes identified by Transport for NSW to the proposed airport, as shown in Figure 5-2. These routes are:

- 2-4 Liverpool-Badgerys Creek-Penrith (suburban).
- 2-3 Campbelltown-Oran Park-Badgerys Creek (suburban).
- 3A-6 Leppington-Badgerys Creek-Mt Druitt (local).

These bus routes would have service frequencies that would be determined based on the demand for travel to the proposed airport, with the suburban services having fewer bus stops.

Two existing bus routes that currently traverse the site (789 and 801) will be diverted as required.

Figure 5-2 Proposed bus routes



5.7 Pedestrian and cycling facilities

Sydney's Cycling Future (Transport for NSW, 2013) is a plan to encourage people to ride more often and safely. It includes actions to promote and improve cycling which are relevant to the WSA proposal. One of these actions includes providing shared off-road pedestrian and cycle facilities in appropriate locations to provide links between key centres and activities across the Sydney Metropolitan Area. This includes a plan for the development of network of strategic bicycle corridors potentially linking Liverpool, Blacktown, Penrith and the future town centre of Leppington to the Airport site in the future.

As the South West Priority Growth Area and Broader Western Sydney Employment area lands develop additional cycleway links are to be enhanced and integrated within the regional Western Sydney cycle way network. By 2018, the expected Bringelly Road Stage 1 and Stage 2 upgrades described in the *Western Sydney Infrastructure Plan* will deliver more than 10 km of shared pedestrian and cyclist paths in the area.

Also, according to the *Western Sydney Infrastructure Plan*, the proposed M12 motorway, the Northern Road and Bringelly Road upgrades are expected to have pedestrian and cyclist infrastructure included as part of the project planning. These proposals will improve walking and cycling access within the vicinity of the Airport Site by providing shared paths along The Northern Road and Bringelly Road, therefore potentially increasing the mode share towards active transport to the Airport site.

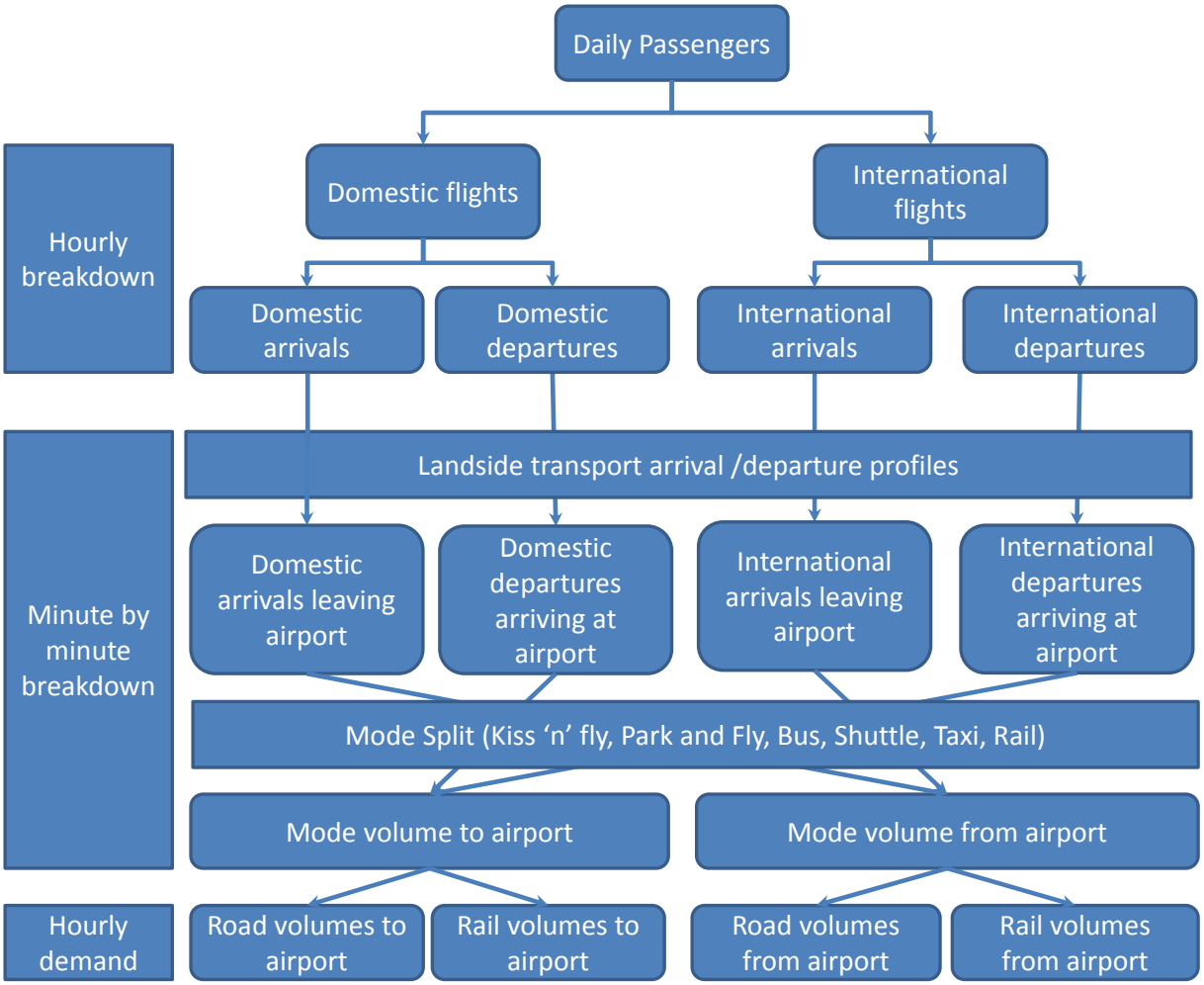
6. Trip generation

6.1 Introduction

In 2031, it is estimated that the proposed airport would be operating with passenger movements of 10 million per annum and an employee level of approximately 7,600 persons. In order to determine the impact of these passenger movements on the ground transport system, including impacts on the road and public transport networks, it is necessary to disaggregate these trips into a form for which an assessment can be undertaken.

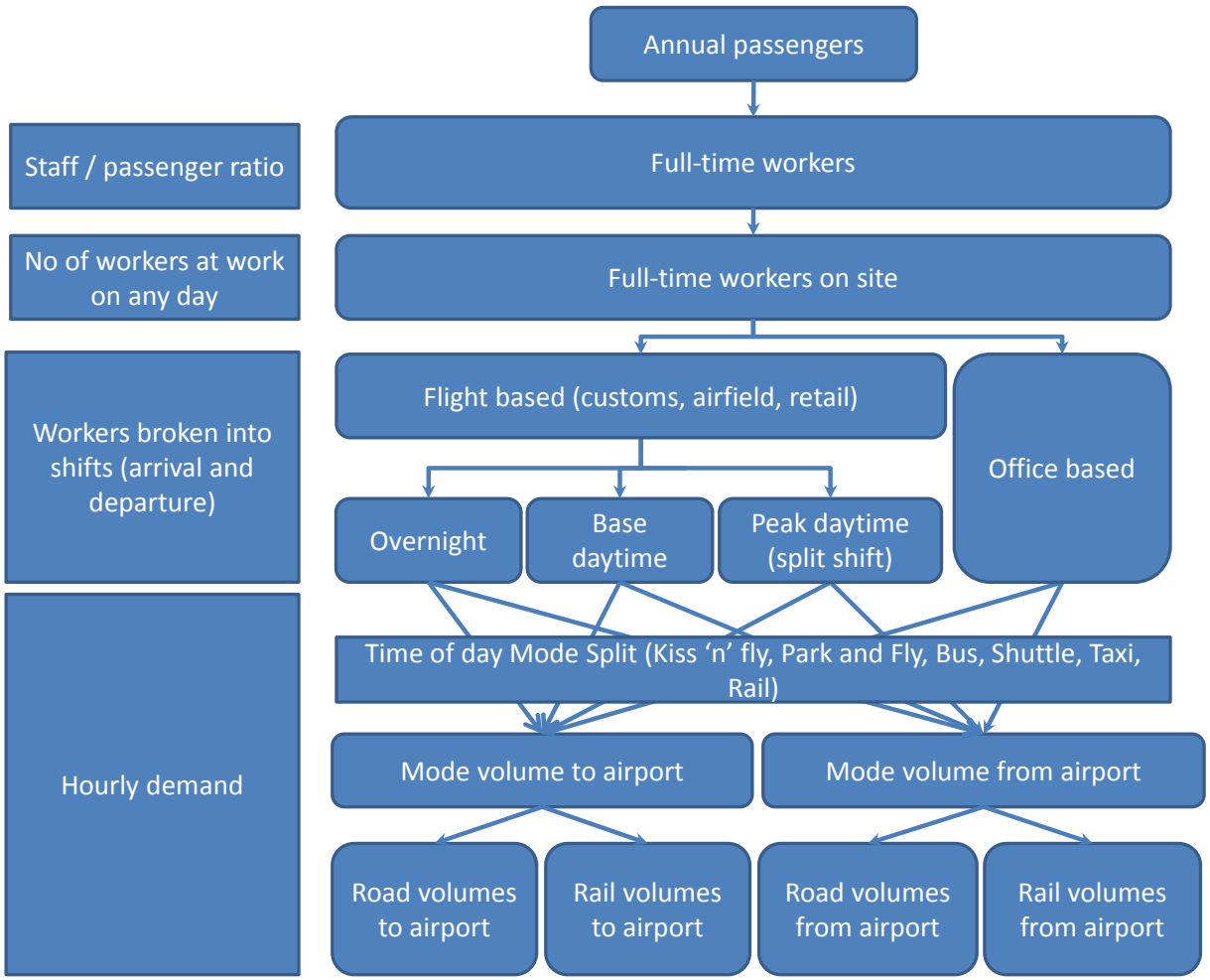
Information provided as part of the proposed airport concept plan includes daily passenger volumes and peak hour flights. From these data sets, it was necessary to determine the number of passengers that would be arriving and departing in any one hour period. The method for deriving passenger volumes is shown in Figure 6-1 and described in section 6.2.

Figure 6-1 Passenger trip generation and mode assignment



Airfield, terminal and airside employment estimates are directly related to the volume of passengers passing through the airport. Having regard to the experience at other major airports, a ratio of 750 workers per 1 million annual passenger movements is considered a reasonable basis on which to estimate the number of full time employees at the airport. In order to determine the trip generation of these employees, these employees need to be broken down into shifts across the 24 hour operations of the proposed airport. The method for deriving this is shown in Figure 6-2 and described in section 6.3.

Figure 6-2 Employee trip generation



6.2 Passenger trip generation

Passenger trip generation to the proposed airport would be dependent on a number of factors including:

- the number of flights arriving and departing during the airport's peak hours and the carrying capacity of each flight;
- terminal factors time, such as the Customs and Border Protection clearances for international passengers and security clearances for departing domestic passengers; and
- the effects of landside uses within the airport precinct and surrounding areas.

6.2.1 Flight profiles

The passenger flight profile for the site shown in Table 6-1 has been determined based on a synthesised profile of the number of daily and peak hour passenger flights.

Table 6-1 Daily flight movements 2031

Design Day Passenger Air Traffic Movements	2031
Domestic passenger flights	149
International passenger flights	21
Total	**170**

Source: LEK Airport Demand Summary April 2015

Additionally, the number of flights per peak hour has been determined as shown in Table 6-2.

Table 6-2 Peak hour flight movements 2031

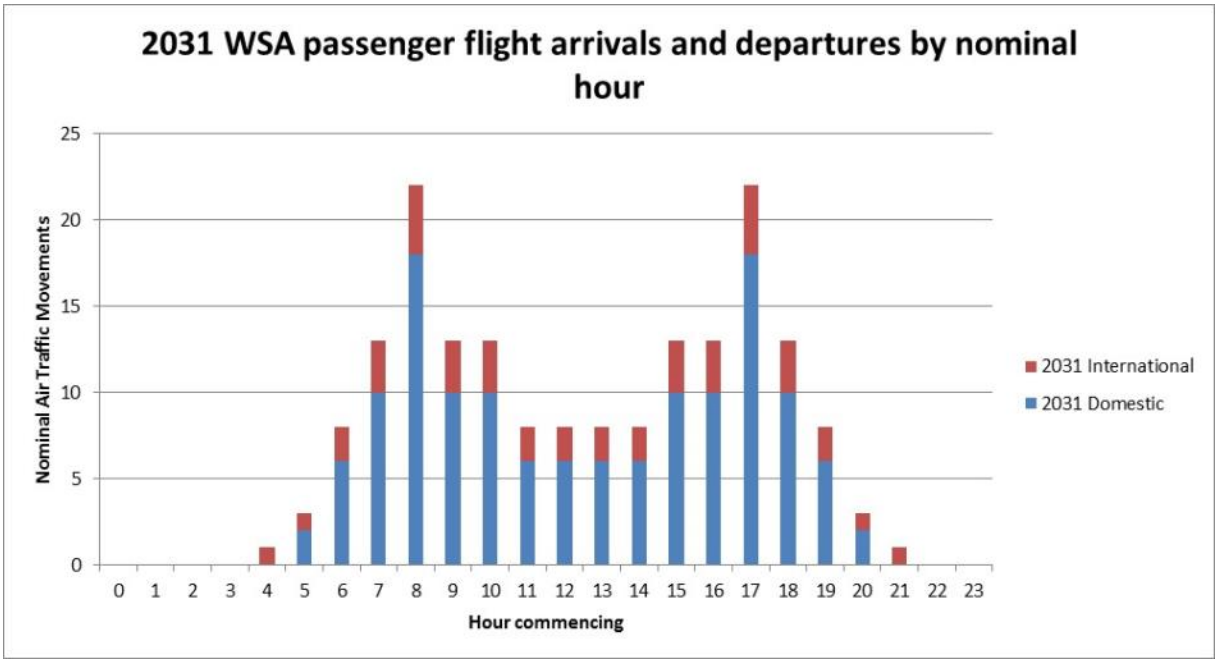
Peak hour flights	No flights	% of daily total
Arrivals (Domestic and International)	11	6.1
Departures (Domestic and International)	11	6.1
Total	**22**	**12.2**

Source: LEK Airport Demand Summary April 2015

The operations of airports with 24 hour operations (including Tullamarine, Adelaide and Brisbane Airports) were examined to determine the ratio of arriving and departing flights by hour. It was found that similar sized airports with 24 hour operation have limited overnight flights between 2100 and 0500 hours. Based on the high ratio of the peak hour to the other hours of the day there would be limited flights outside of the peak travel hours. A synthetic plane arrival and departure profile has been developed by the traffic and transport specialist team to account for the peak to non-peak profiling of flight arrivals and departures. This is shown in Figure 6-3.

Tables relating to the figures in section 6.2 are provided in Appendix C.

Figure 6-3 Synthesized 2031 daily flight profile



6.2.2 Passenger arrival profiles

For each domestic and international flight, a profile for the passengers entering and exiting the airport has been determined. In determining this profile, the Sydney Airport Land Transport Model (SALTM) has been used as a starting point. However, this model was based on survey data completed prior to 2012 and before the advent of Smart gates at Passport Control and self-check-in and online check-in for both domestic and international passengers. Additionally, information from the USA Customs and Border Protection and Transport Security Administration, who keep detailed information on all airports in the USA, has been used as a basis for the analysis to create arrival and departure profiles for passengers with shorter dwell times at the airport. Similar published information is not currently available for Australia.

In order to develop a more realistic future passenger arrival profile, it has been assumed that check in and departures will take less time as a result of the above new technologies and based

on field observations. The derived landside passenger arrival and departure profiles are shown in Figure 6-4 and Figure 6-5.

Figure 6-4 Assumed landside arrival – percentage of passengers

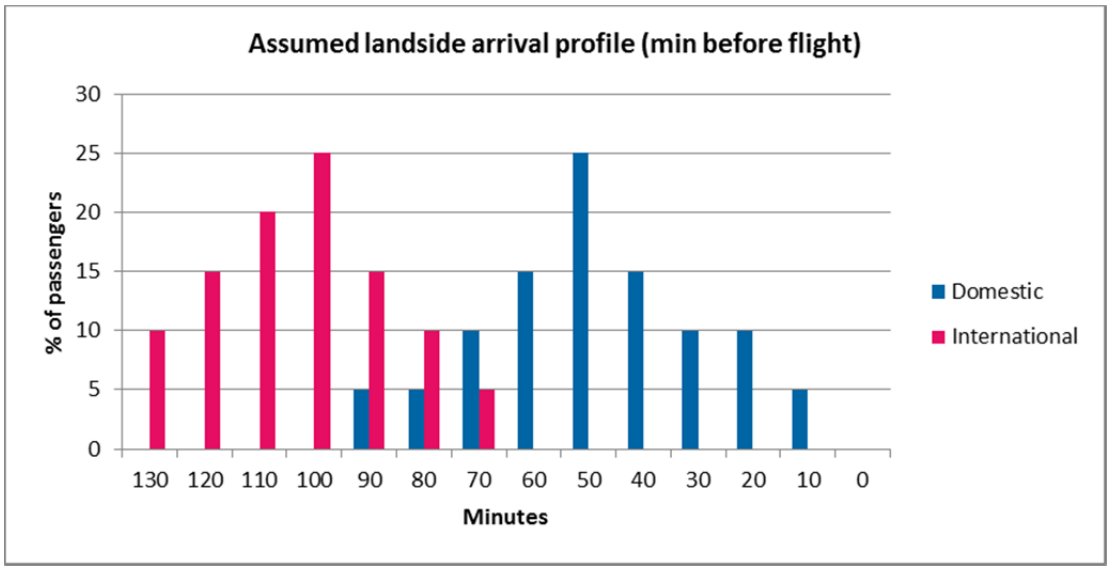
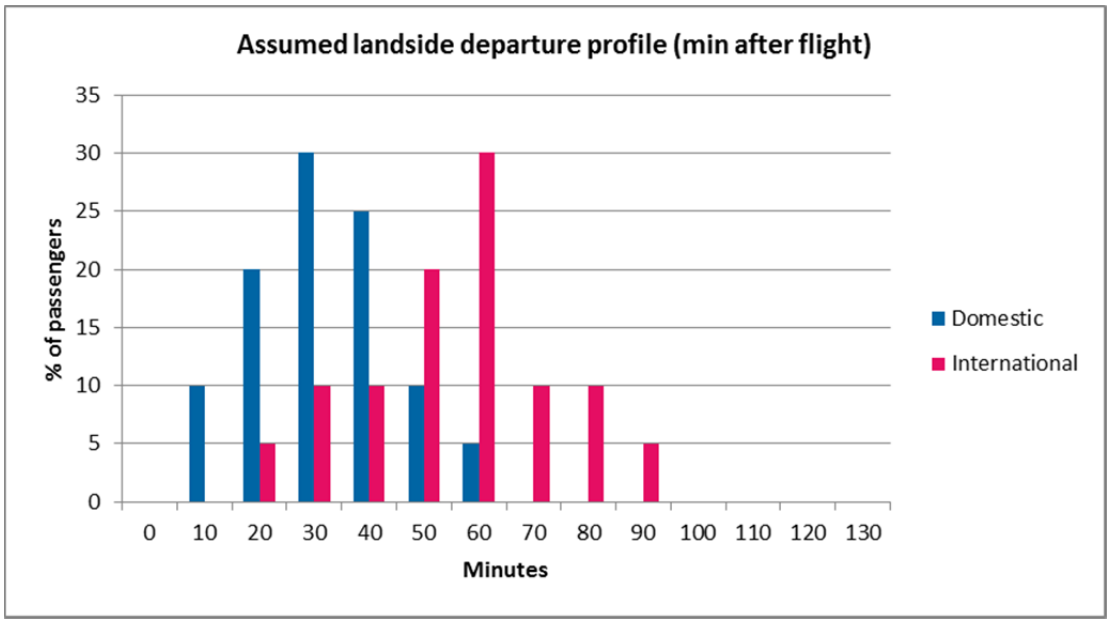


Figure 6-5 Assumed landside departure profile – percentage of passengers



The profiles were converted into passengers as follows:

- for each domestic aircraft, an assumed average capacity of 180 passengers with an average flight occupancy of 90 per cent has been assumed.
- for each international aircraft, an assumed average capacity of 420 passengers with an average flight occupancy of 90 per cent has been assumed.

The arrival and departure profiles, as passenger numbers, are shown in Figure 6-6 and Figure 6-7.

Figure 6-6 Landside arrival profile for passengers – volumes

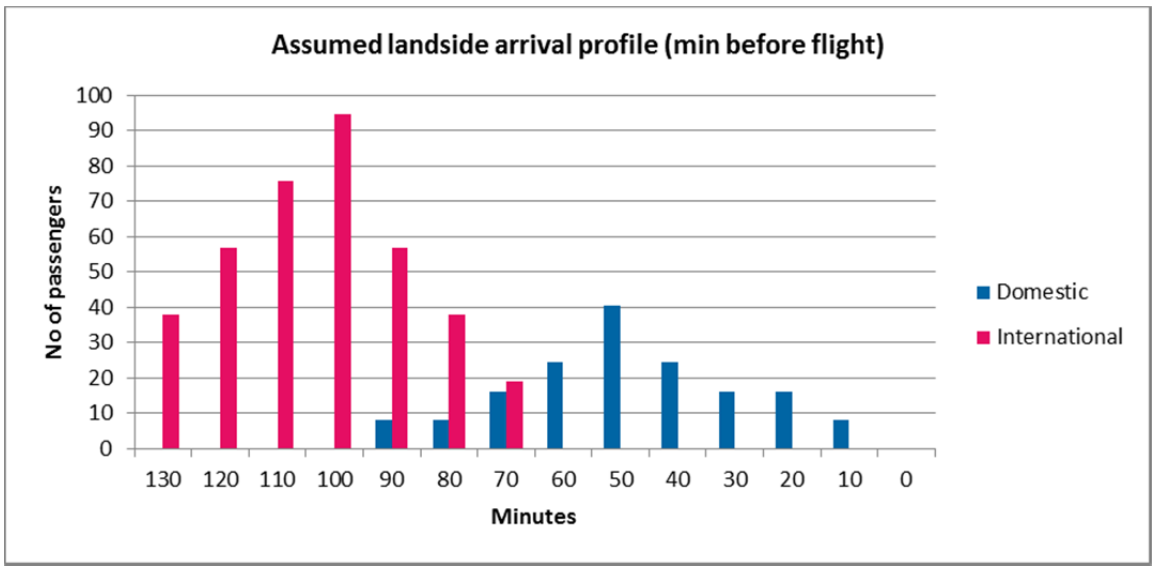
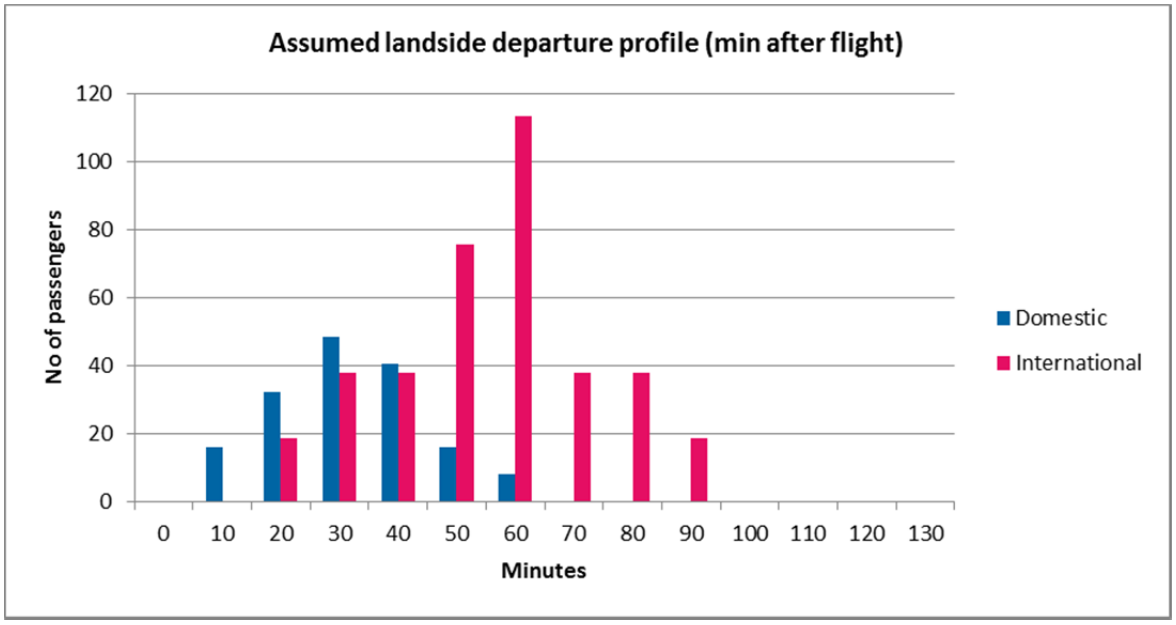
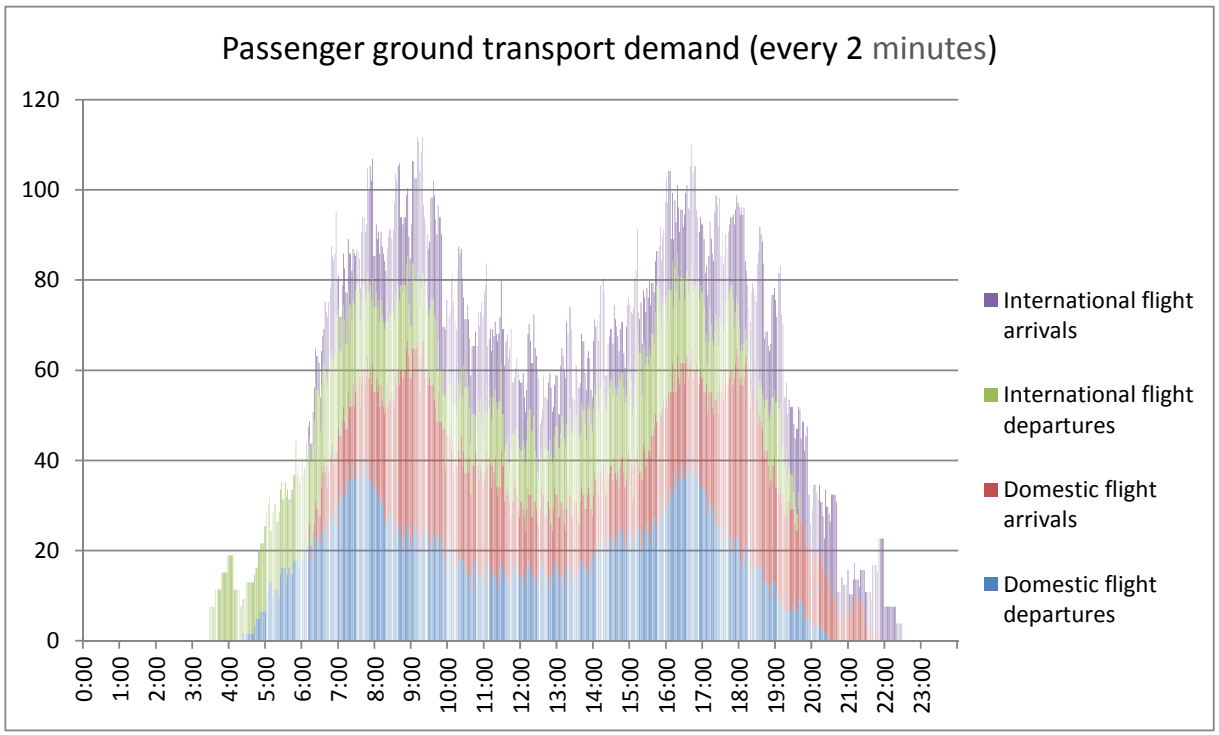


Figure 6-7 Landside departure profile for passengers – volumes



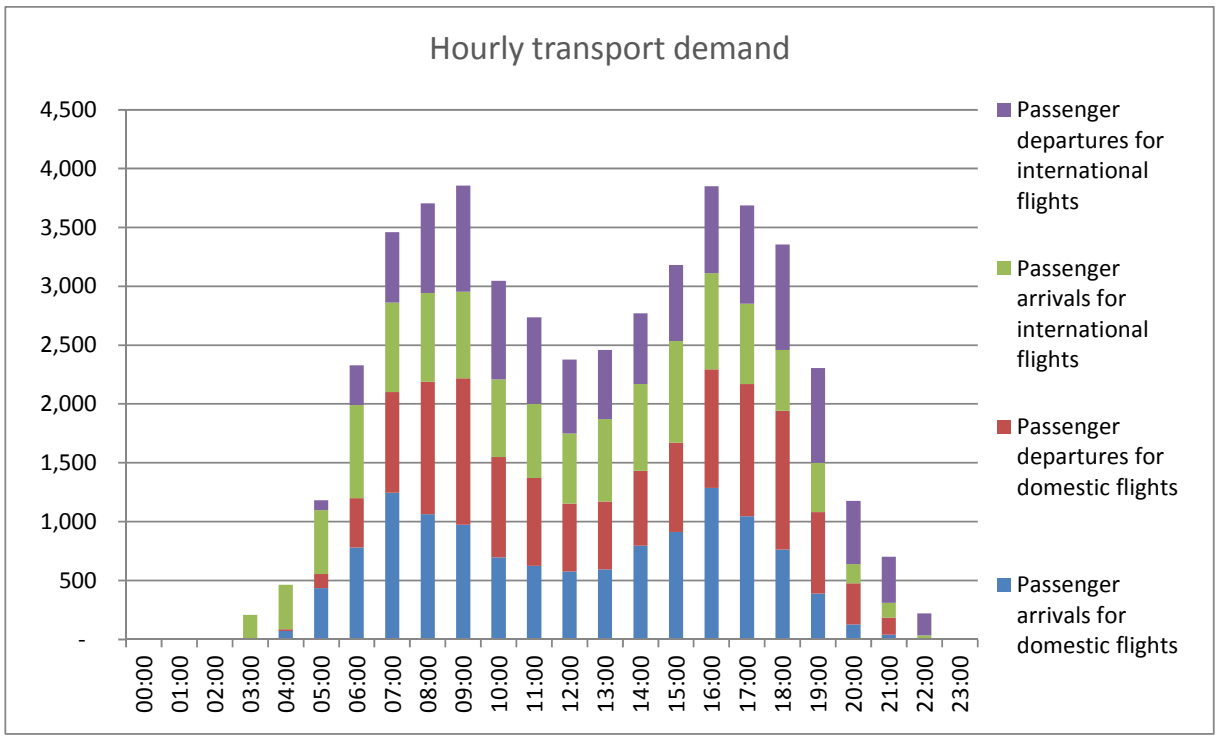
The combination of the arrival and departure profiles and the flight profiles results in a passenger distribution across the day in two minute intervals. A two-minute interval was chosen so that the longer term 2063 airport demand could be compared with the intervening years between 2031 and 2063. This is shown in Figure 6-8.

Figure 6-8 Two minute passenger ground transport demand - 2031



When this is converted into hourly volumes, the peak hourly demand is shown in Figure 6-9.

Figure 6-9 2031 ground transport demand per hour



6.2.3 Ground transportation modes

Departing and arriving passengers at the proposed airport would use various modes of travel. These have been assigned as the following modes:

- kiss ‘n’ fly;
- park ‘n’ fly;
- taxi;
- shuttles;
- bus;
- rail; and
- other modes.

Kiss ‘n’ fly

Kiss ‘n’ fly is the term used to describe air passengers being dropped at the airport terminal for departure or in short term parking for passenger arrival. These trips feature a trip to the airport in close proximity to a trip leaving the airport.

It has been assumed that each Kiss ‘n’ fly vehicle will contain 1.1 domestic passengers and 1.5 international passengers.

Park ‘n’ fly

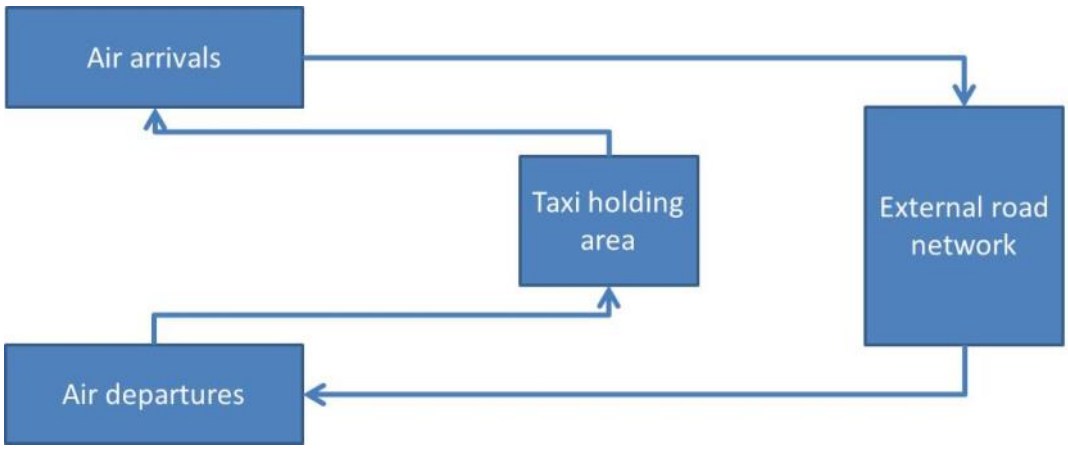
Park ‘n’ fly is the term used to describe air passengers driving themselves and parking in all day or longer term parking prior to flying and exiting the airport later in the same or subsequent days.

It has been assumed that each Park ‘n’ fly vehicle will contain 1.5 Park ‘n’ fly passengers.

Taxi

Taxis are a common form of travel to airports as they provide air passengers with flexibility in arrival. This category includes hire cars and “Uber” type services for the purposes of analysis. Each taxi is assumed to have an external trip to the airport, an internal trip to the holding area, another internal trip to pick up and a final external trip following collection of passengers leaving the airport. This is shown in Figure 6-10.

Figure 6-10 Airport taxi movements



It has been assumed that each taxi vehicle will contain 1.5 taxi passengers.

Shuttles

Shuttles are dedicated bus services with limited stops that run between major centres and key destinations and airports. These vehicles usually operate on motorway and arterial road networks to provide the most direct service and are privately operated.

It has been assumed that each shuttle will contain 15 passengers, representing a full mini bus.

Bus

Regular bus services would serve the proposed airport as part of their normal service. These buses provide in-direct connections to rail services on the Sydney Trains network at Penrith, Leppington and Liverpool. With the completion of the South West Rail Link Extension, these services may be redesigned to serve other areas.

It has been assumed that these buses will make one stop at each of the domestic and international terminals.

It has also been assumed that each terminal will have 15 arriving and 15 departing passengers per bus (within the arrival and departure profiles).

Rail

While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

For this assessment rail is assumed to service the proposed airport only after 2031. Provision of rail has been considered within the concept plan, with the preservation of a corridor within the airport. The analysis of rail has been considered to as part of the metropolitan Sydney network operated by Sydney Trains.

It has been assumed that the future rail station will have one stop to serve both terminals and will carry 200 arriving and departing passengers per train (within the arrival and departure profiles).

Other modes

Due to the relative isolation of the proposed airport terminal (2.5 km from Elizabeth Drive) and the unknown size and scale of any commercial development within the airport boundary, it has been assumed that walking and cycling to the airport (as passengers) will be minimal and is not included in the analysis.

6.2.4 Mode split

Based on the Sydney Airport Land Transport Model (SALTM), the proportions of use of each transport mode have been assigned, with the rail mode being discounted as it is assumed that no railway will exist for WSA until after 2031.

The approach used within this analysis varies from the SALTM model, as the SALTM model is a 4-step model that determines transport mode splits based on travel times and origin/destination pairs. The capacity of the proposed access road network has been identified as a constraint to be taken into account in the modelling. This constraint requires mode split proportions to be an input. The proportions assumed for each mode are shown in Table 6-3.

Table 6-3 2031 assumed mode split

Mode	2031 mode splits			
	Domestic		International	
	Drop off	Pick up	Drop off	Pick up
Kiss and Fly	30%	30%	40%	40%
Park and Fly	35%	35%	30%	30%
Taxi	20%	20%	20%	20%
Shuttle	5%	5%	5%	5%
Bus	10%	10%	5%	5%
Train	0%	0%	0%	0%

6.2.5 Dwell times

For each transport mode, there is a range of dwell times based on the mode type and trip purpose. For example, an international Kiss 'n' fly pickup trip may involve arriving prior to the flight's arrival at the proposed airport, allowing enough travel time to cater to the variability in the external road network and the passengers being collected passing through the border. In comparison, a bus vehicle will have a nominated dwell time at each stop.

The nominated dwell times for each mode are shown in Table 6-4.

Table 6-4 2031 assumed dwell times by mode

Mode	Dwell time (minutes)			
	Domestic		International	
	Drop off	Pick up	Drop off	Pick up
Kiss and Fly	6	16	120	44
Park and Fly	-	-	-	-
Taxi	16	16	16	16
Shuttle	30	30	30	30
Bus	3	3	3	3
Train	3	3	3	3

6.2.6 Mode distribution

Using the values identified in the previous sections, each passenger has been assigned to a transport mode. The hourly demand is shown in Figure 6-11 to Figure 6-14.

These passenger demands are then agglomerated into passenger entries and exits from the airport as shown in Figure 6-15 to Figure 6-16.

Figure 6-11 Domestic air departures – ground arrival at the proposed airport

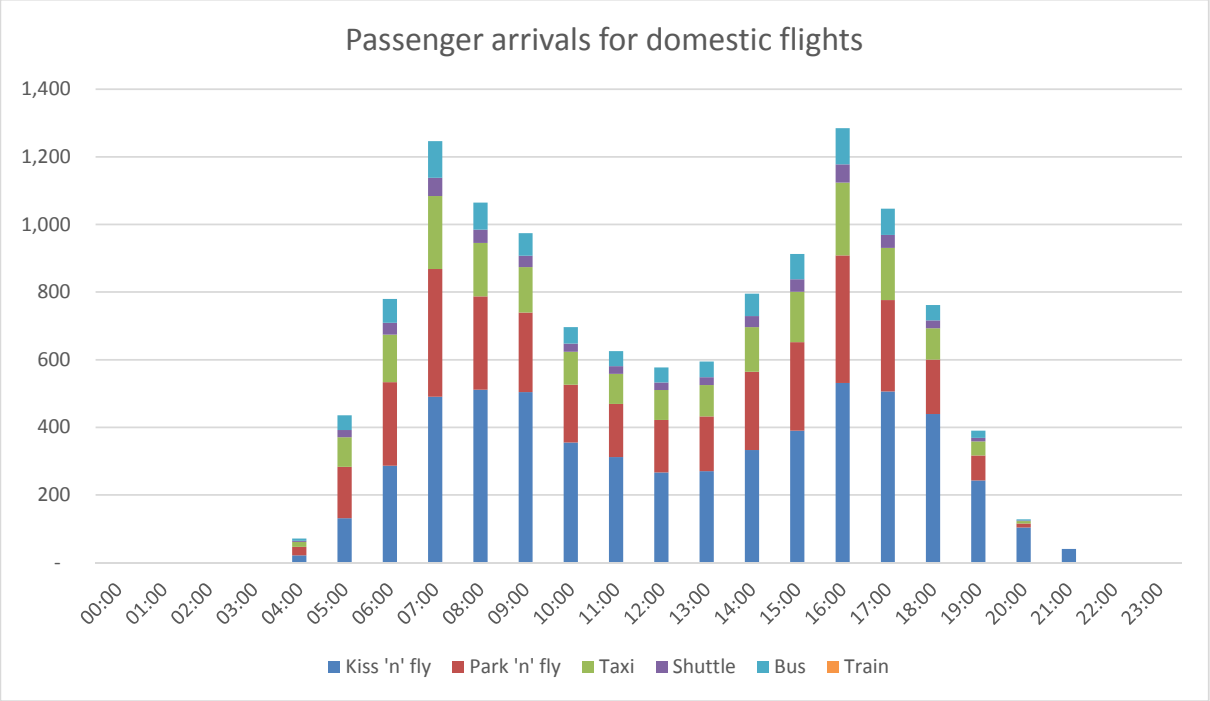


Figure 6-12 Domestic air arrivals – ground departure from the proposed airport

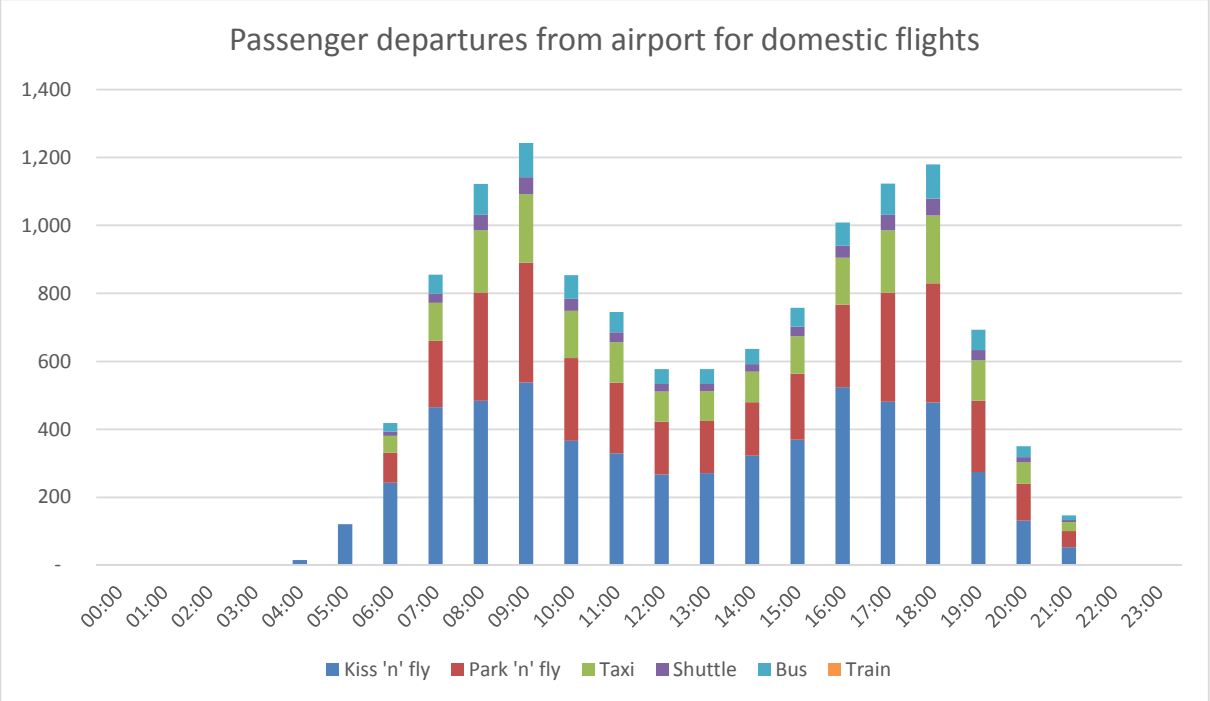


Figure 6-13 International air departures – ground arrival at the proposed airport



Figure 6-14 International air arrivals – ground departure from the proposed airport

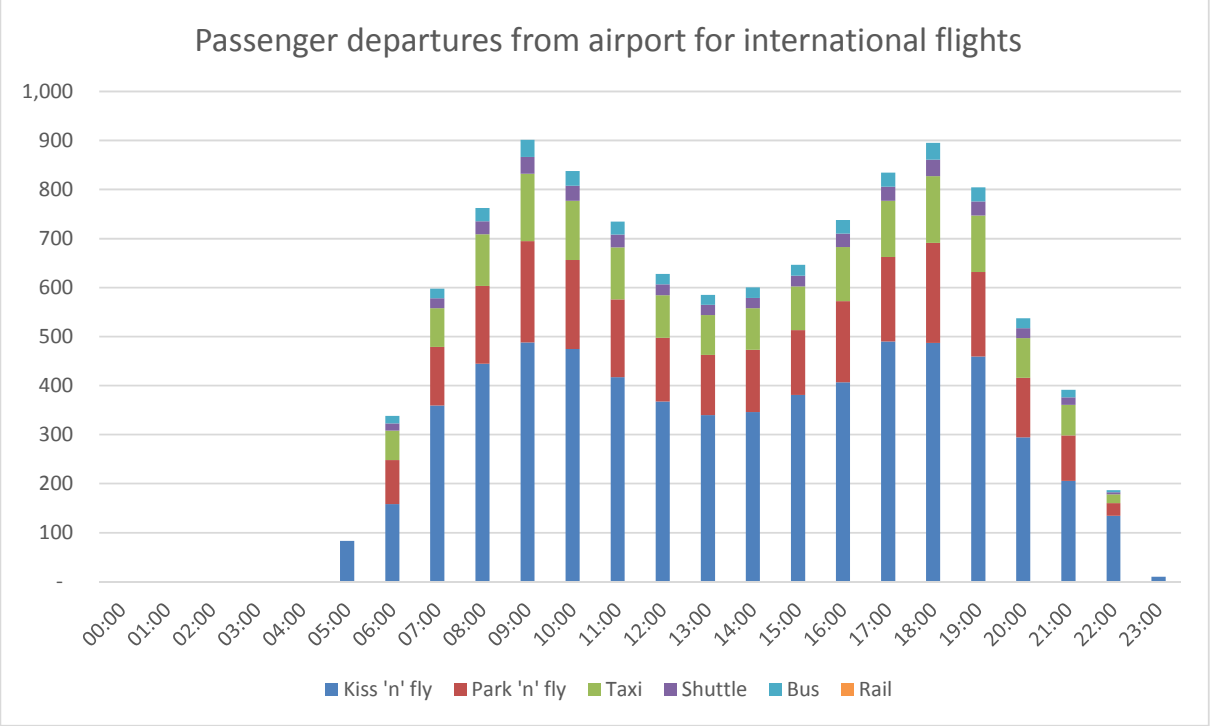


Figure 6-15 Total air departures – ground arrival at the proposed airport

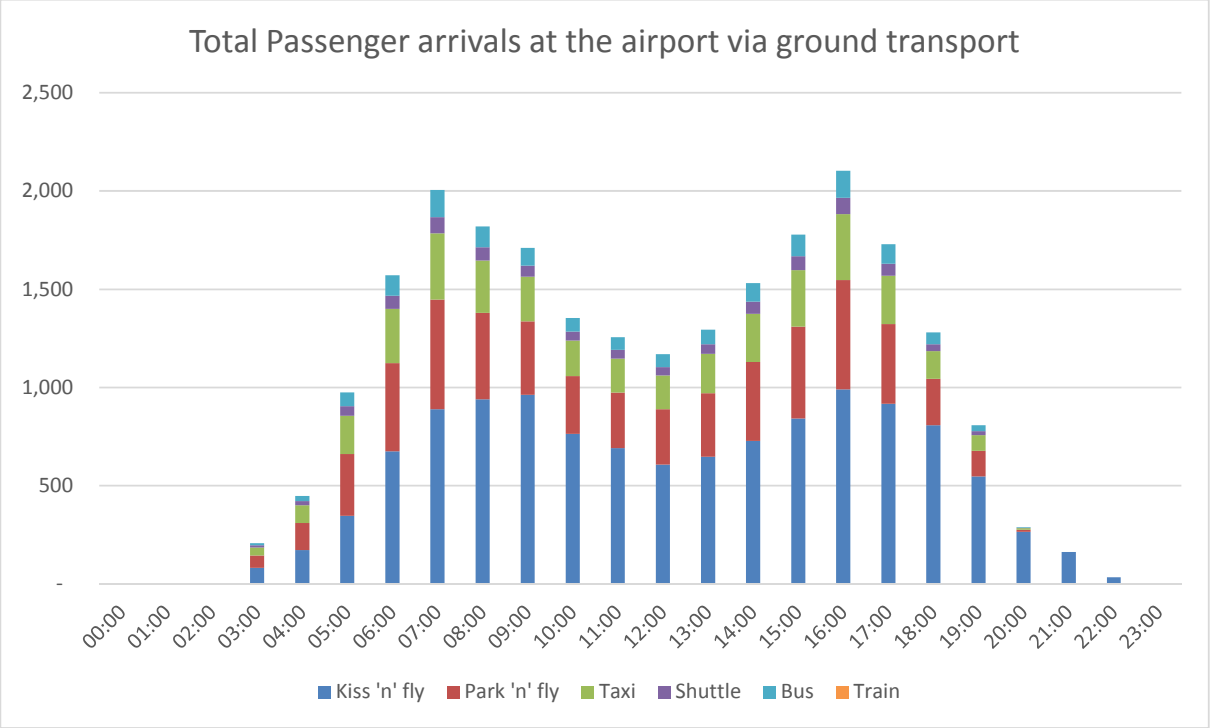
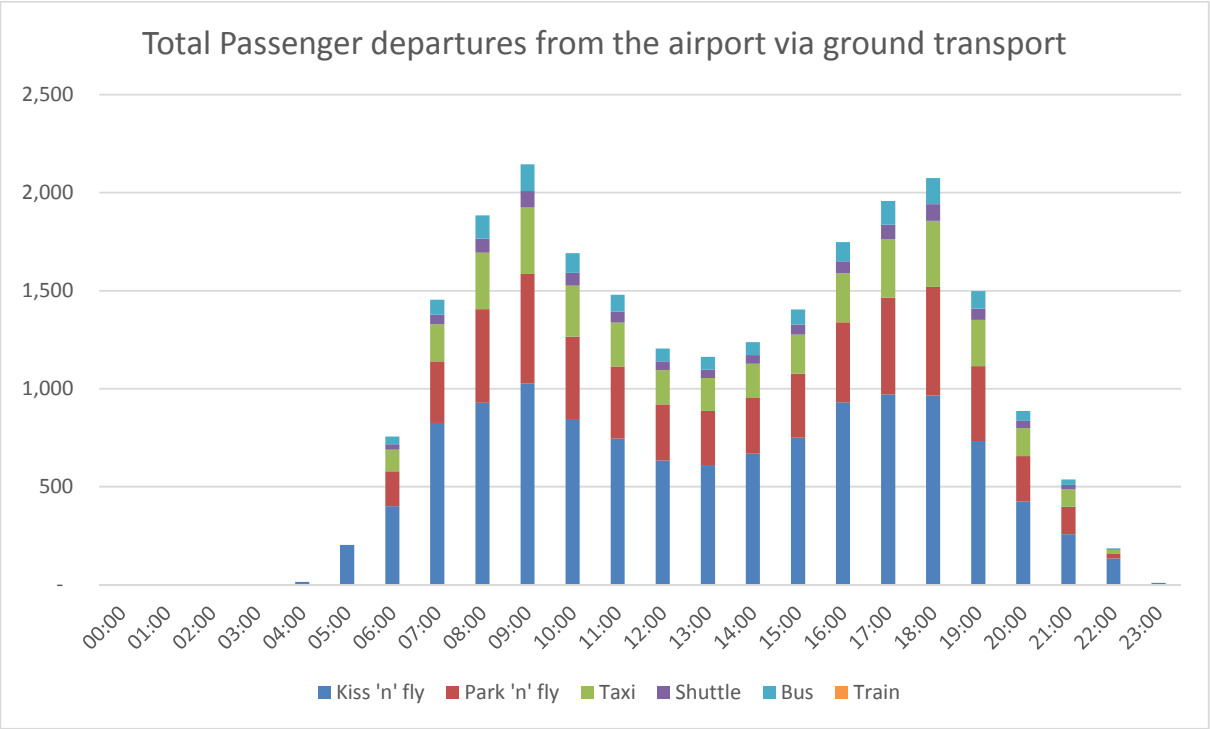


Figure 6-16 Total air arrivals – ground departure from the proposed airport



6.2.7 Traffic generation

The trips developed in section 6.2.6 are then assigned to vehicles entering the airport at the northern boundary point and onto the internal road network. The vehicle volumes across the day are shown in Figure 6-17 to Figure 6-22.

Figure 6-17 Passenger vehicles entering at the northern boundary of the proposed airport by mode

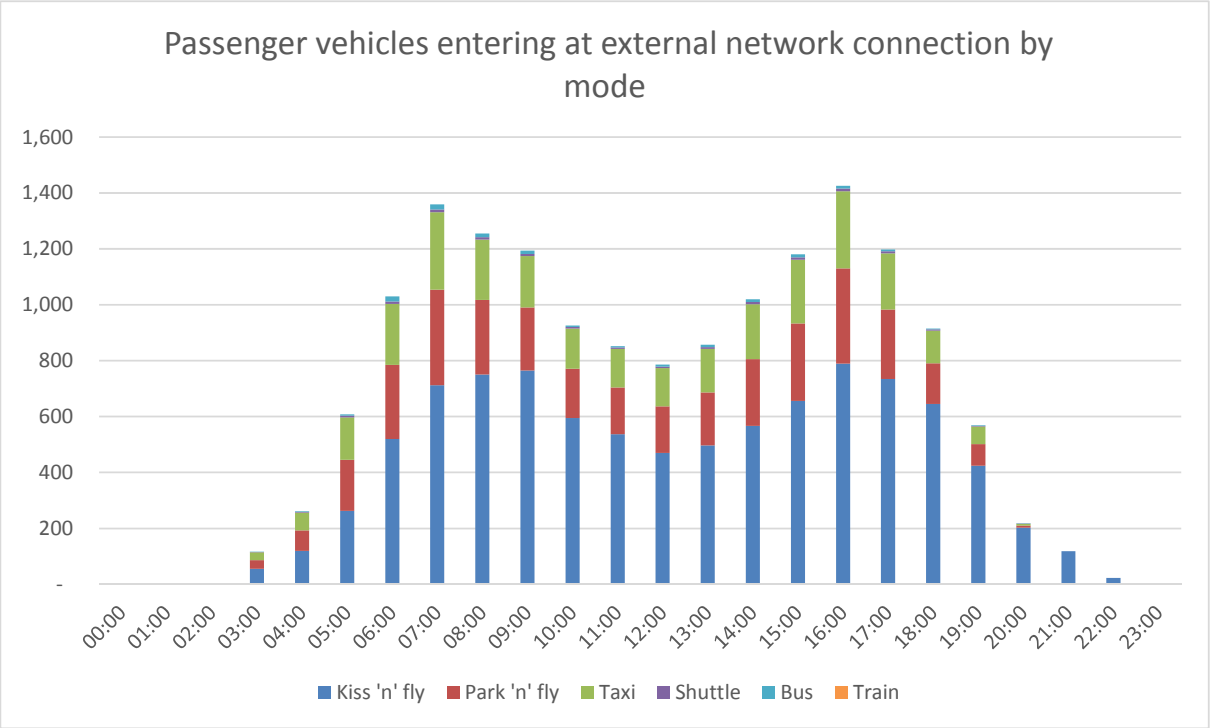


Figure 6-18 Passenger vehicles exiting at the northern boundary of the proposed airport by mode

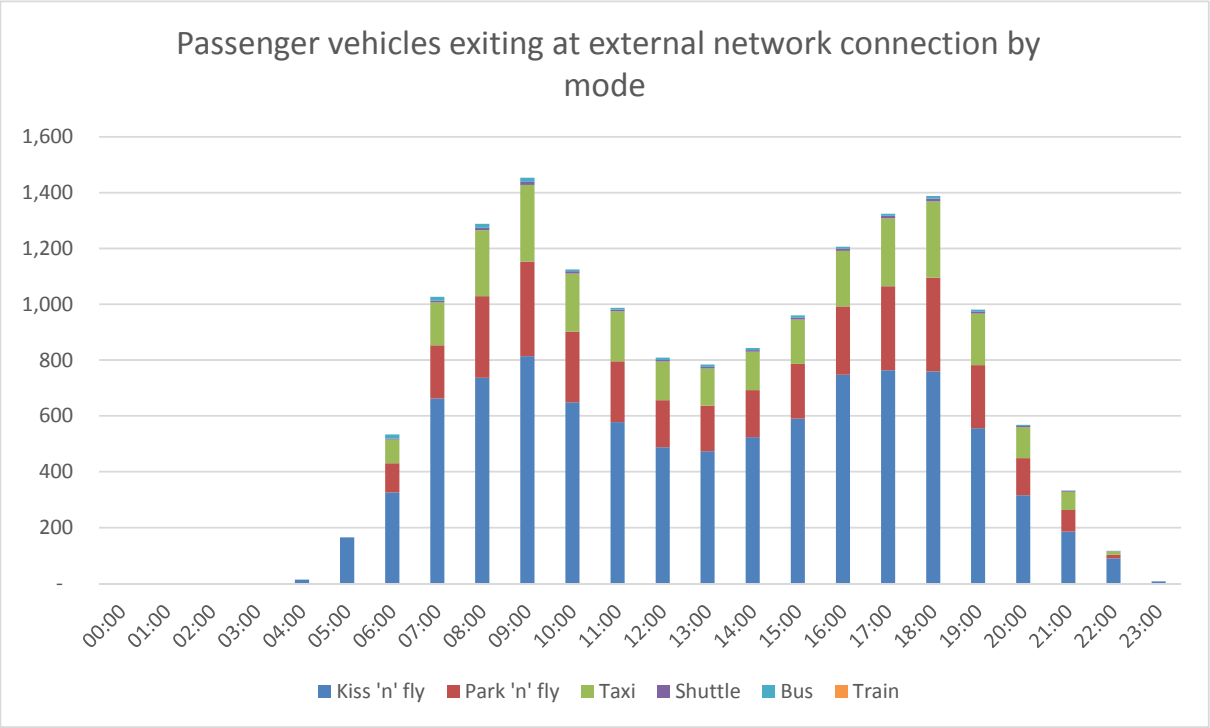


Figure 6-19 Passenger vehicles entering at the northern boundary of the proposed airport by vehicle type

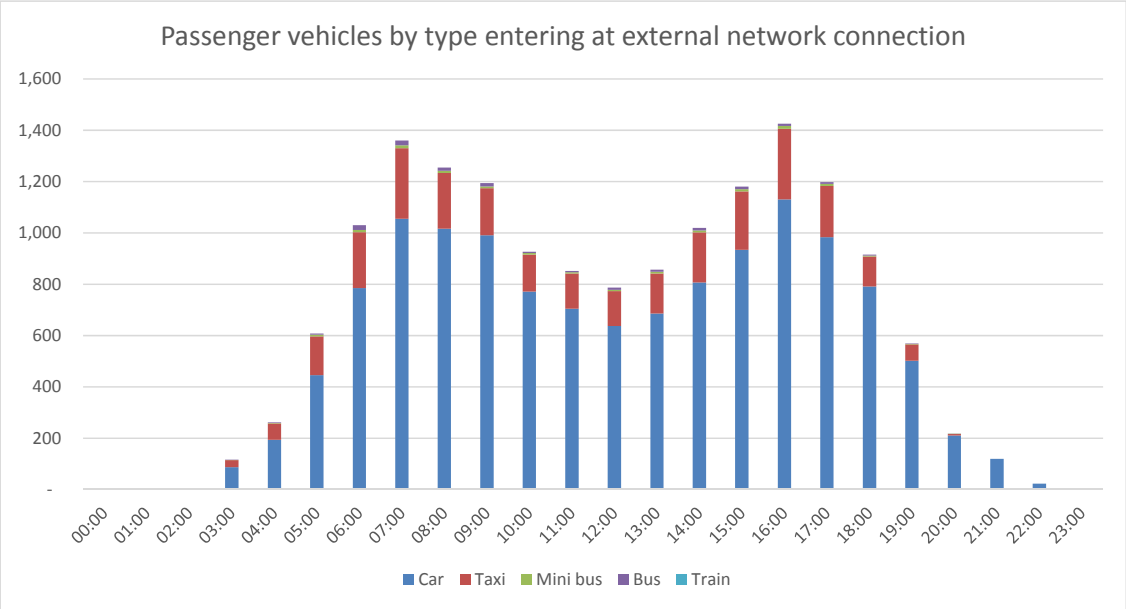


Figure 6-20 Passenger vehicles exiting at the northern boundary of the proposed airport by vehicle type

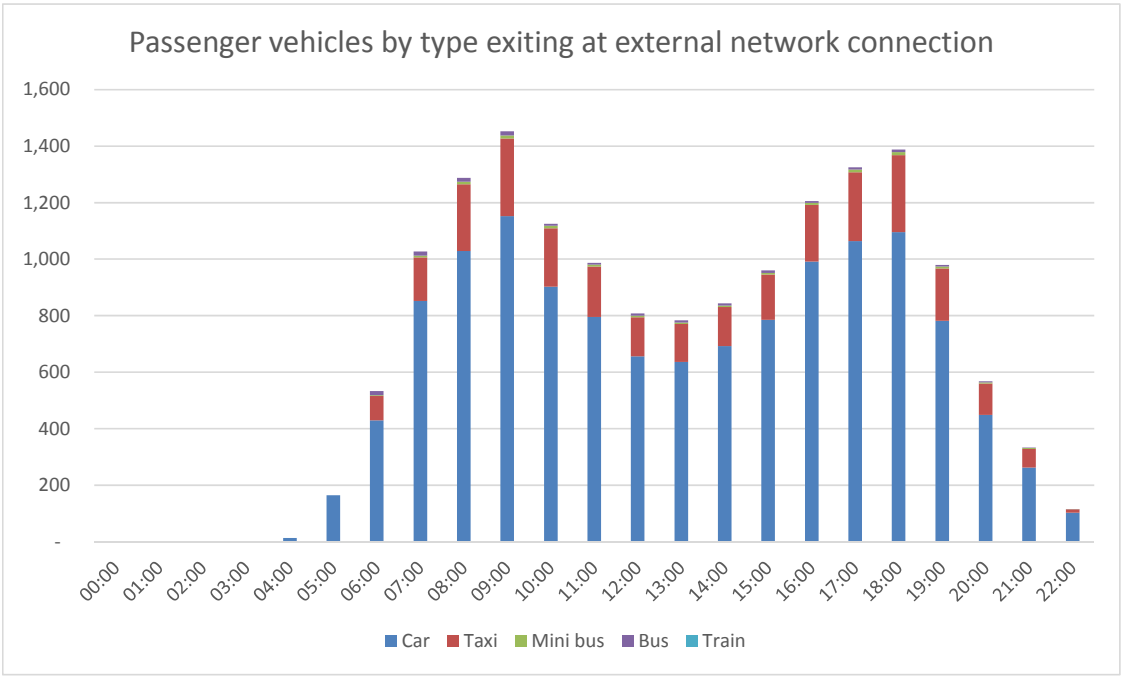


Figure 6-19 shows that the projected vehicle demand is 1,359 vehicles entering the proposed airport during the AM traffic peak and 1,425 vehicles entering the proposed airport during the PM peak period.

Figure 6-20 shows 1,453 vehicles leaving the proposed airport during the AM peak and 1,388 leaving the proposed airport during the PM peak.

In addition to the vehicles arriving at the boundary of the proposed airport, the circulating movements of the taxis (as shown in Figure 6-10) are added into the traffic volumes to determine the internal traffic demand.

Figure 6-21 Passenger vehicles arriving at terminal and car park entrances

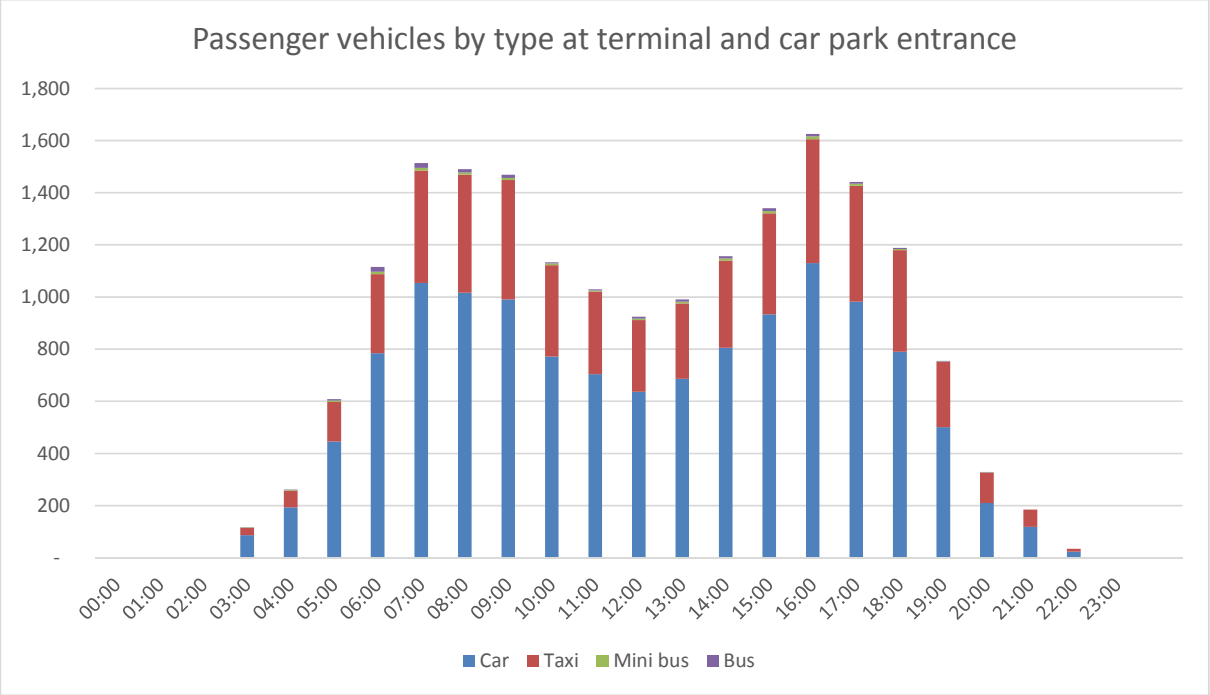


Figure 6-22 Passenger vehicles leaving the terminal and car park exits

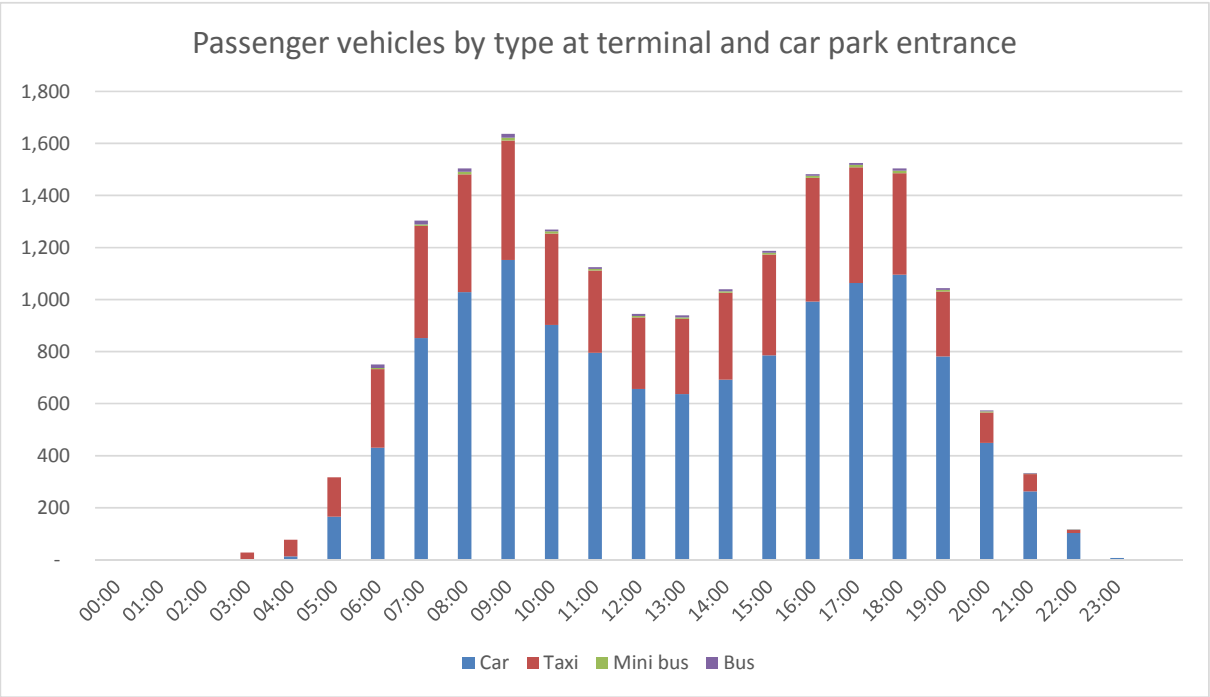


Figure 6-21 shows that the vehicle demand is 1,625 vehicles entering the terminal area in the AM peak and 1,441 vehicles entering the terminal area during the PM peak.

Figure 6-22 shows that the vehicle demand is 1,637 vehicles leaving the terminal area of the airport during the AM peak and 1,525 vehicles leaving the terminal area of during the PM peak.

6.3 Employee trip generation

Employee trip generation for the proposed airport has been assumed to be based on shifts determined on a synthetic basis and based on SALTM.

6.3.1 Total employee estimate

The number of employees required in 2031 can be estimated based on a ratio of employees per million annual passengers (MAP). A ratio of 750 employees per MAP has been used for estimating employee trip generation.

The application of this ratio results in an employee level of approximately 7,600 for the 2031 airport operation.

Only airport-related employees are included in the traffic modelling. As noted on page 1, non-aeronautical commercial operations could be allowed on the site, which could generate extra traffic, from workers and potentially customers. While these potential operations are not part of the proposed action, it is acknowledged that these operations and their consequential traffic impacts have not been factored into the assessment.

6.3.2 On site employees

The 2011 Census (ABS) identifies that 15,296 people were employed at Sydney Airport within the airport boundary. Of these, 13,522 worked on census day, resulting in an employee on site ratio of 88 per cent.

The Census also identified that when the travel zones for Mascot directly north of the airport, are included (Qantas Headquarters and catering), the number of employees increases to 38,002 with 33,595 working on census day – also a ratio of 88 per cent.

The Airport Cooperative Research Program (ACRP) under the Transportation Research Board (TRB) has undertaken a benchmarking exercise for mode splits at USA and select international airports in the ACRP Report 4 – *Ground Access to Major Transports by Public Transportation* (2008).

This report reveals that for the USA (which has similar travel characteristics to Australia), airports that have public bus services only have low employee mode splits, while those served by either rail or staff shuttles have a higher public transport mode split. Table 6-5 shows a sample of mode splits from airports in the USA for workers.

Table 6-5 Airport employment characteristics – USA airports

Airport	Size (a)	Estimated number of employees on-site, typical	Estimated % of employees working	Estimated % of employees traveling during commute peaks	Estimated % of employee residences served by transit	Estimated % of employee residences served by transit	Other major employment centres
						Number of Centres	Number of Centres with Transit
Birmingham (AL)	S	n/a	50%	70%	0%	3	3
Boston	L	14,600	68%	78%	n/a	2	2
Chicago O'Hare	L	n/a	56%	48%	n/a	3	1
Dallas/Fort Worth	L	40,000	n/a	90%	70%	2	2
John Wayne	M	1,000	50%	70%	80%	0	n/a
Las Vegas	L	8,000	85%	30%	90%	0	n/a
Louisville	M	n/a	5%	10%	n/a	1	1
Omaha	M	2,500	45%	33%	0%	0	n/a
Sacramento	M	1,500	80%	25%	50%	0	n/a
Salt Lake City	L	n/a	75-80%	60%	75%	3	3
San Diego	L	3,000	97%	15%	n/a	0	n/a

From Table 6-5, where both airport employee values and percentage of employees working information is available, there is an average 71 percent of employees working. Averaging the USA and Sydney (Kingsford Smith) Airport data (88 per cent) results in an approximate 80 per cent of employees being on site.

For the purposes of the EIS, it has been assumed that 80 per cent of employees will be on-site on any given day to allow for changes in shift work over the next 48 years to 2063. This results in the proposed airport having 6,158 employees on site on any day in 2031.

The shift profiles are shown in Table 6-6.

6.3.3 Employee shifts

The airport employees have been categorised into the following:

- airfield operations: 3 shifts of 8.5 hours.
- terminal support: 2 main shifts plus 2 split shifts
- office workers: 2 shifts offset by 1 hour.

Shift profiles of workers can be seen in Table 6-6.

Airfield operations

Airfield operations consist of the activities that keep the airfield operating safely such as aircraft control, site security, firefighters etc.

This also includes a component of terminal support for overnight operations.

This has been assumed to be a constant 4 per cent of employees undertaking this activity at any time based on the number of flights arriving and departing during the late night/ early morning periods.

Terminal support

Terminal support includes Customs and Border Protection, retail and dining and airside activities such as baggage handling and refuelling. These shifts are dependent on the number of passengers using the airport.

It has been assumed that there would be two (2) x seven (7) hour shifts with two additional ½ shifts of 4 hours.

Office workers

Office workers include back office support and administration for airfield, airline and terminal activities and a level of regular terminal activities. For the purposes of the EIS analysis, it has been assumed that flexible work practices apply with some employees starting in the hour between 7 and 8 AM and the remainder commencing work between 9 and 10 AM, with a 9 hour shift for each group.

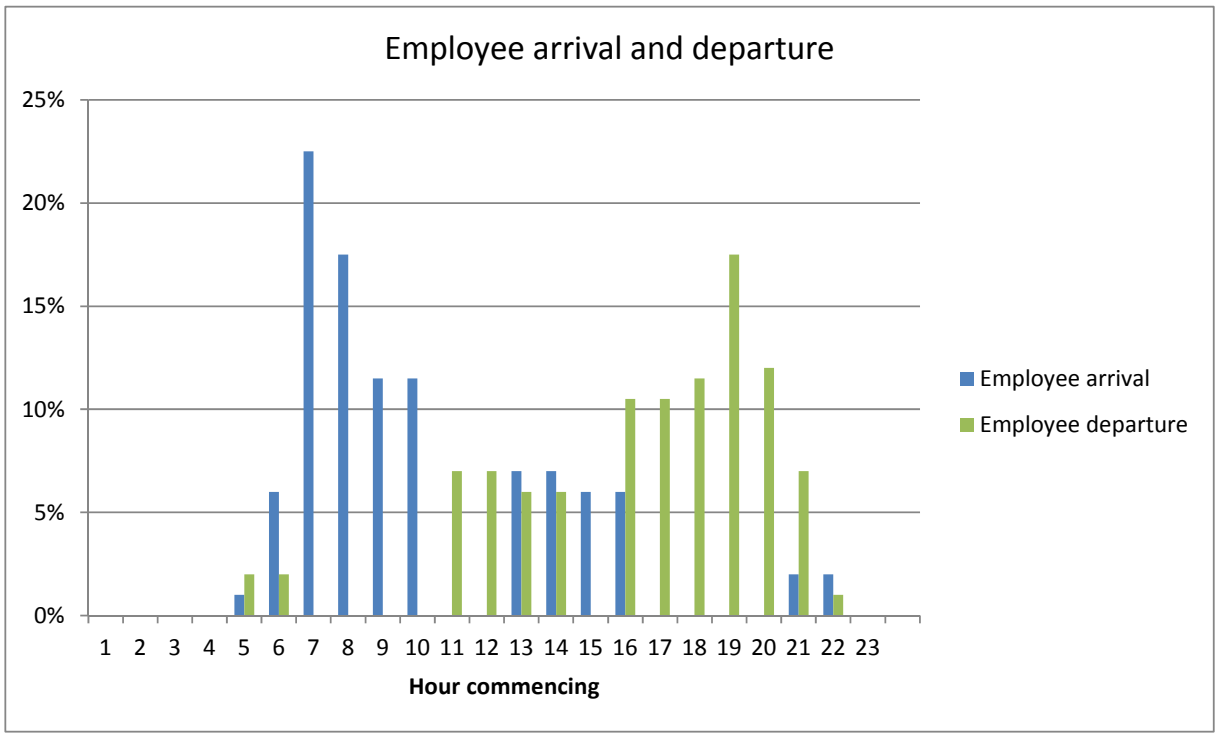
Table 6-6 WSA assumed 2031 shift profiles

Worker type	Start	Finish	Percent of total employees	No. of employees
Airfield and terminal overnight	21:00	05:00	2	220
Airfield day	05:00	13:00	3	123
Airfield afternoon	13:00	21:00	3	123
Terminal support morning	06:00	13:00	10	616
Terminal support afternoon	13:00	20:00	10	739
Terminal supplementary morning	06:00	11:00	14	862
Terminal supplementary afternoon	15:00	19:00	14	739
Office early start	07:00	17:00	21	1,293
Office later start	09:00	19:00	23	1,416
		Total	**100**	**6,158**

6.3.4 Employee arrival and departure profiles

A synthetic profile for employee arrivals and departures prior to and after their shifts has been created to allow for some early and late starts and finishes for employees. For each shift, 50 per cent of employees have been assumed to arrive in the hour before their shift starts and the remaining in the hour that the shift starts. A similar process has been developed for completion of shifts. This results in the profile shown in Figure 6-23.

Figure 6-23 Employee arrival and departure profile - percentage



This translates into the volume of employees arriving and departing in each hour as shown in Figure 6-24.

Figure 6-24 Employee arrival and departure profile - volume

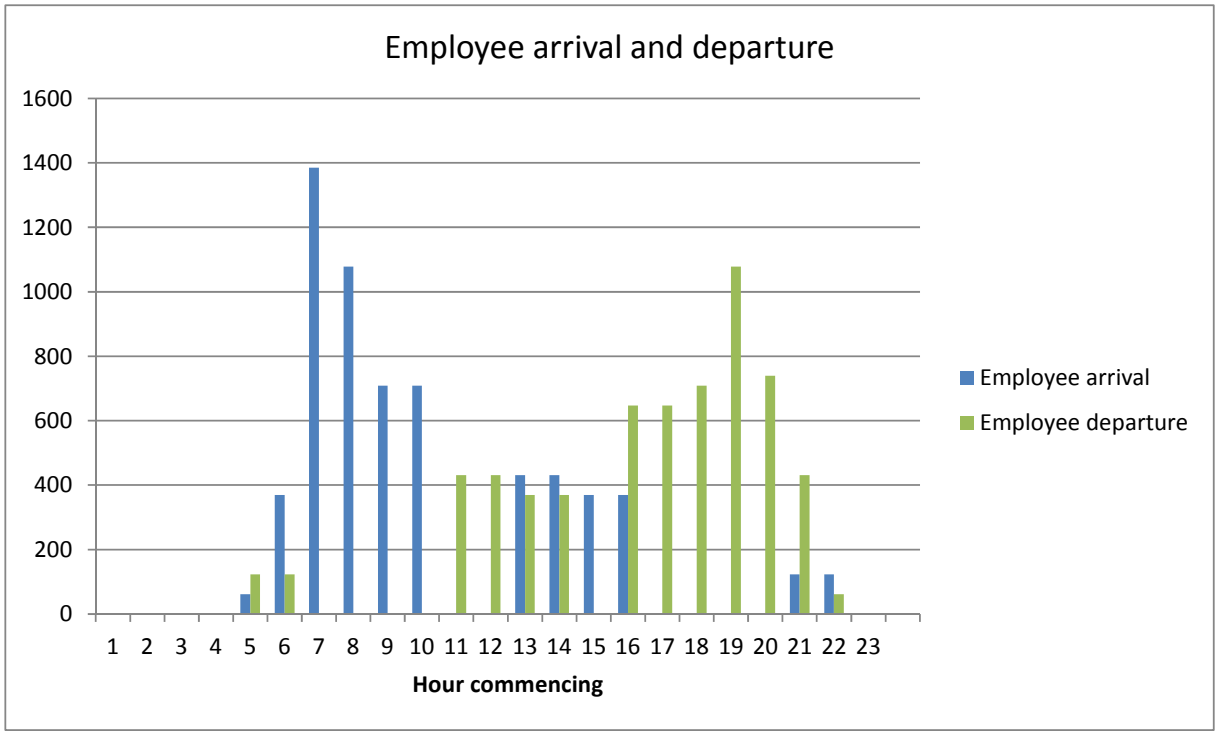
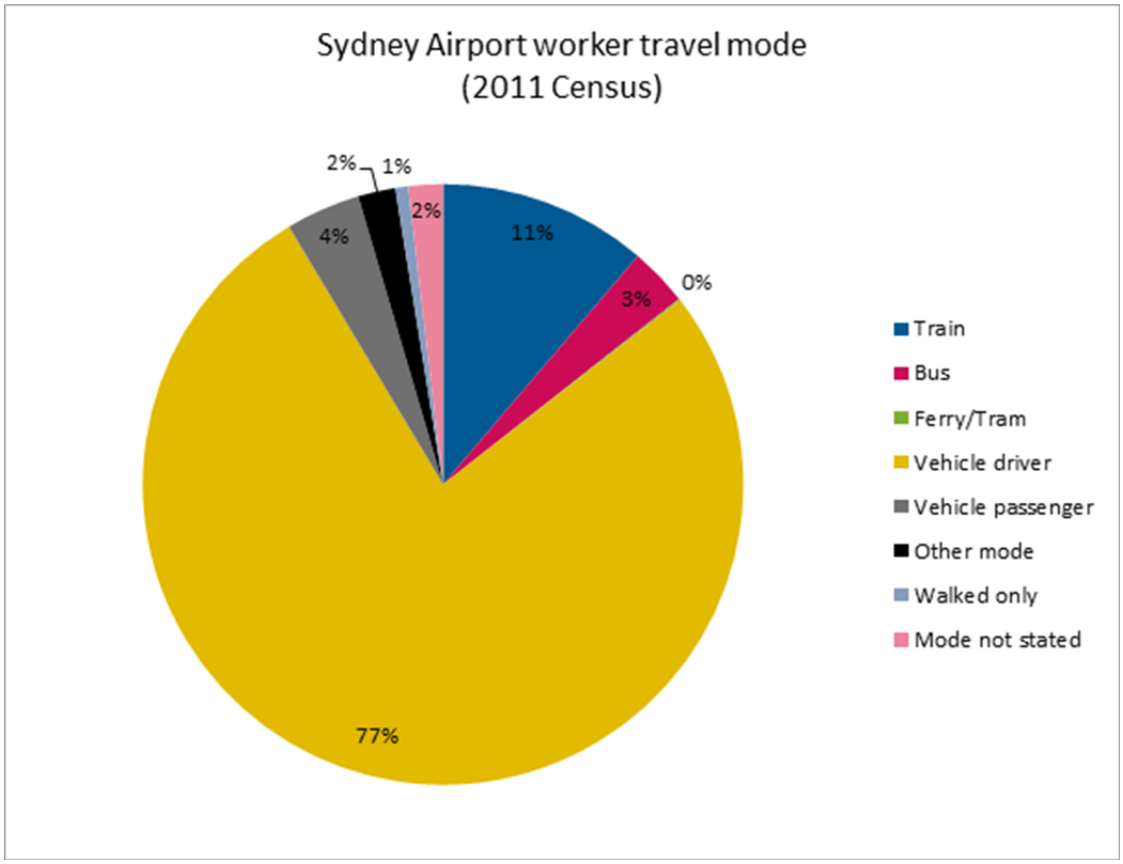


Figure 6-24 shows that the peak arrival for the AM peak period is 1,386 employees and the PM peak departure for employees is after the main transport network peak between 7 and 8 pm, with 1,086 employees leaving in this hour.

6.3.5 Mode split

The employee mode split has been determined using the Sydney Airport overall mode splits for journey to work and modifying it by reassigning the train mode to car based modes. The Sydney Airport mode splits are shown in Figure 6-25.

Figure 6-25 Sydney (Kingsford-Smith) Airport employee mode split



Source: Bureau of Transport Statistics 2011

Sydney Airport has a rail mode split of 11 per cent. As it is assumed that the proposed airport will not have a railway line until after 2031, these trips have been apportioned to other modes.

Additionally, as the proposed airport is relatively isolated from the surrounding development, it has been assumed that no employees would use public transport in the early hours of the morning to arrive at the airport due to service limitations.

An evaluation of the existing mode splits for employment in areas surrounding the airport site shows the limited use of public transport for overall workplace travel (Table 6-7).

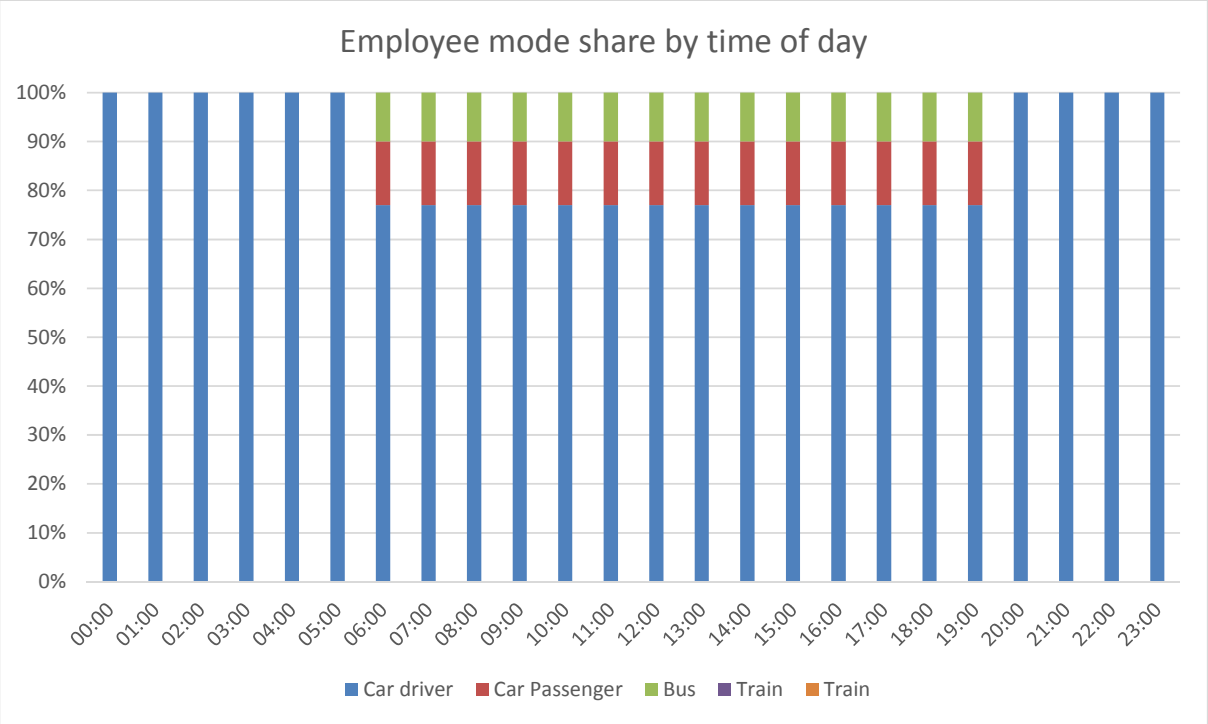
Table 6-7 Employee mode split for areas adjacent to WSA in 2011

LGA	Population	Car Driver	Car Passenger	Public Transport	Other
Liverpool	180,143	64	5.8	12.4	17.8
Penrith	178,467	64.7	5.5	10.7	19.1
Camden	56,720	69	4.6	6.8	19.6
Fairfield	187,766	63	7.4	13.1	16.5
Campbelltown	145,967	60.1	5.7	17.1	17.1
Blacktown	301,099	60.5	5.9	17.6	16
Holroyd	99,163	57.5	5.5	20.4	16.6
Average	**164,189**	**62.7**	**5.8**	**14.0**	**17.5**
Population weighted average		**62.2**	**5.9**	**14.6**	**17.2**

Source: Transport for NSW Journey to Work browser

The assumed mode split by time of day is shown in Figure 6-26.

Figure 6-26 2031 employee mode split by time of day



Using the distributions applied in the previous sections, the employee trips have been assigned to the transport modes. These are shown in Figure 6-27 and Figure 6-28 for arrivals and departures respectively.

Figure 6-27 Employee arrivals by mode by time of day

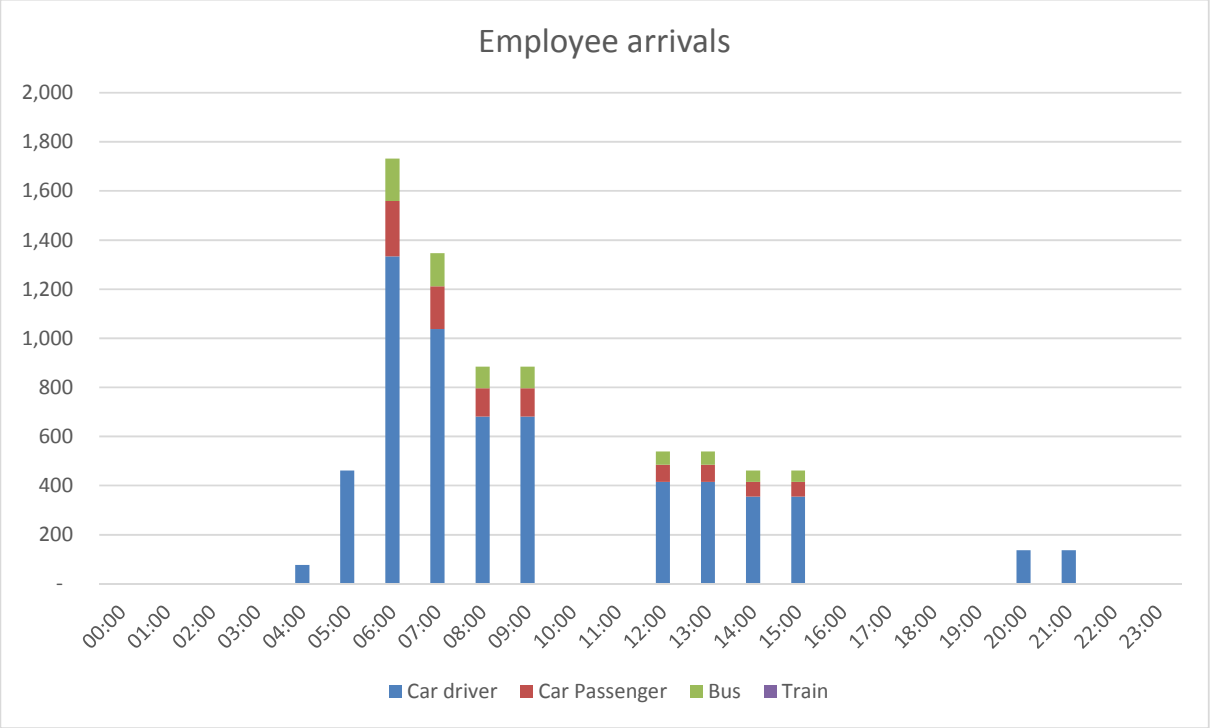


Figure 6-28 Employee departures by mode by time of day

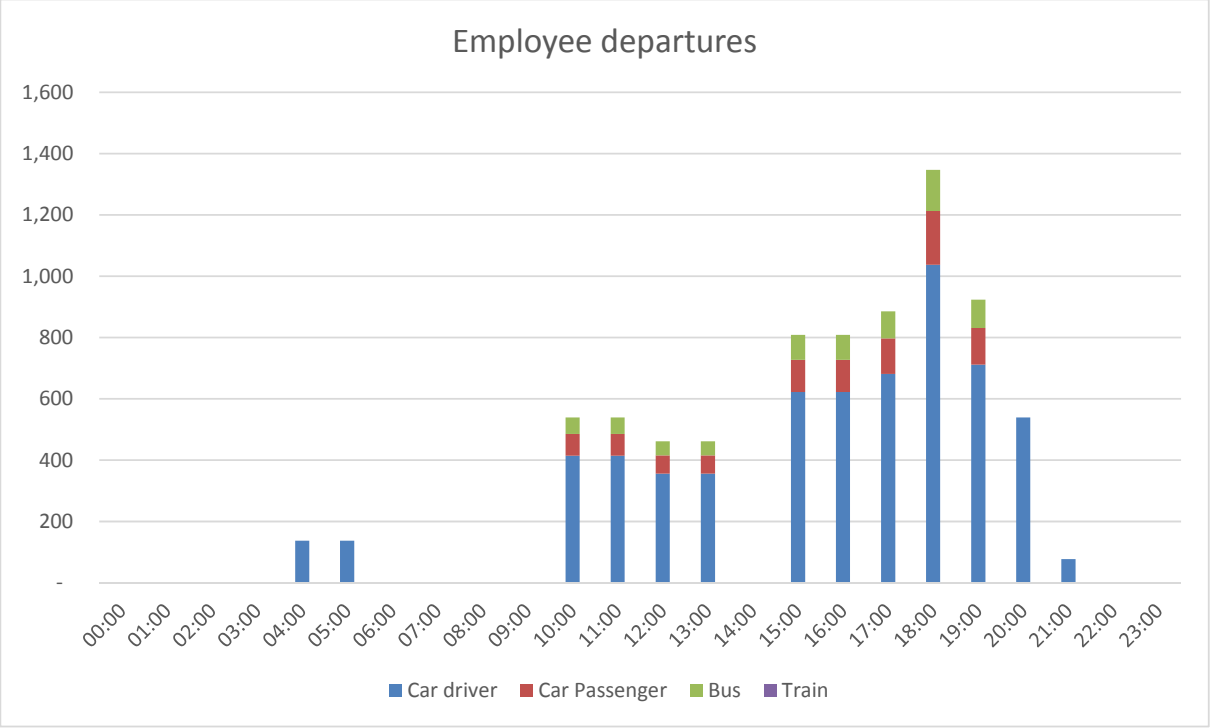


Figure 6-27 shows that the AM peak hour arrival volume for employees is greater than 1,700 arriving during the 7-8 am traffic peak time period, with the majority being car drivers.

Figure 6-28 shows that the PM peak hour departure volume for employees is greater than 1,300 during the PM peak period.

6.3.1 Traffic generation

The traffic generation for employees is shown in Figure 6-29 and Figure 6-30.

Figure 6-29 2031 employee vehicle arrivals by mode

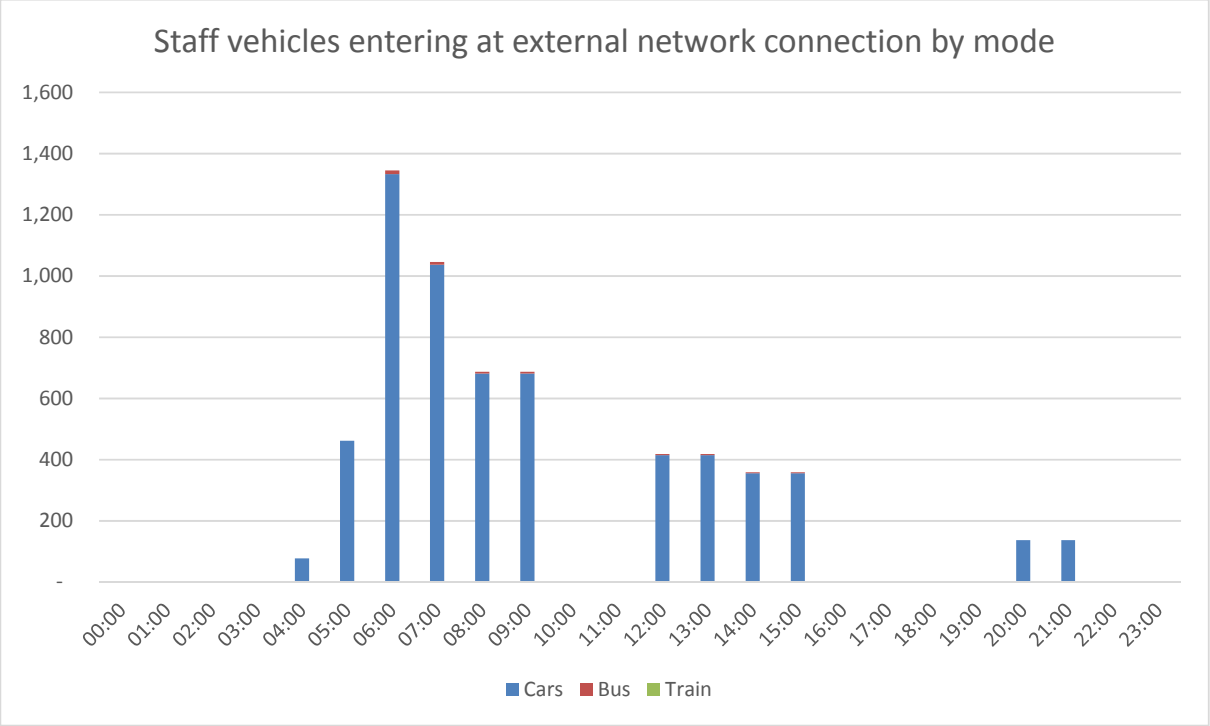


Figure 6-30 2031 employee vehicle departures by mode

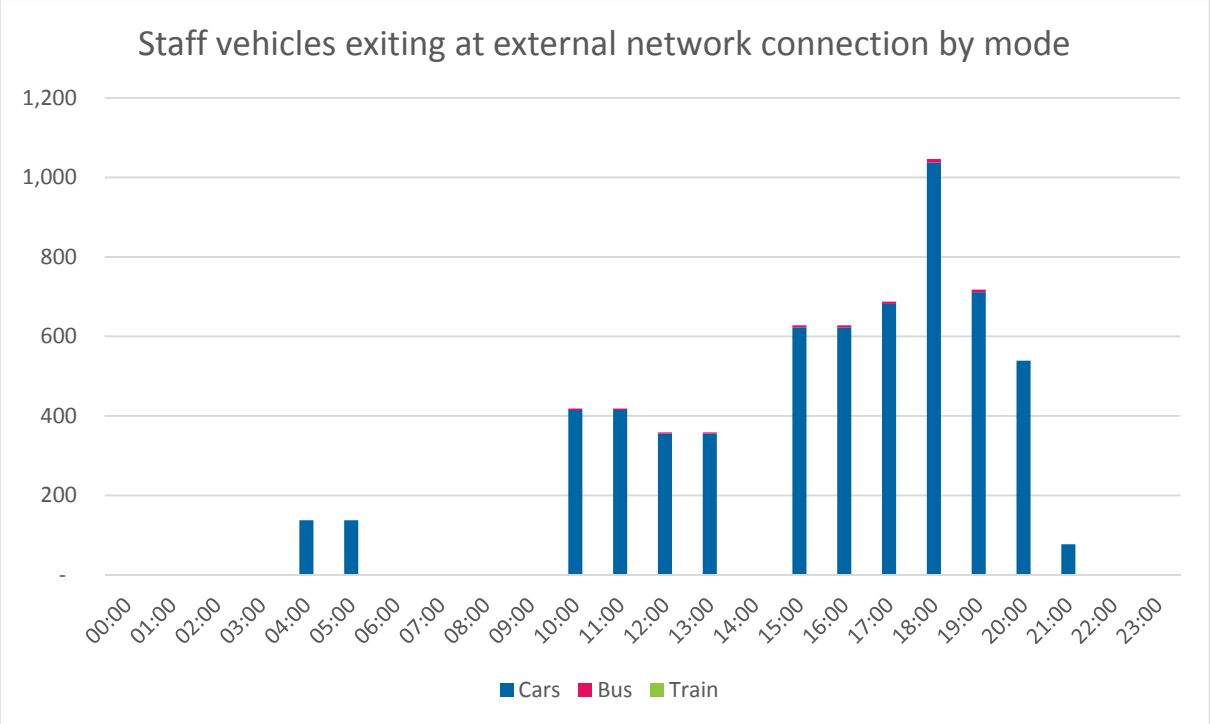


Figure 6-29 and Figure 6-30 show that the employee traffic generation peaks are outside the nominal main traffic peaks (of 7-9 AM and 4-6 PM as used in the STM) for both the arrival and departure of employees.

6.4 Combined air passenger and employee trip generation

The total trip generation for air passengers and employees for 2031 based on the total trips for each hour is shown in Figure 6-31 and Figure 6-32.

Figure 6-31 Total arrival trip generation by mode

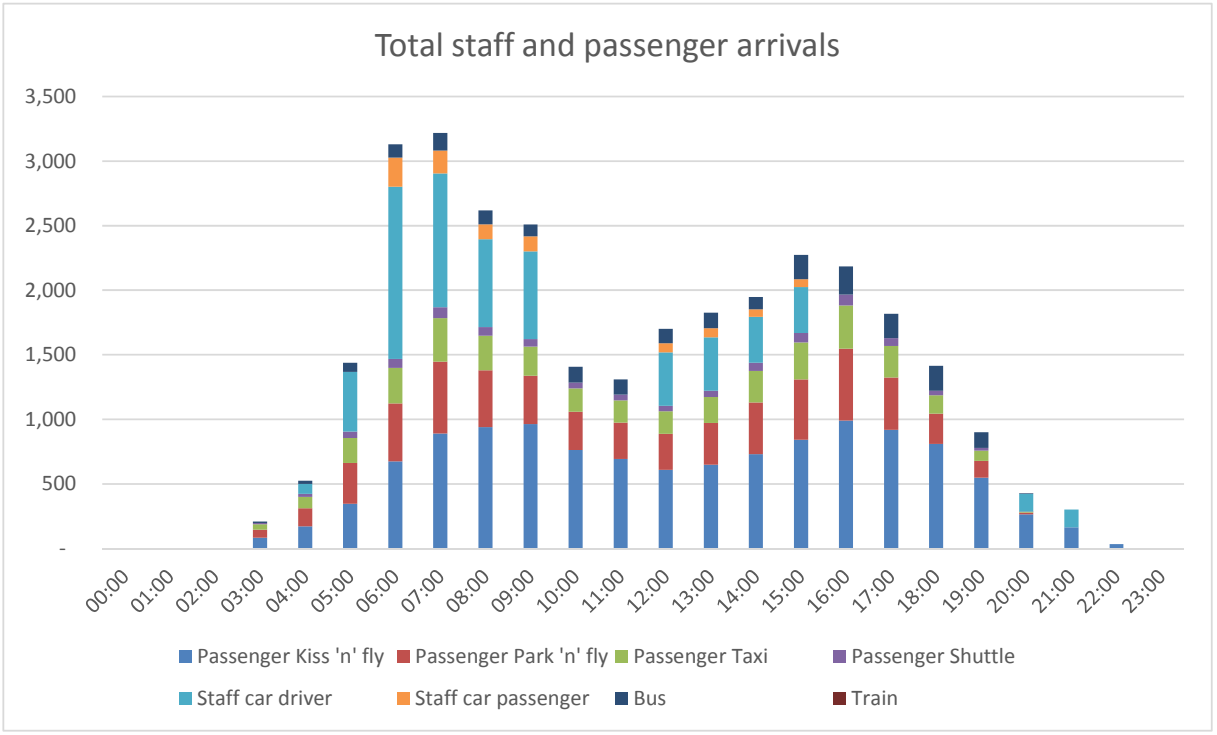


Figure 6-32 Total departure trip generation by mode

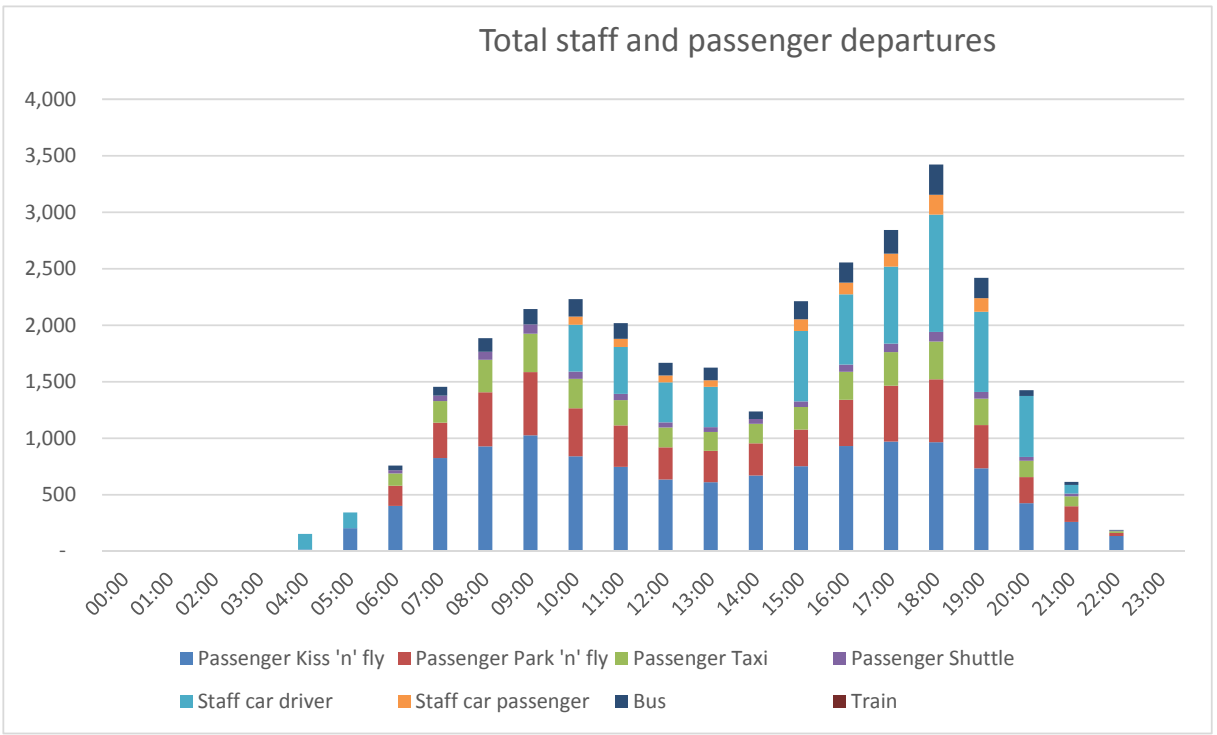
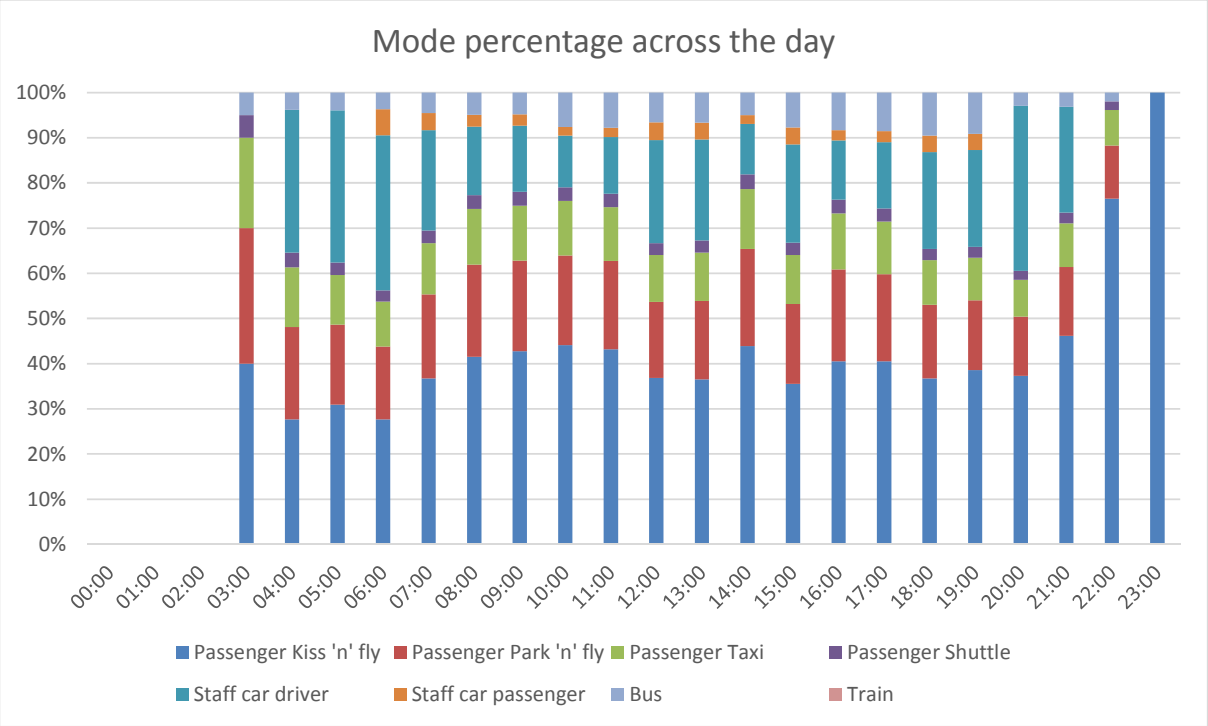


Figure 6-31 shows that the peak trip generation to the proposed airport occurs between 7 and 8 AM and is 3,218 trips.

Figure 6-32 shows that the peak trip generation from the proposed airport occurs between 6 and 7 PM and is 3,422 trips.

When the actual mode splits across the day are determined based on the preceding sections, the resultant average mode split is as shown in Figure 6-33.

Figure 6-33 Mode split across the day



6.5 Total air passenger and employee traffic generation

The trips identified in Sections 6.2 and 6.3, converted into traffic trips to and from the proposed airport via the connection to the external transport network, are shown in Figure 6-34 to Figure 6-37.

Figure 6-34 Traffic generation to the main entrance of the proposed airport by mode

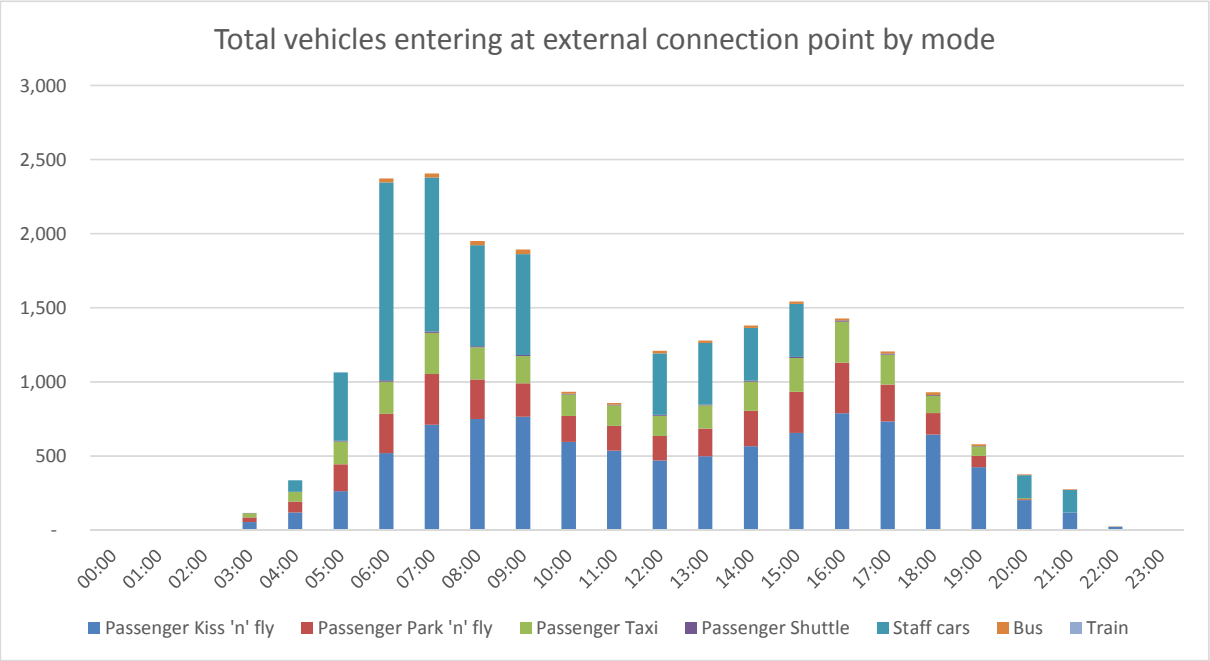


Figure 6-35 Traffic generation from the main entrance of the proposed airport by mode

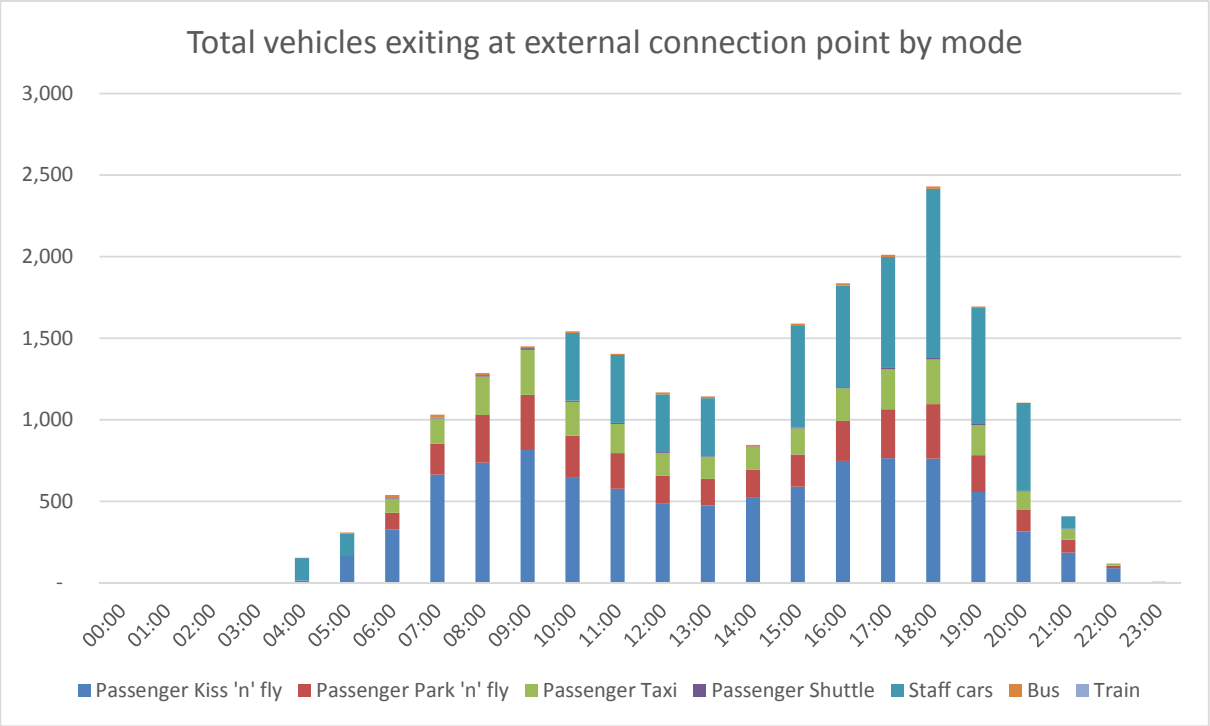


Figure 6-36 Traffic generation to the main entrance of the proposed airport by vehicle type

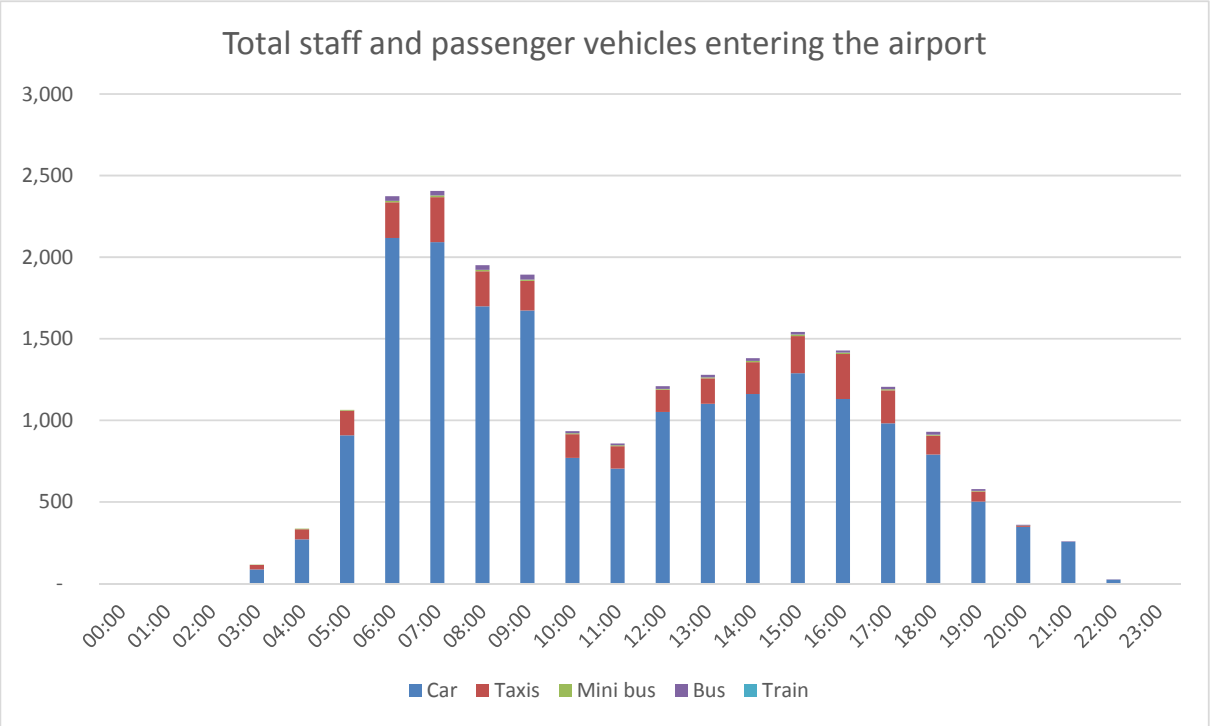


Figure 6-37 Traffic generation from the main entrance of the proposed by vehicle type

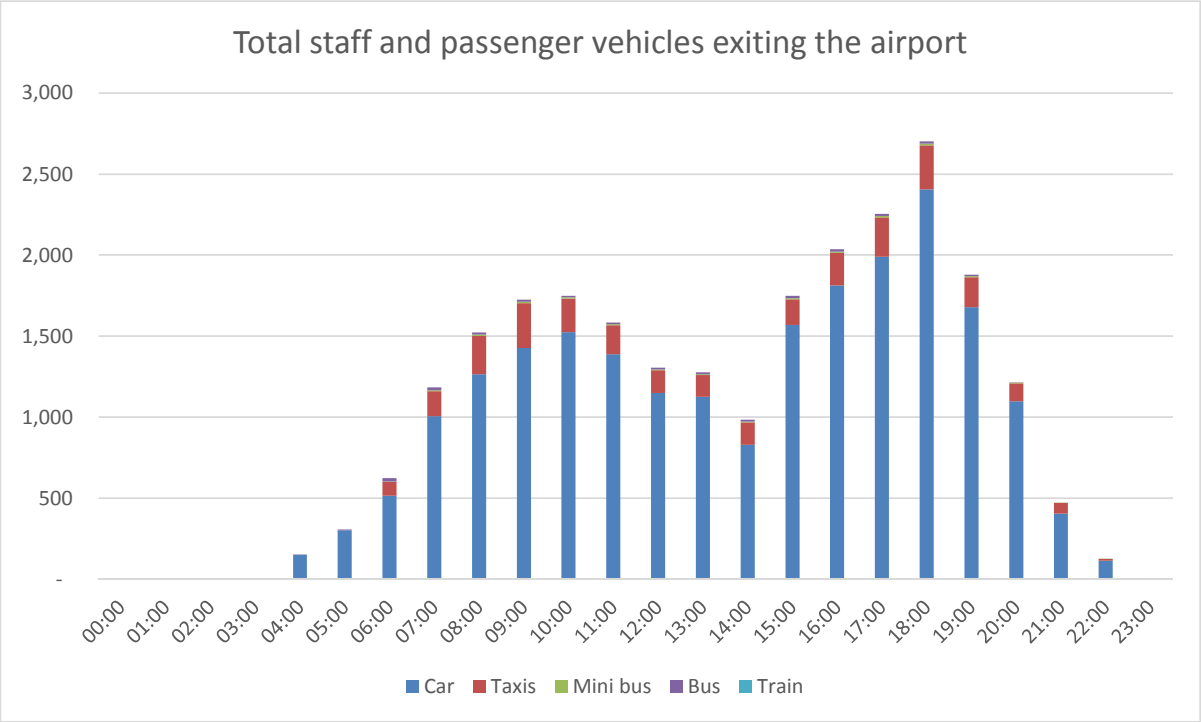


Figure 6-36 shows that the peak vehicle demand to the proposed airport is between 7 and 8 AM and is 2,406 vehicles per hour.

Figure 6-37 shows that the peak vehicle demand away from the proposed airport is between 6 and 7 PM and is 2,702 vehicles per hour.

6.6 Freight trip generation

Freight demand has been provided for air freight cargo and for the fuel depot. No demand estimates for airport consumables (e.g. food, retail items) or predictions of waste removal quantities from the proposed airport terminals are available as it is not possible to determine these items without a detailed terminal plan.

6.6.1 Air freight

The freight demand for air cargo is estimated to be 190,793 tonnes in 2031.

In order to turn these cargo loads into freight trips, it has been assumed that the cargo freight arrives using the proportions of heavy rigid trucks, semi-trailers and B-doubles as shown in Table 6-8.

Each freight cargo truck carrying mass and its percentage of the fleet is shown in Table 6-9.

Table 6-8 2031 freight vehicle expansion factors

Vehicle type	Percentage of vehicle fleet	Number of car equivalents (pcu)	Cargo mass carried (tonnes)
Heavy Rigid Truck (12.5 metres long)	65	2	12.5
Semi-Trailer (19 metres long)	25	3	40
B-Double (23 -26 metres long)	10	5	56

Table 6-9 2031 two-way freight truck movements

Vehicle type	2031 Annual movements	2031 Daily movements	2031 Hourly movements	2031 Car equivalents (pcu) per hour
Heavy Rigid Truck (12.5 metres long)	53,051	152	6	13
Semi-Trailer (19 metres long)	6,376	17	1	2
B-Double (23 -26 metres long)	1,822	5	0	1

6.6.2 Fuel deliveries

It has been estimated that in 2031, approximately 43 B-Doubles of fuel per day would be required serve the operations at the proposed airport until such time as a fuel pipeline is provided.

Based on the expansion factors used in section 6.6.1, this would result in two B-Doubles per hour, or 35 passenger car units (pcus) per hour entering the site and the same number exiting the site. These volumes are minimal in comparison to the volumes generated by other airport activities.

6.7 Total airport traffic generation estimate

The traffic generation calculations presented in this section are inserted into the traffic model to assess their impact. The figures are presented for the representative 2-hour periods used in STM3, with a 24 hour total. Table 6-10 provides the collation of trip generation estimates developed in the section.

Table 6-10 Total modelled traffic to/from the proposed airport in 2031

	AM Peak 2 hour	Interpeak 2 hour	PM Peak 2 hour	Evening 2 hour	24 Hour
Accessing Airport					
Passengers	2,582	1,862	2,518	1,276	15,774
Airport Workers	1,375	498	190	573	4,871
Freight (TNR)	9	26	13	57	277
Total (Accessing)	**3,966**	**2,386**	**2,721**	**1,905**	**20,922**
Egressing from Airport					
Passengers	2,286	1,983	2,312	1,357	15,774
Airport Workers	0	411	1,027	704	4,885
Freight (TNR)	9	26	13	57	277
Total (Egressing)	**2,295**	**2,420**	**3,353**	**2,117**	**20,936**

Note that the analysis excludes the traffic to and from the proposed airport generated by associated commercial development or freight traffic for consumables.

The slight discrepancy in accessing and egressing totals is due to park-and-fly trips where access and egress profiles are calculated separately and external taxi trips where the inbound and outbound occupancy rates differ.

6.8 Airport traffic distribution

The traffic generated from the Airport was distributed using STM3. This calculates traffic distribution from first principles, by using the land use inputs combined with the generalised costs of travel from origin to destination zone. As such, this source is considered the best available for the proposed airport generation, considering the condensed timeframes for this stage of the study.

7. Operational impact assessment

7.1 Background traffic growth

As a result of existing and future planned developments in Western Sydney, there is expected to be a considerable amount of development growth in coming years, largely comprised of:

- South West Priority Growth Area
- Broader Western Sydney Employment Area
- Greater Macarthur Land Release Investigation Area
- the proposed Western Sydney Airport
- smaller growth centres

An analysis has been carried out of the number of trips originating in each of the SA3 statistical areas within approximately 10 km of the airport site, as shown in Figure 7-1.

Figure 7-1 Statistical areas in the vicinity of the airport site

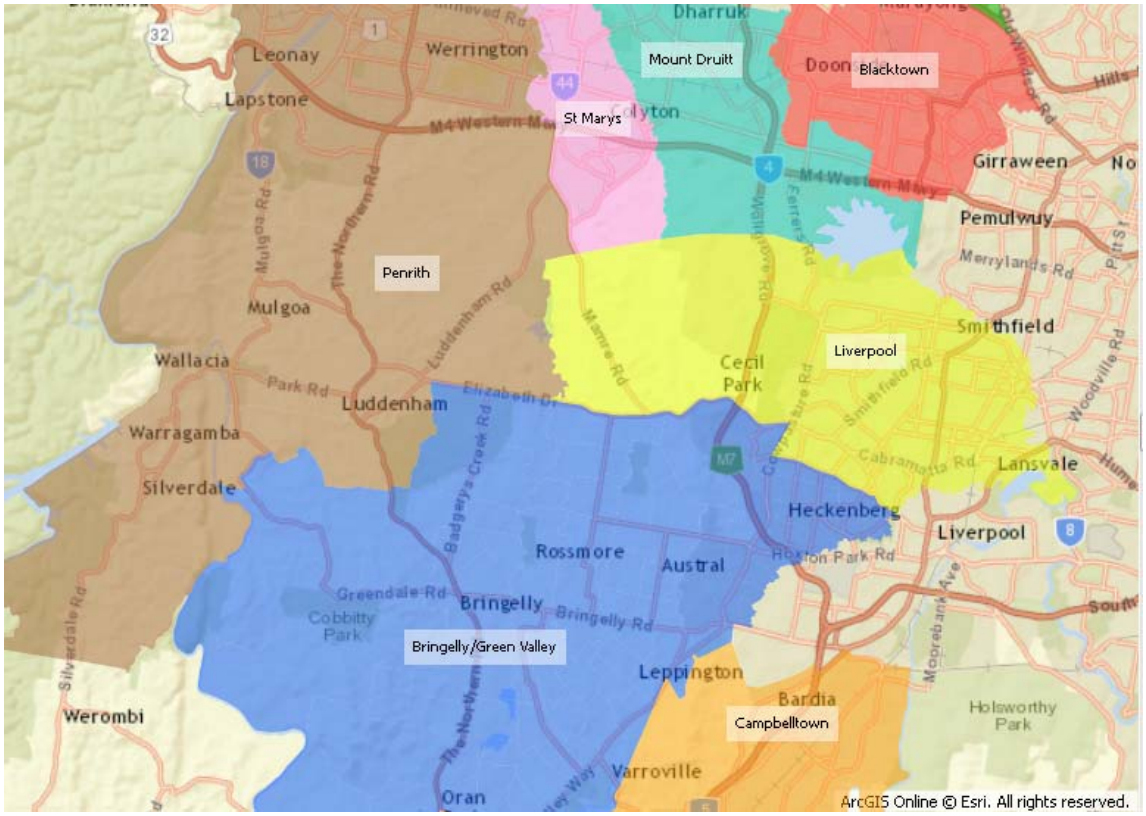
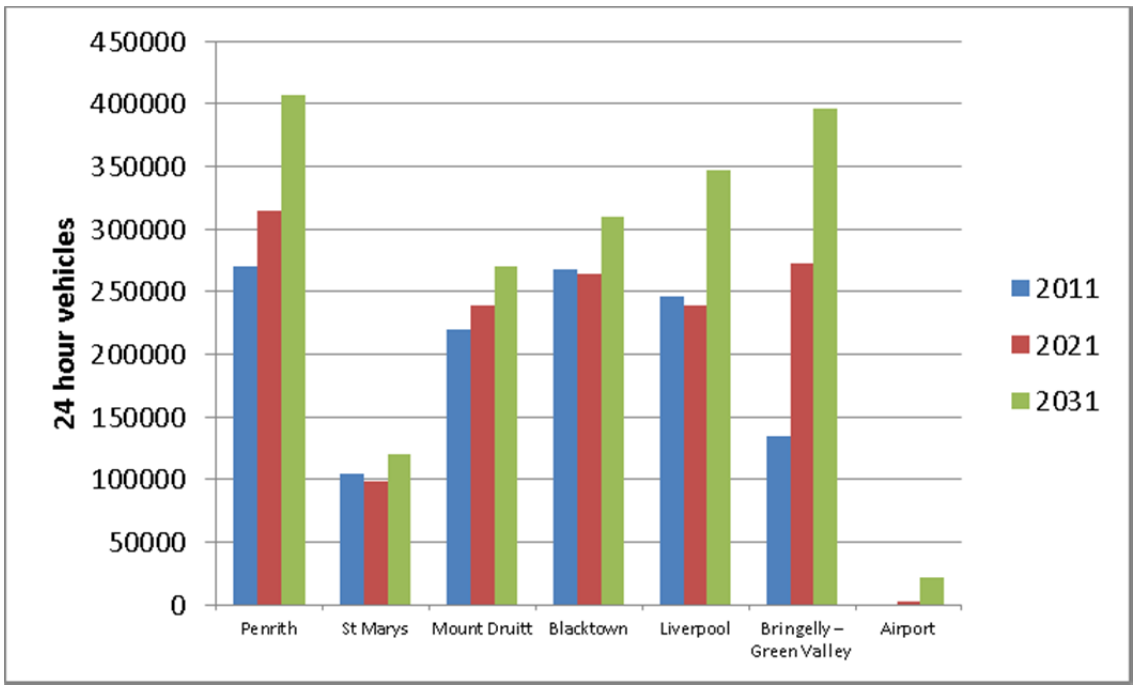


Figure 7-2 provides a summary of the magnitude of trips in the vicinity of the proposed airport, and shows the expected growth to 2031. It indicates that the proposed airport would be a very small component of overall trip demand in 2031.

Figure 7-2 Vehicle movements originating within surrounding SA3 (24 hour)



Data Source: STM3 model outputs

7.2 Future road network performance

The vehicle movements generated by WSA in addition to the existing trips in the model are presented in Table 6-10. For modelling purposes, it is assumed that all passengers and airport workers would access the proposed airport via the northern side of the site, either using the M12 or Elizabeth Drive. Freight from the south would access the site using The Northern Road.

Figure 7-3 and Figure 7-4 show the changes in traffic volumes in 2031 between the Do Minimum and With Airport scenarios. The differences are in pcu for the 2-hour peak periods.

The M12 is included in the 'With Airport' scenarios only. The M12 is included in the difference plots and therefore, in effect, displays the total volume forecast on the M12.

Figure 7-3 and Figure 7-4 show:

- the opening of the M12 attracts traffic from the M4 corridor, Elizabeth Drive, Bringelly Road and Fifteenth Avenue, reducing the volumes on these east-west routes.
- the reduction in volumes on the parallel routes is greatest eastbound in the AM peak and westbound in the PM peak
- attracting traffic to the M12 increases the traffic volumes on The Northern Road
- the WSA increases the volume of traffic on the north-south routes in the study area, including the Northern Road, where no additional infrastructure is currently assumed beyond the upgrade to a four-lane road in the vicinity of the airport scheduled to be complete by 2025.

There are two drivers of the changes in volumes. Firstly, the airport introduces more trips on the network in this area. Secondly the M12, introduced to provide sufficient access to the airport, has a diversionary effect on traffic movements in the wider area, attracting vehicles to the M12 corridor that would otherwise have used Bringelly Road or the M4. This has the effect of:

- reducing volumes on the M4;
- reducing volumes on Bringelly Road; and

- increasing volumes on The Northern Road.

The M12 as included within the assessment transport model also reduces congestion in the M12 /Elizabeth Drive corridor, as can be seen in the comparative volume/capacity plots in Figure 7-6 and Figure 7-7.

Figure 7-3 Traffic volume difference plot 2031 with Proposed Airport – 2031 Do Minimum AM Peak

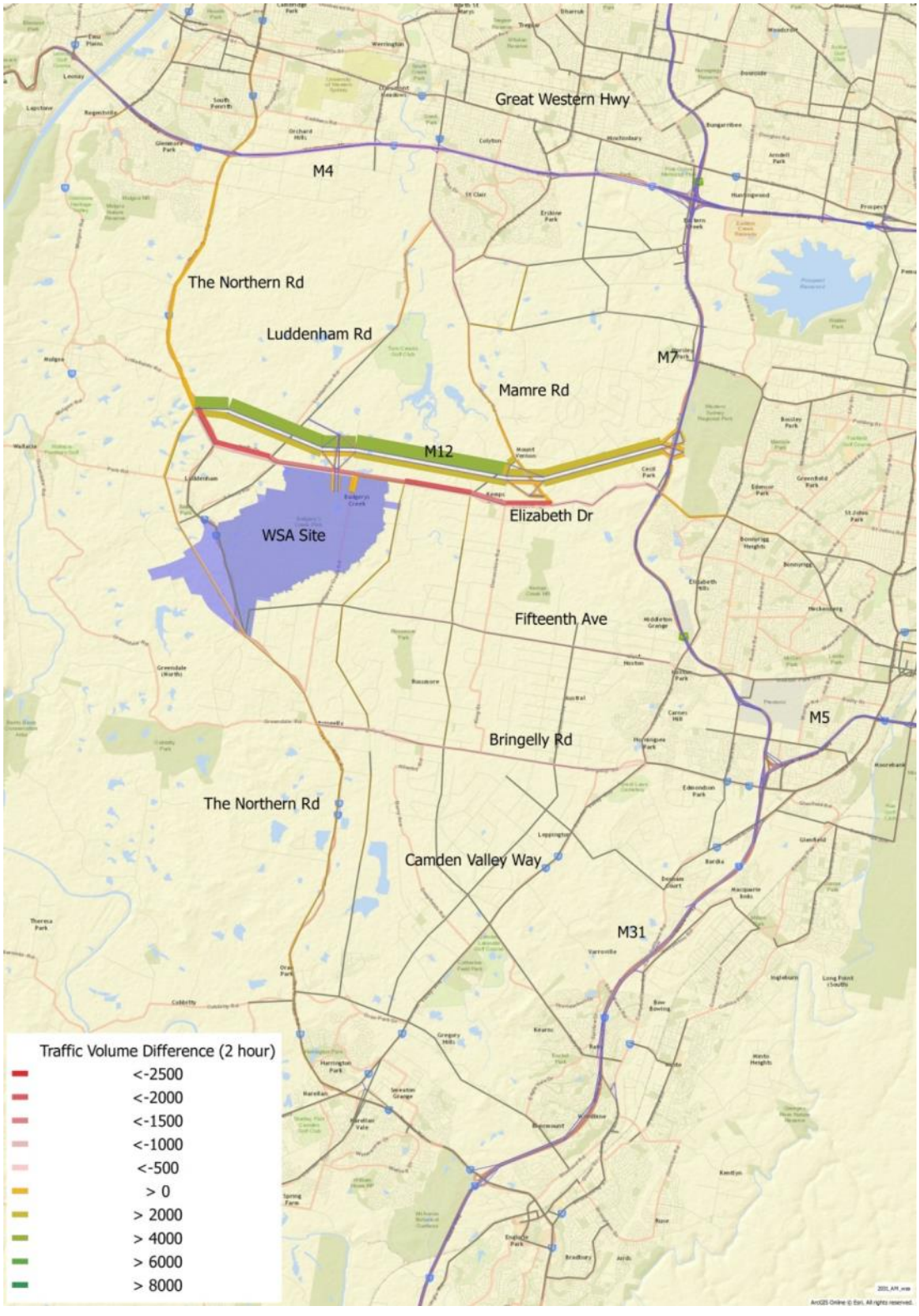
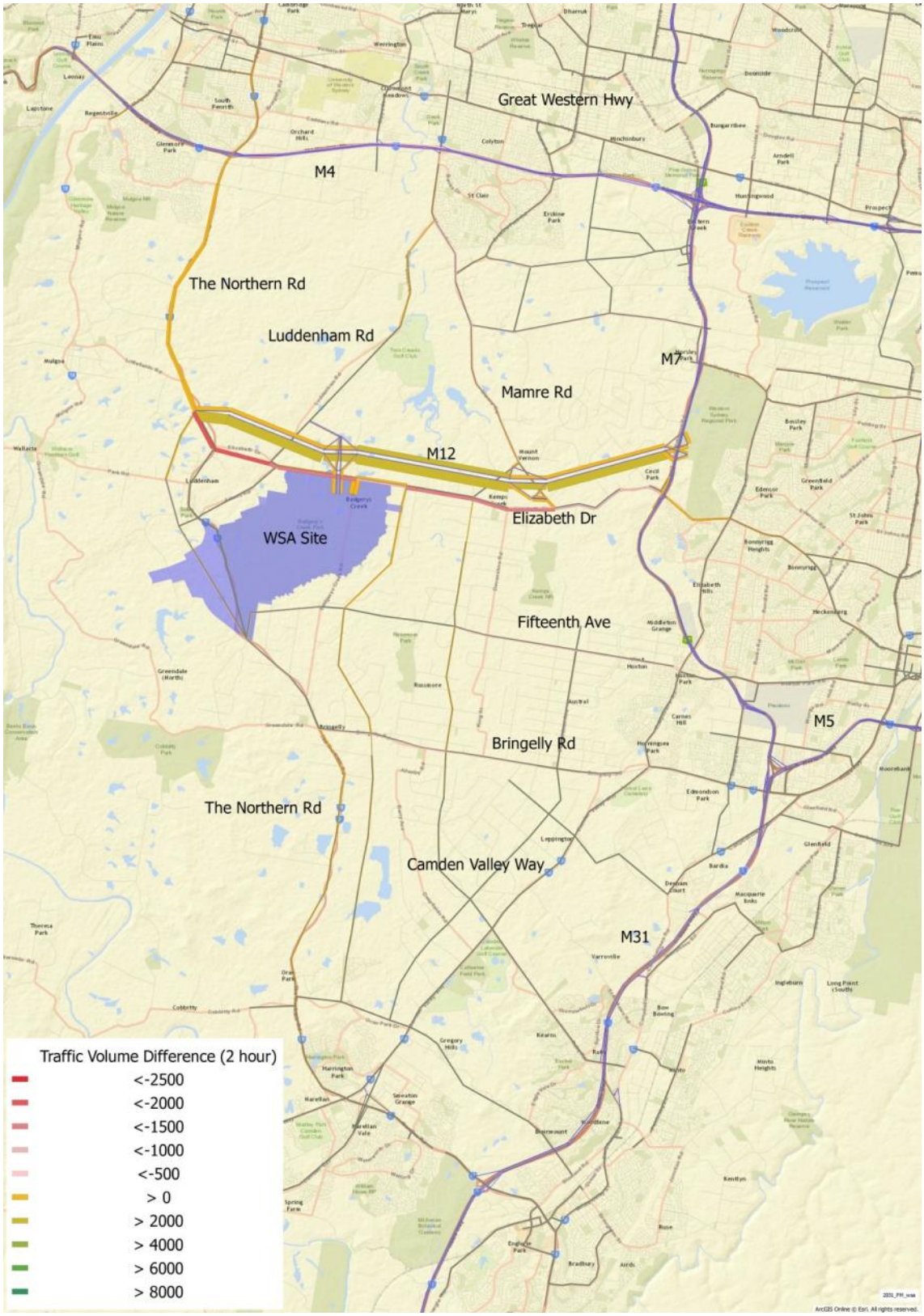


Figure 7-4 Traffic volume difference plot 2031 with Proposed Airport – 2031 Do Minimum PM Peak



An analysis has been carried out on the mid-block level of service for the Do Minimum and the With Airport scenarios. The Level of Service is shown figuratively in Figure 7-6 and Figure 7-7 for the AM and PM peaks respectively. A summary of the Level of Service at key links in the network is provided in Table 7-1, with a map of the location of the key links provided in Figure 7-5.

Figure 7-5 Location of Tabulated Level of Service output

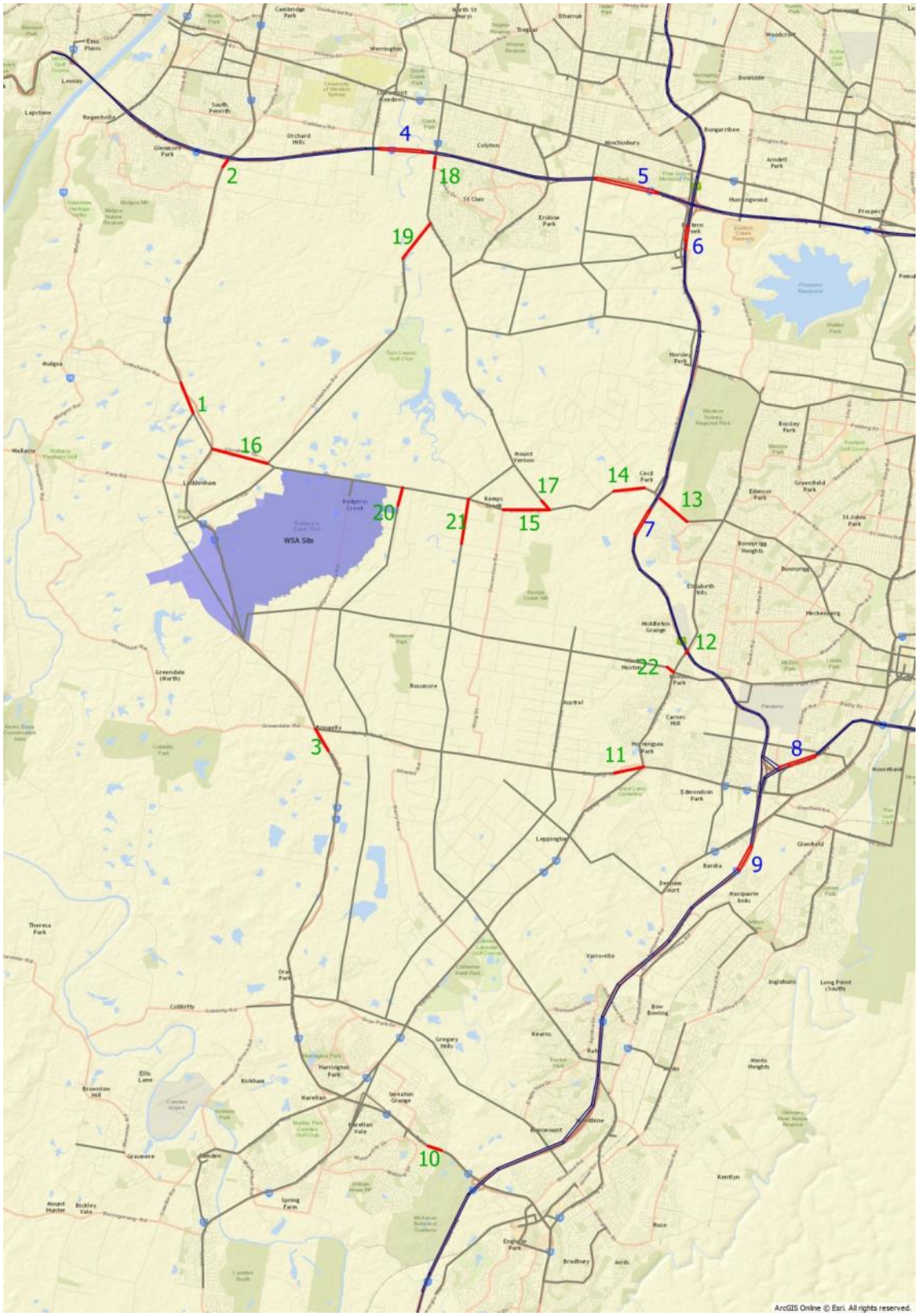


Table 7-1 Level of Service for 2031 With and Without Western Sydney Airport

Id	Road	Location	Baseline (Without WSA)				With WSA			
			AM Peak		PM Peak		AM Peak		PM Peak	
			Nbd/Ebd	Sbd/Wbd	Nbd/Ebd	Sbd/Wbd	Nbd/Ebd	Sbd/Wbd	Nbd/Ebd	Sbd/Wbd
1	The Northern Road	North of Elizabeth Dr	C	D	C	C	C	**E**	**D**	C
2	The Northern Road	South of M4	F	C	D	F	F	D	D	F
3	The Northern Road	South of Bringelly Rd	C	B	B	C	**D**	B	B	C
4	M4	West of Mamre Road	F	D	D	F	F	D	D	F
5	M4	West of M7	F	D	D	E	F	D	D	E
6	M7	South of M4	F	F	F	E	F	F	F	E
7	M7	South of Elizabeth Drive	F	D	D	D	F	D	D	**E**
8	M5	East of M7	F	E	E	F	F	E	E	F
9	M31	South of Campbelltown Road	F	E	D	E	F	E	D	E
10	Narellan Road	North of Tramway Dr	D	F	D	D	D	F	D	D
11	Bringelly Road	West of Cowpasture Road	D	C	C	C	D	C	C	C
12	Cowpasture Road	At M7	F	E	D	F	F	E	D	F
13	Elizabeth Dr	East of M7	D	F	D	C	**E**	F	**E**	**D**
14	Elizabeth Dr	West of M7	E	D	C	D	**D**	**C**	C	**C**
15	Elizabeth Dr	West of Mamre Road	F	B	B	D	**C**	B	B	**C**
16	Elizabeth Dr	East of the Northern Road	C	A	A	B	**A**	A	A	**A**
17	Mamre Road	North of Elizabeth Dr	F	C	C	F	F	**E**	**D**	F
18	Mamre Road	South of M4	D	F	E	D	D	F	E	D
19	Luddenham Dr	West of Mamre Road	D	C	C	C	**C**	C	C	**D**
20	Lawson Rd	South of Elizabeth Dr	C	A	A	C	**D**	A	A	C
21	Western Rd	South of Elizabeth Dr	D	A	B	C	D	**B**	B	**D**
22	Fifteenth Ave	West of Cowpasture Rd	C	A	A	C	C	A	A	C
23	M12	West of M7	-	-	-	-	A	A	A	A
24	M12	West of Mamre Road	-	-	-	-	B	A	A	A
25	M12	East of the Northern Road	-	-	-	-	B	A	A	B

Note: Bold text has been used to identify a change in LoS from the base case – whether this is an improvement or deterioration.

Figure 7-6 2031 AM Peak Volume/Capacity - Do Minimum (Left), with Proposed Airport (Right)

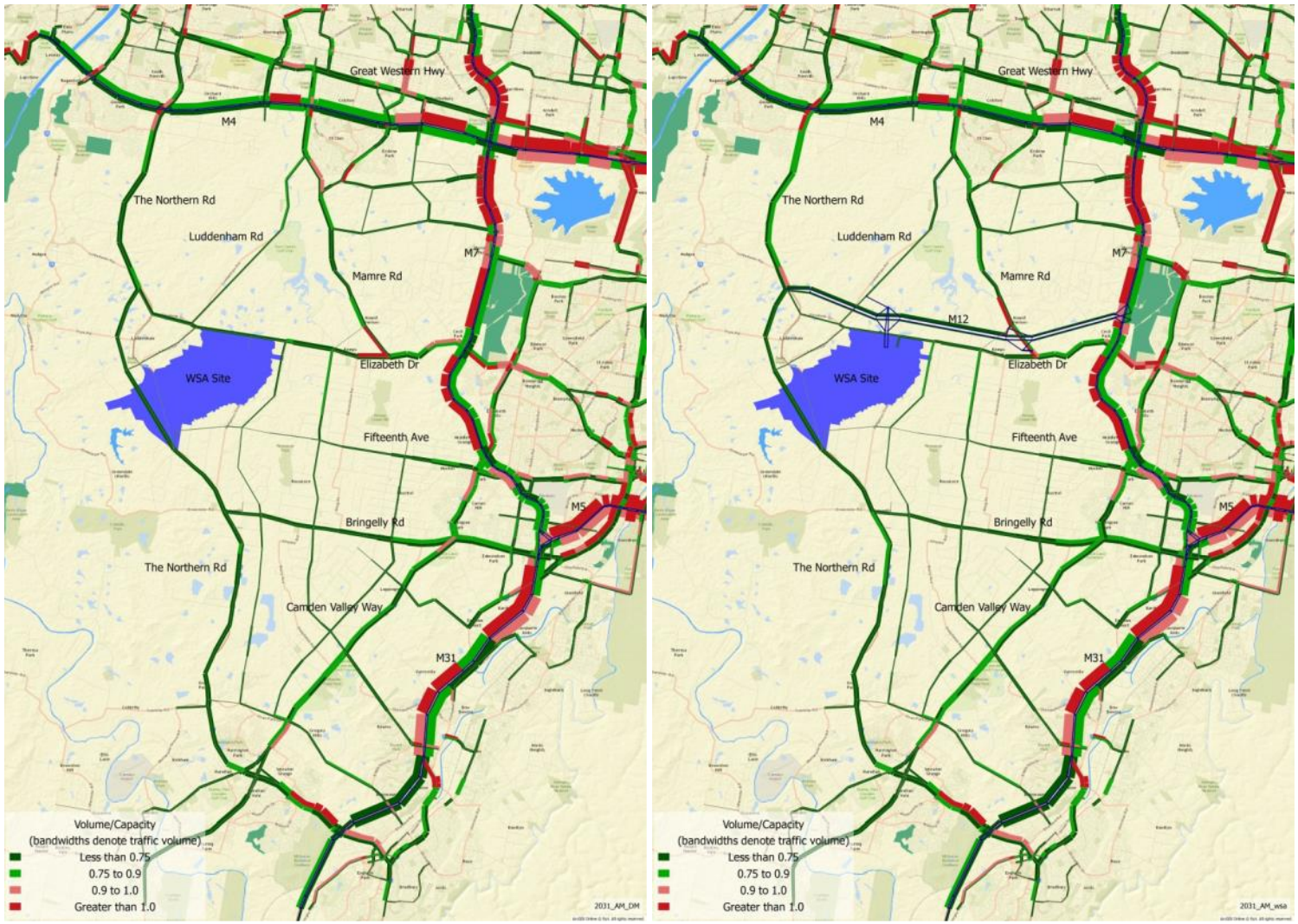
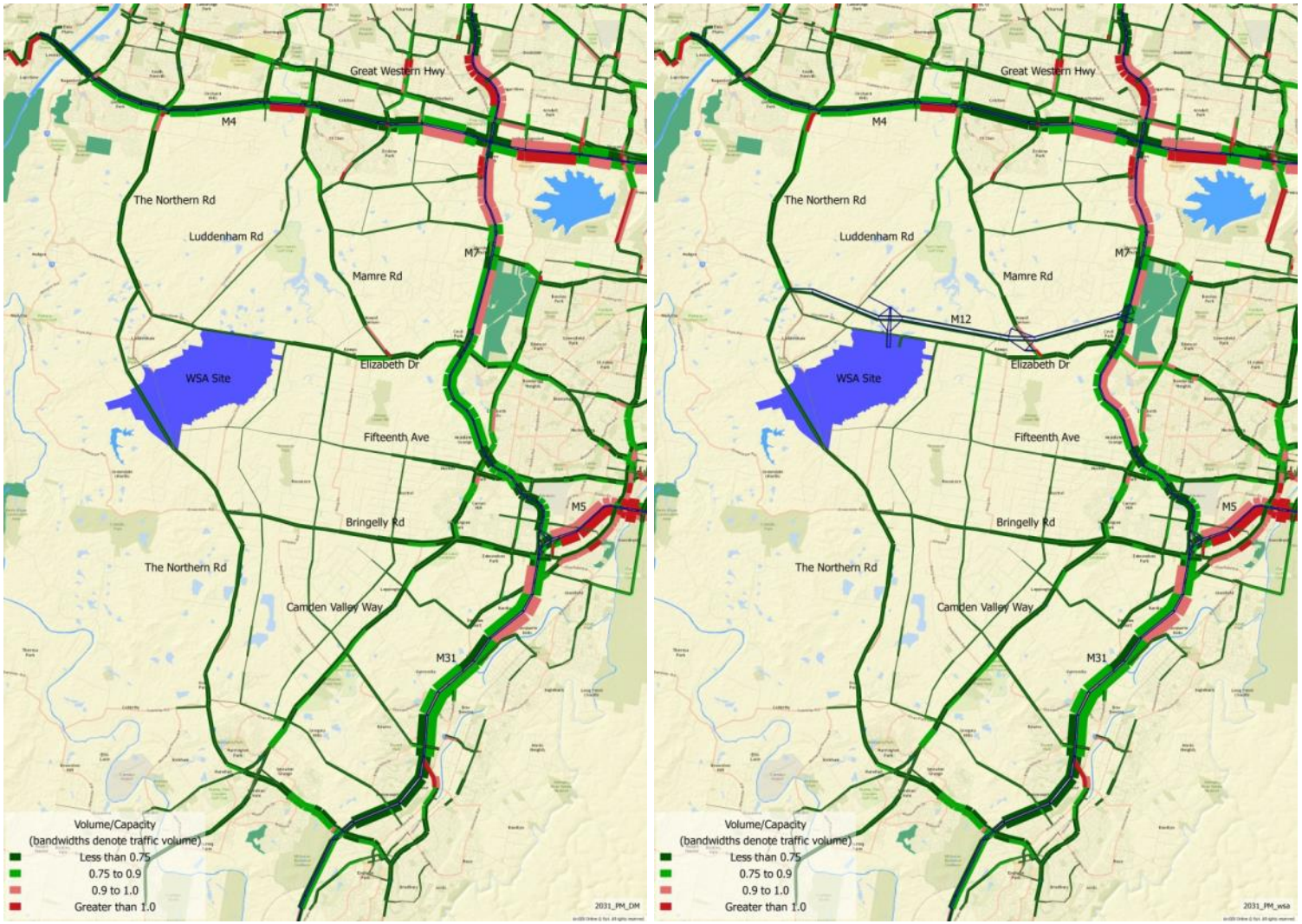


Figure 7-7 2031 PM Peak Volume/Capacity - Do Minimum (Left), with Proposed Airport (Right)



7.3 Impacts on roads and access

The road upgrades identified as part of the WSIP have been determined to support the proposed airport. The evaluation of the impacts is a comparative assessment of the WSIP (including the airport) and M12 with the airport and the WSIP without the airport. Therefore, the overall improvements to the transport system as a consequence of the WSIP have been included within the 'without airport' scenario.

The introduction of the proposed airport and the M12 would have the following effects on the capacity of the strategic road network (over and above the scenario without the airport), as shown in Figure 7-6 and Figure 7-7.

- a worsening of LoS on Elizabeth Drive as a result of the diversion of trips on to the M12;
- a worsening of LoS on The Northern Road:
    - to LoS D on sections of The Northern Road between the M12 and M4 (AM/PM peaks)
    - to LoS E just north of Elizabeth Drive (AM peak)
    - to LoS F just south of the M4 (AM/PM peaks)
- a worsening of LoS on sections of Mamre Road near the M12.
- an improvement of LoS on Mamre Road north of Erskine Park Road; and
- the M12 operates at LoS B or better.

Overall, by 2031 the proposed initial airport development would not generate the level of traffic required significantly to impact the operation of the surrounding road network.

7.4 Key findings

The following key findings have been derived concerning passenger and employee trip generation and freight trip generation:

- daily passenger and employee vehicle trip generation of 22,134 vehicles to the proposed airport and 24,857 vehicles from the airport;
- the peak passenger and employee vehicle demand to the proposed airport is between 7:00 AM and 8:00 AM and is 2,406 vehicles per hour;
- the peak passenger and employee vehicle demand away from the proposed airport is between 6:00 PM and 7:00 PM and is 2,429 vehicles per hour;
- daily freight vehicle trip generation of 20,922 vehicles to the proposed airport and 20,936 vehicles from the airport;
- the freight AM peak (2 hour) vehicle demand is 3,966 to the proposed airport and 2,295 from the airport; and
- the freight PM peak (2 hour) vehicle demand is 1,905 to the proposed airport and 2,117 from the airport.

The introduction of the proposed airport and the M12 has the following effects on the capacity of the strategic road network:

- some increase in congestion at The Northern Road/M4;
- a small increase in congestion on Mamre Road; and
- overall by 2031, the initial airport development does not generate the level of traffic required significantly to impact on the operation of the surrounding road network.

As demonstrated in this Chapter, the proposed initial airport operations would not have a significant impact on the capacity of the road network. This is primarily because the substantial package of road improvements proposed as part of the WSIP, in addition to those identified in the BWSEA and SWGC, would have sufficient capacity to cater for the expected airport passenger and employee traffic demand in 2031.

The public transport and walking and cycling systems proposed by the NSW Government and local councils would also have sufficient capacity to cater to the expected airport passenger and employee demand.

As such, no transport mitigation measures are considered to be required for the proposed Stage 1 airport.

Part B – Assessment of the longer term airport development

8. Airport facilities and road network conditions

Key details of the longer term airport development are provided in Section 1.1 and more comprehensively in the project description section of the Volume 1 of the EIS. A principal component of the longer term airport development would involve construction of a second, parallel runway in the southern area of the site and related airside and landside facilities sufficient to service an estimated 82 million passengers per year. The EIS assessment assumes 2063 as the appropriate year to analyse the potential impacts of the longer term airport development on traffic and transport conditions.

8.1 Airport access

The mode splits for the long term development have been mediated on the capacity of the airport access motorway from the proposed M12 motorway. This motorway has a long term design of 3 traffic lanes plus a bus lane in each direction. The functional capacity of this motorway is 5,100 cars per hour over the 3 lanes to provide a poor Level of Service D. As part of the airport concept development, it has been identified that this forecast level is predicted to be achieved in based on current airport passenger volumes 2050 and investment in rail infrastructure would be required beyond this point, if not already provided, to enable the airport to reach the desired 82 MAP outlined above. Beyond 2050, it has been assumed that some, limited additional access roadway capacity is made available, but overall parking levels remain stagnant - limiting traffic growth.

All trip and traffic generation estimates used in this assessment are based on this assumption.

8.2 Road network improvements

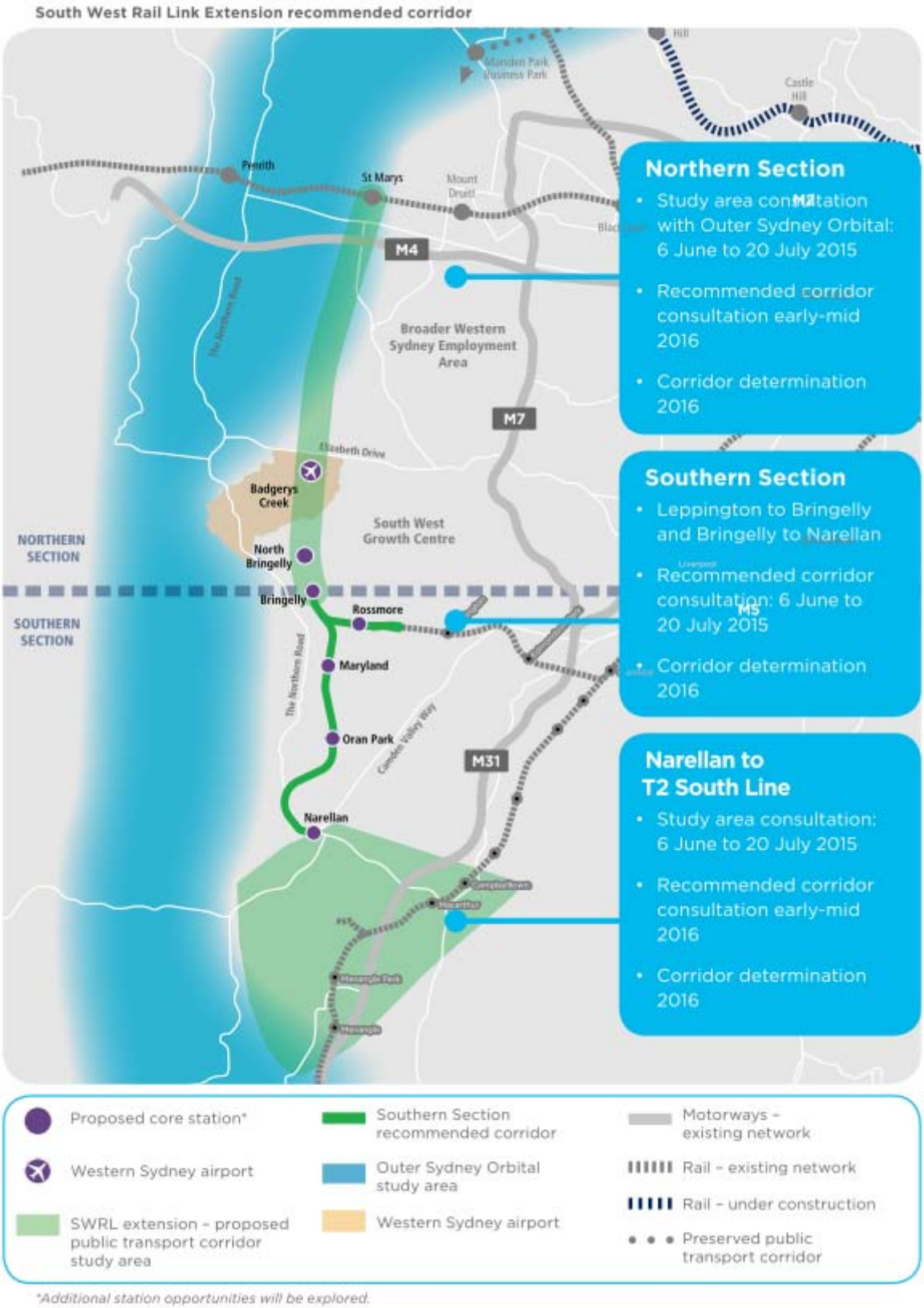
The assumed road network for the 2063 assessment year is generally consistent with the 2031 model, with the addition of the proposed Castlereagh Highway. The Castlereagh Highway would provide a new link between Bells Line of Road at Kurrajong, with the north-western section of the M7 Motorway near Dean Park. This new road link will provide two traffic lanes in each direction along the entire corridor. The Outer Sydney Orbital (while shown in Figure 8-1) is not included in the network and is subject to investigation by the NSW Government.

8.3 Public transport

The public transport assessed in the modelling for the longer term development is similar to the initial stage development with the exception that in the longer term, a rail link to the Sydney Trains network will be introduced.

The NSW Government has started planning for a continuation of the South West Rail Link to extend to Badgerys Creek and on to St Marys, where it would connect with Western Line services, as well as south to Narellan as shown in Figure 8-1.

Figure 8-1 Southwest Rail Link extension and Badgerys Creek Airport



Source: Transport for New South Wales 2014

8.4 Pedestrian and cycling facilities

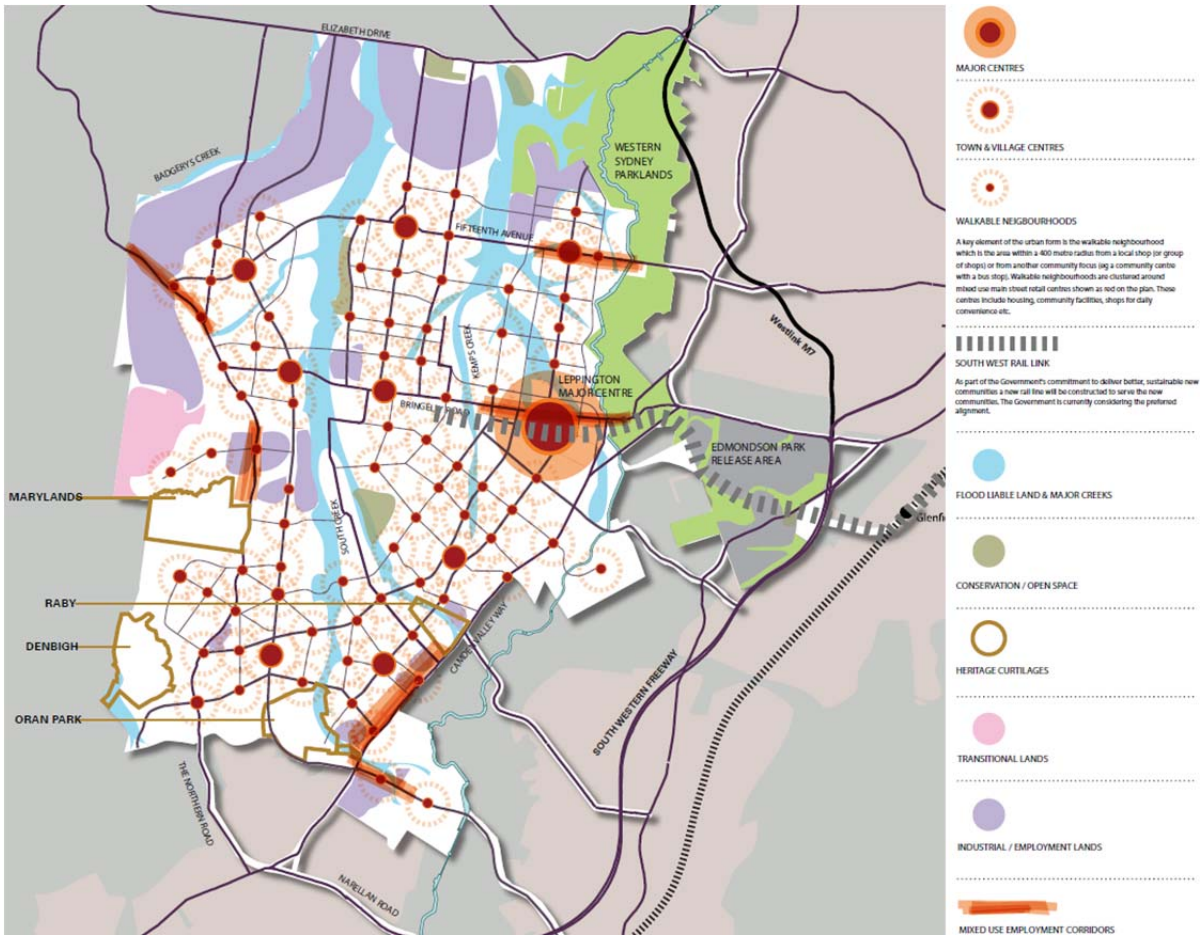
Future planned walking and cycling links in the vicinity of the airport site are identified in the South West Growth Centre Structure Plan and the BWSEA Structure Plan.

8.4.1 South West Priority Growth Area

The South West Growth Centre Structure Plan is shown in Figure 8-2, which identifies key road corridors, major centres and local centres. The Structure Plan also shows walkable neighbourhoods, which is the area within a 400 metre radius from a local shop (or group of shops) or from another community focus (e.g. a community centre with a bus stop).

Although the Structure Plan does not specifically identify cycling and walking paths, it is likely that cycle and walking paths will be provided along these road corridors. Key road links in the vicinity of the airport site identified in the Structure Plan include The Northern Road and Elizabeth Drive.

Figure 8-2 South West Priority Growth Area Structure Plan



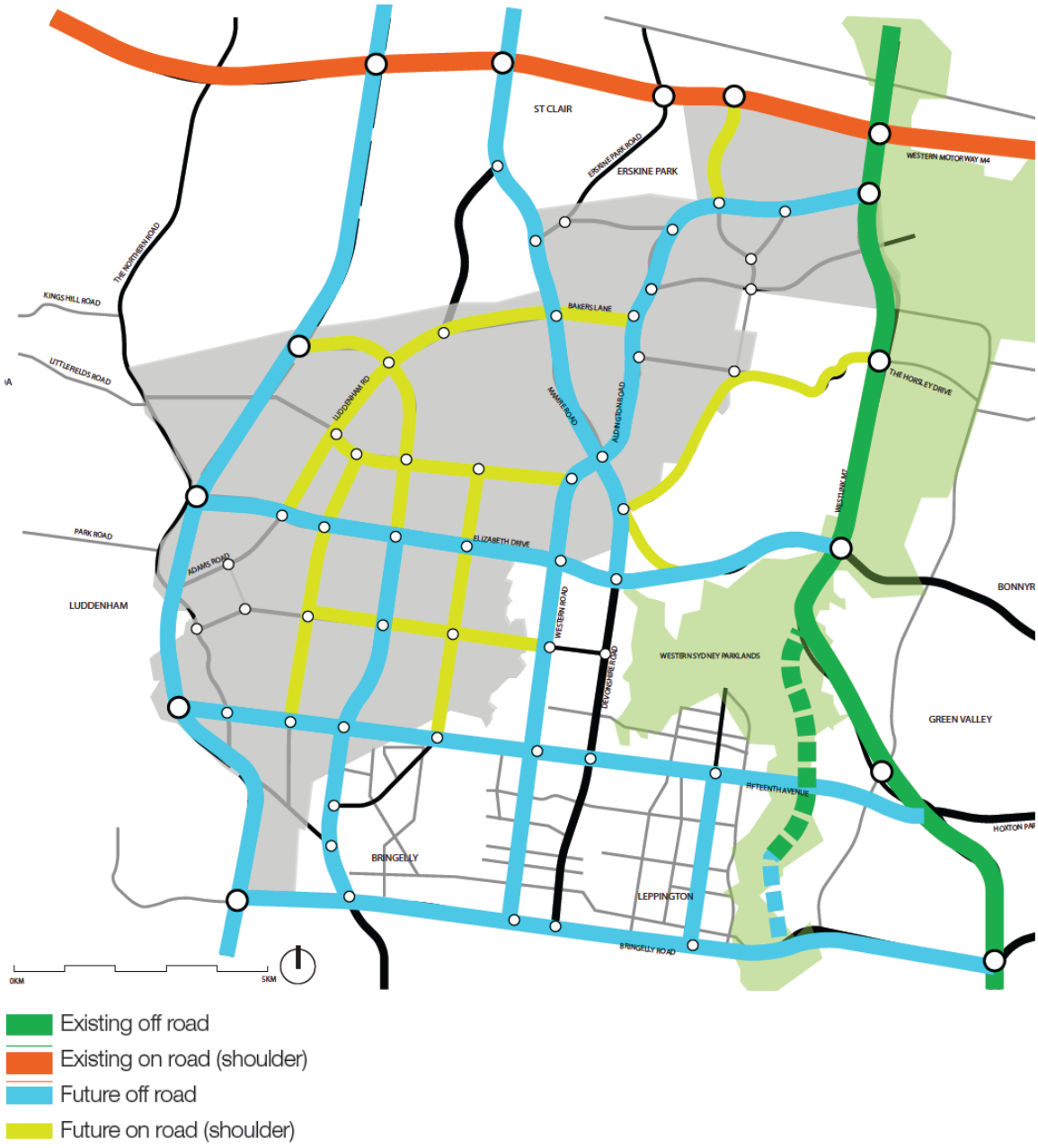
Source: http://growthcentres.planning.nsw.gov.au/LinkClick.aspx?fileticket=DIxdhdNT1b8%3d&tabid=91

8.4.2 Broader Western Sydney Employment Area

The proposed strategic bicycle network for BWSEA, provided from the *BWSEA Transport Planning Preliminary Analysis Exhibition* draft report (GHD 2013) is shown in Figure 8-3. The cycle routes have been defined as shoulder or off-road cycle paths. Off road routes will involve the provision of dedicated cycle ways or shared paths alongside roads or within reserves. Shoulder routes allow for widening of carriageways so that cyclists can travel on road with a safe separation from moving vehicles.

The *BWSEA Transport Planning Preliminary Analysis Exhibition* draft report states that pedestrians will be provided for on all routes, with pedestrian paths provided on both sides of roads with active land uses. In addition, the majority of off road cycle routes would also be paths shared with pedestrians, with some paths separated at locations with high levels of activity near employment centres.

Figure 8-3 Proposed BWSEA bicycle network



Source: Broader Western Sydney Employment Area Transport Planning Preliminary Analysis Exhibition Draft (GHD 2013)

9. Trip generation

9.1 Introduction

The methodology for determining the trip generation for air passengers and employees for the longer term development of the proposed airport uses the same processes as discussed in Chapter 6 which should be referred to for the analytical methods applied within this chapter.

The longer term concept for the proposed airport is based on the year 2063, when forecast annual passenger movements of approximately 82 million and an employee level of approximately 59,500 are assumed.

9.2 Passenger trip generation

9.2.1 Flight profiles

The passenger flight profile for the site has been determined based on a synthesised profile the number of daily and peak hour passenger flights, as shown in Table 9-1.

Table 9-1 Daily flight movements 2063

Design Day Passenger Air Traffic Movements	2063
Domestic Passenger flights	604
International Passenger flights	397
Total	**1,001**

Additionally, the number of flights per peak hour has been determined as shown in Table 9-2.

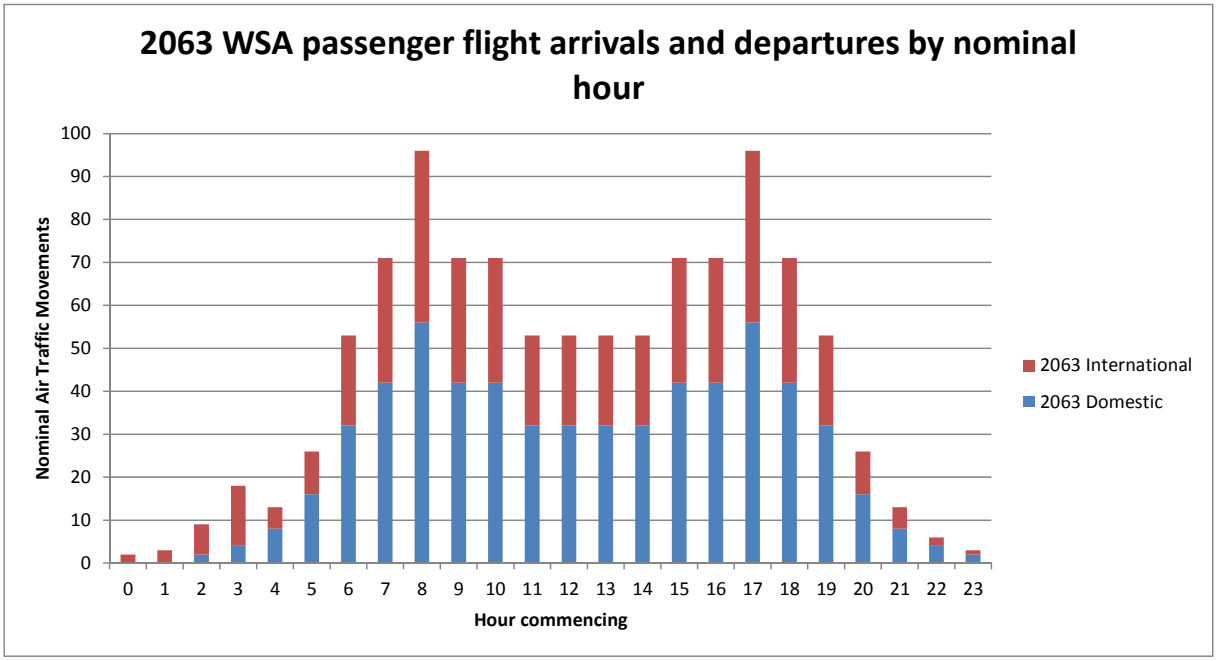
Table 9-2 Peak hour flight movements 2063

Peak hour flights	No flights	% of daily total
Arrivals (Domestic and International.)	46	4.6
Departures (Domestic and International)	48	4.8
Total	**94**	**9.4**

The operations of airports with 24 hour operations (including Kuala Lumpur, Hong Kong and Los Angeles) were examined to determine the ratio of arriving and departing flights by hour. It was found that similar sized airports with 24 hour operation have limited overnight flights between 2100 and 0500 hours. Based on the high ratio of the peak hour to the other hours of the day there would be limited flights outside of the peak travel hours. A synthetic plane arrival and departure profile has been developed by the traffic and transport specialist team to account for the peak to non-peak profiling of flight arrivals and departures. This is shown in Figure 9-1.

Tables relating to the figures in section 9.2 are provided in Appendix D.

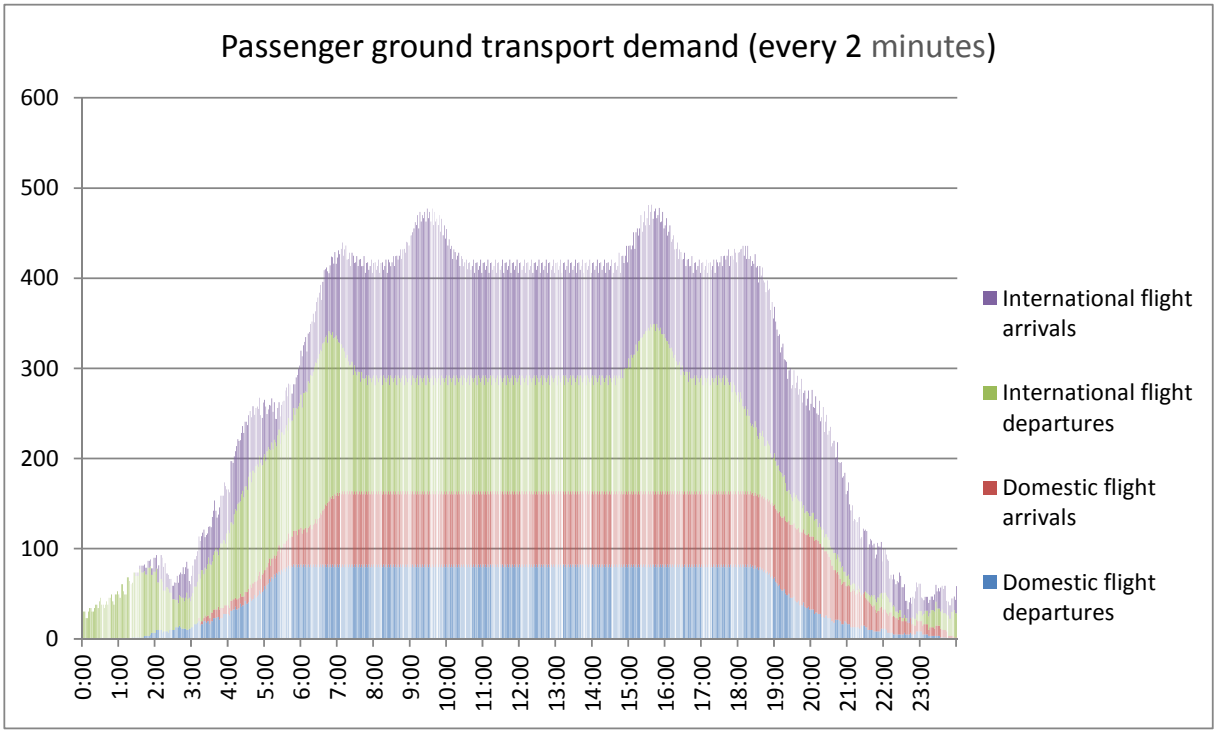
Figure 9-1 Synthesized 2063 daily flight profile



9.2.2 Passenger arrival profiles

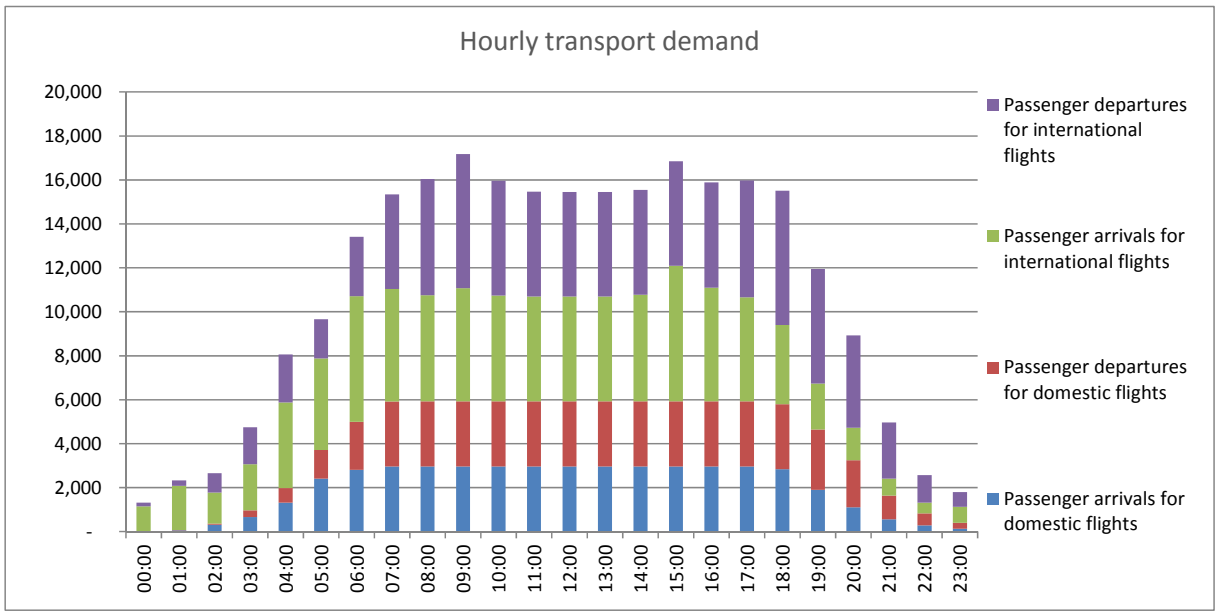
The two minute interval passenger profile for 2063 is shown in Figure 9-2.

Figure 9-2 Two minute ground passenger transport demand - 2063



When this is converted into hourly volumes, the peak hourly demand is shown in Figure 9-3.

Figure 9-3 2063 ground transport demand per hour



9.2.3 Ground transportation modes

The departing and arriving passengers at the proposed airport would use various modes of travel. These have been assigned as the following modes:

- kiss ‘n’ fly;
- park ‘n’ fly;
- taxi;
- shuttles;
- bus;
- rail; and
- other modes.

For a description of these modes refer to section 6.2.4.

9.2.4 Mode split

The approach used within this analysis varies from the SALTM model, as the SALTM model is a 4-step transport model that determines transport mode splits based on travel times and origin/destination pairs. As the modelling undertaken for the concept plan requires the capacity of the proposed access road network to be a constraint, the mode split proportions are required to be an input. The proportions used for each mode are shown in Table 9-3.

Table 9-3 2063 assumed mode split

Modes	2063 Mode split			
	Domestic		International	
	Drop off	Pick up	Drop off	Pick up
Kiss and Fly	22%	22%	26%	26%
Park and Fly	20%	20%	18%	18%
Taxi	20%	20%	20%	20%
Shuttle	5%	5%	5%	5%
Bus	13%	13%	13%	13%
Train	20%	20%	18%	18%

9.2.5 Dwell times

For each transport mode, there is a range of dwell times based on the mode type and trip purpose. For example, an international Kiss 'n' fly pickup trip may involve arriving prior to the flight's arrival at the proposed airport, allowing enough travel time to cater to the variability in the external road network and the passengers being collected passing through the border. In comparison, a bus vehicle will have a nominated dwell time at each stop.

The nominated dwell times for each mode are shown in Table 9-4.

Table 9-4 2063 assumed dwell times by mode

Mode	Dwell time (minutes)			
	Domestic		International	
	Drop off	Pick up	Drop off	Pick up
Kiss and Fly	6	16	120	44
Park and Fly	-	-	-	-
Taxi	16	16	16	16
Shuttle	30	30	30	30
Bus	3	3	3	3
Train	3	3	3	3

9.2.6 Mode distribution

Using the values identified in the previous sections, each passenger has been assigned to a transport mode. The hourly demand is shown in Figure 9-4 to Figure 9-7.

These passenger demands are then agglomerated into passenger entries and exits from the airport as shown in Figure 9-8 and Figure 9-9.

Figure 9-4 Domestic air departures – ground arrival at the proposed airport

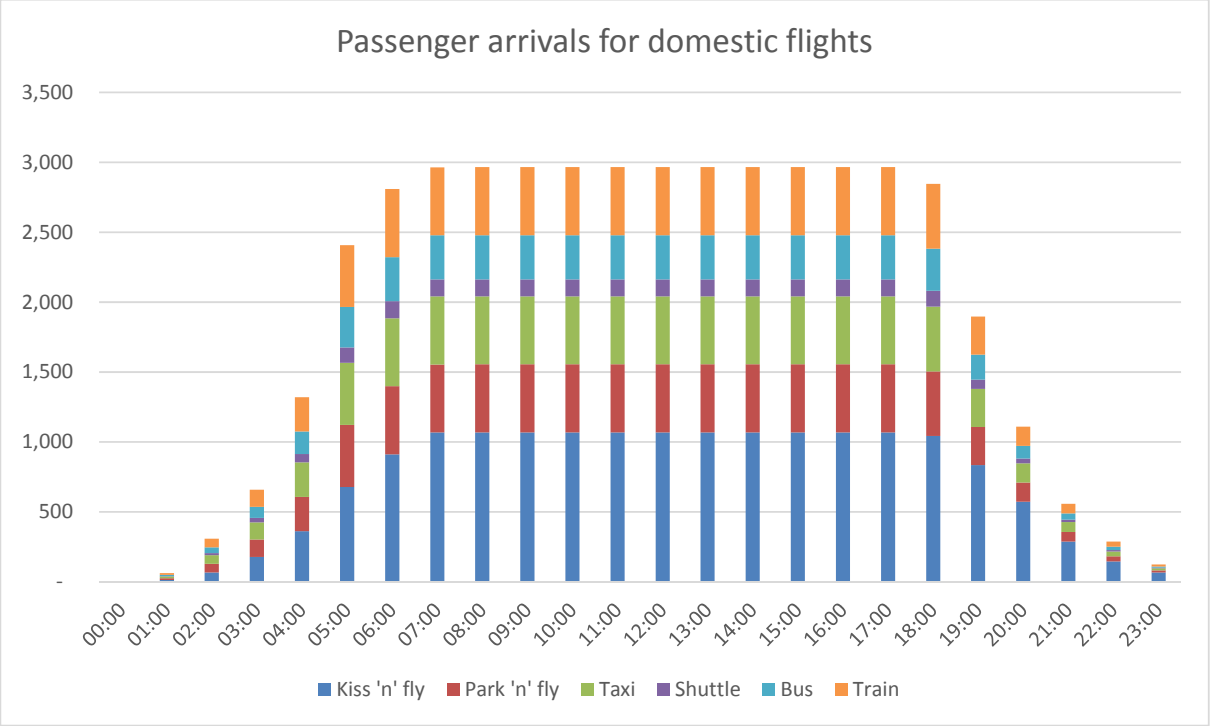


Figure 9-5 Domestic air arrivals – ground departure from the proposed airport

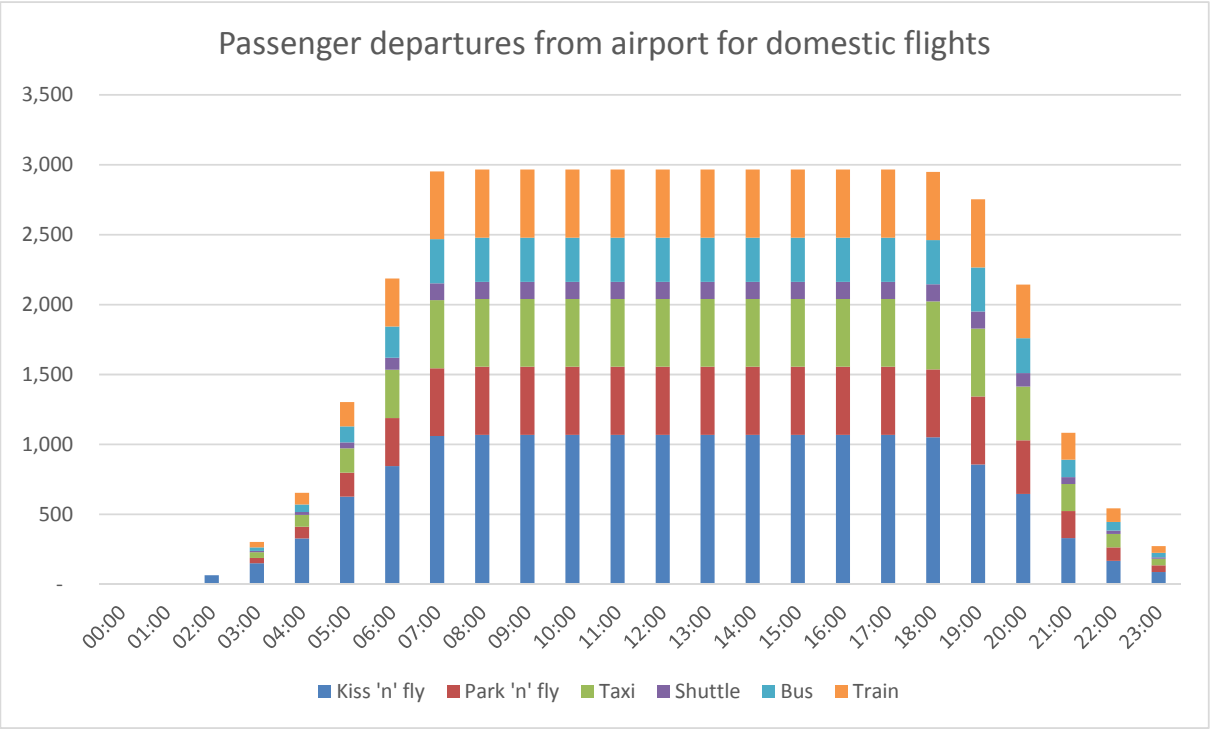


Figure 9-6 International air departures – ground arrival at the proposed airport

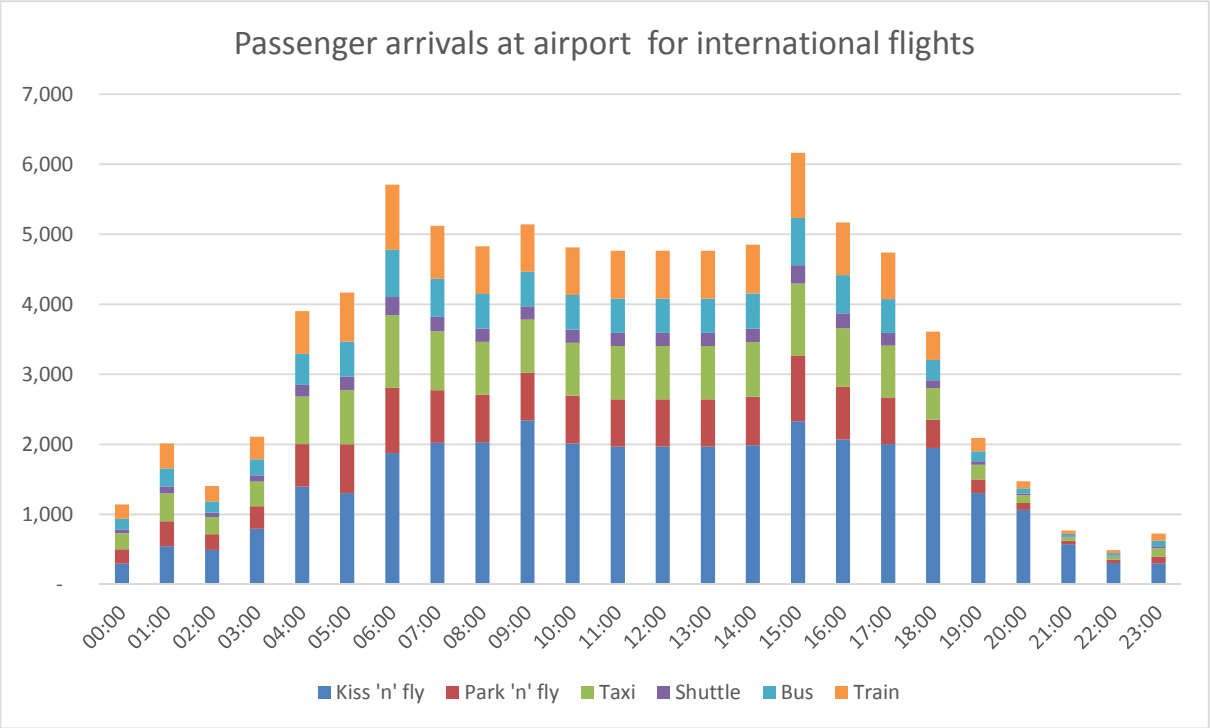


Figure 9-7 International air arrivals – ground departure from the proposed airport

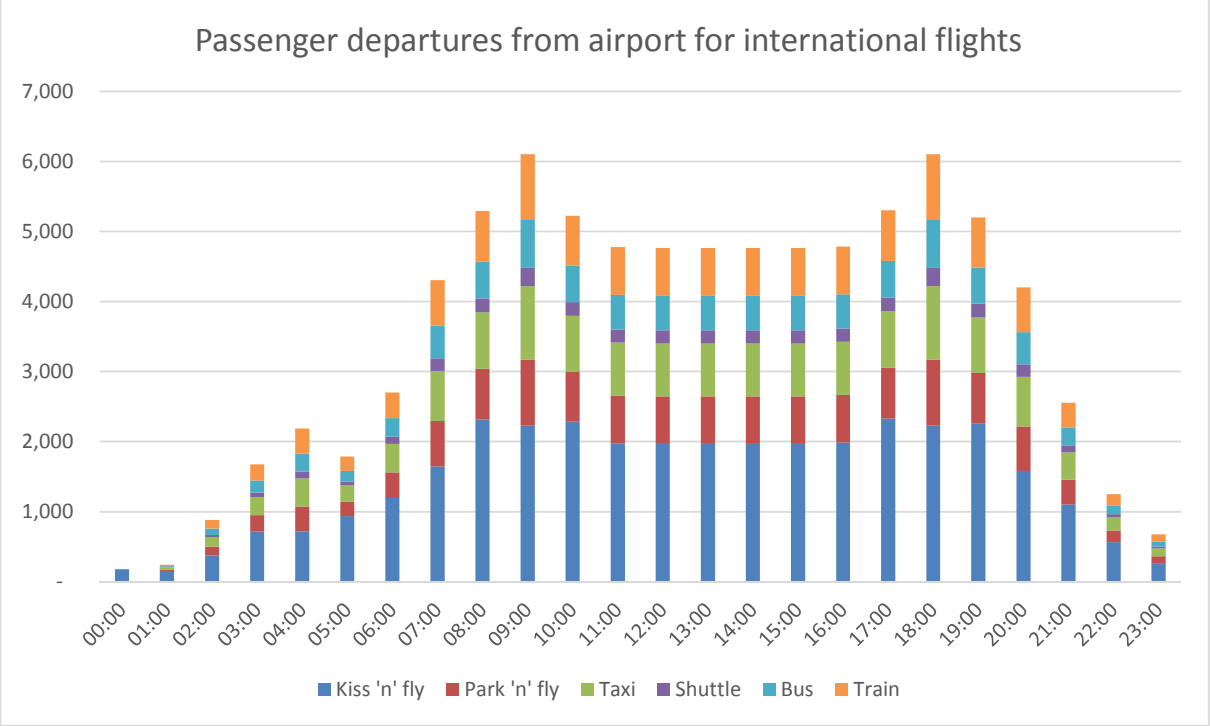


Figure 9-8 Total air departures– ground arrival at the proposed airport

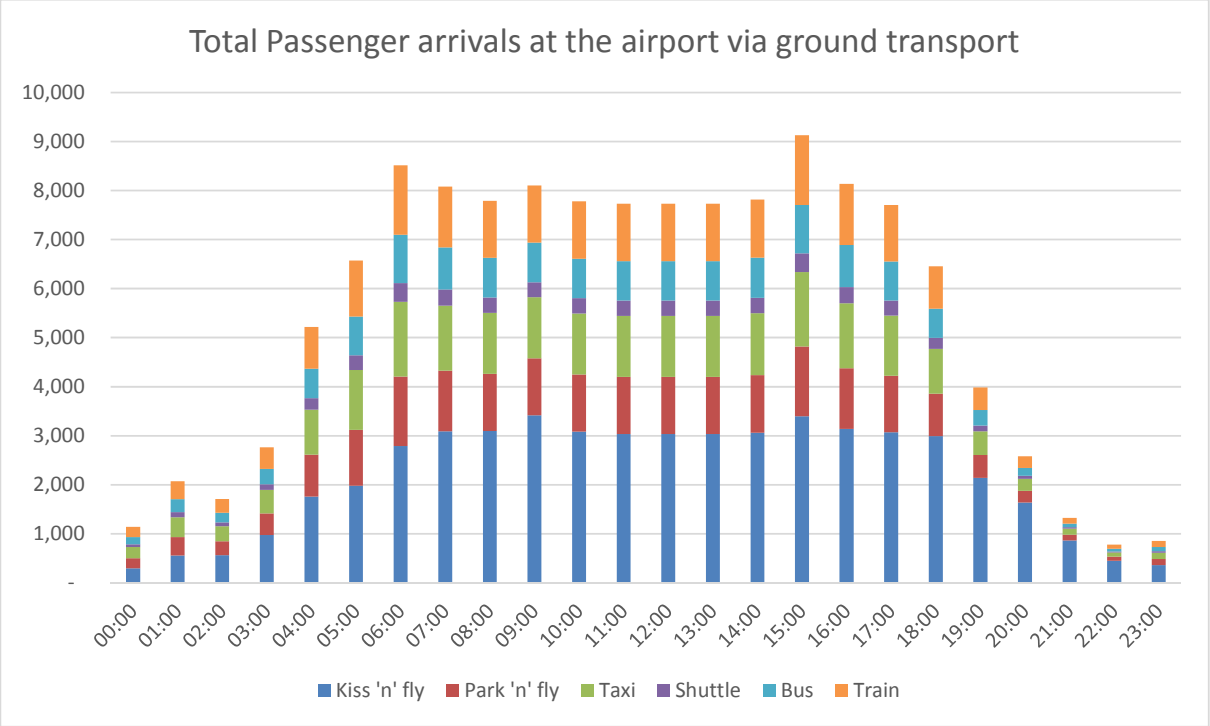
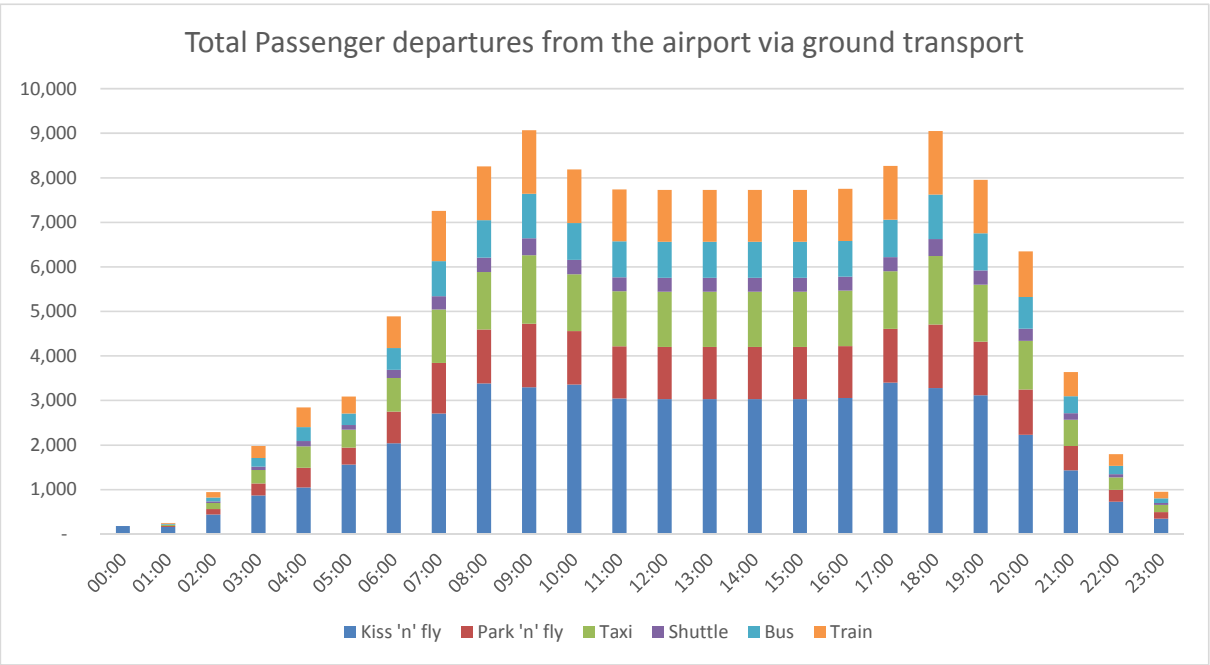


Figure 9-9 Total air arrivals – ground departure from the proposed airport



9.2.7 Traffic generation

The trips developed in section 9.2.6 were assigned to vehicles entering the proposed airport at the northern boundary point and onto the internal road network. The vehicle volumes across the day are shown in Figure 9-10 to Figure 9-15.

Figure 9-10 Passenger vehicles entering at the northern airport boundary by mode

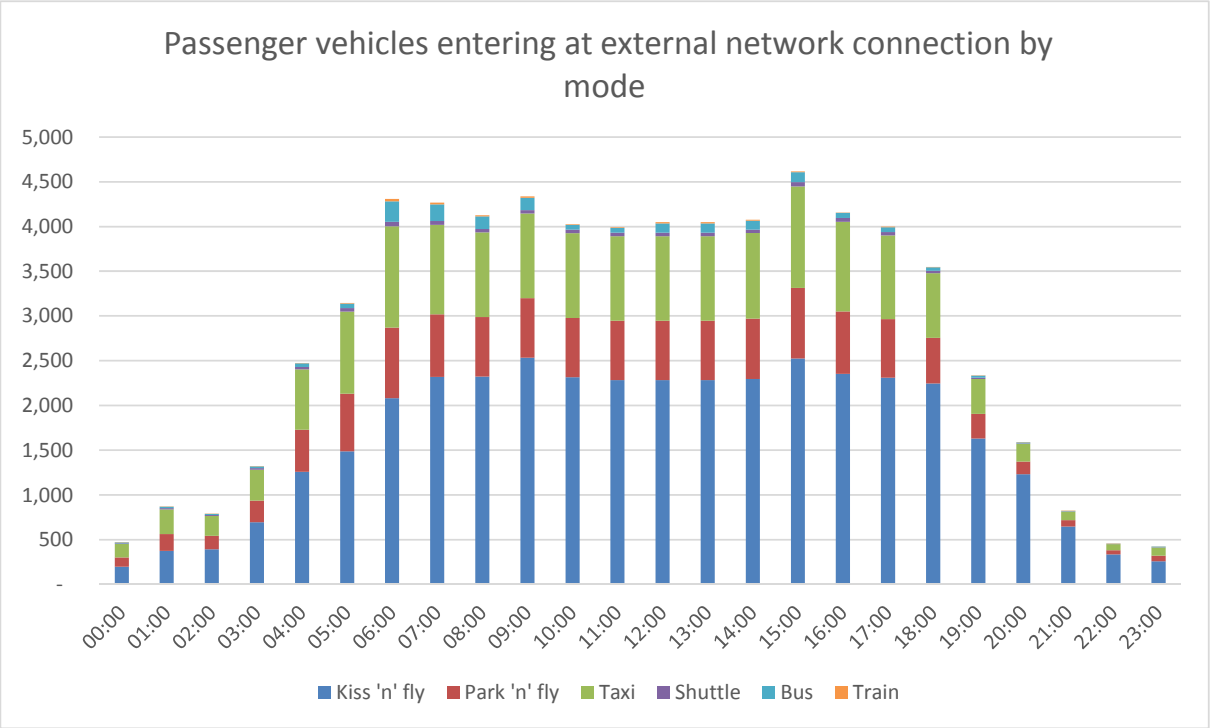


Figure 9-11 Passenger vehicles exiting at the northern airport boundary by mode

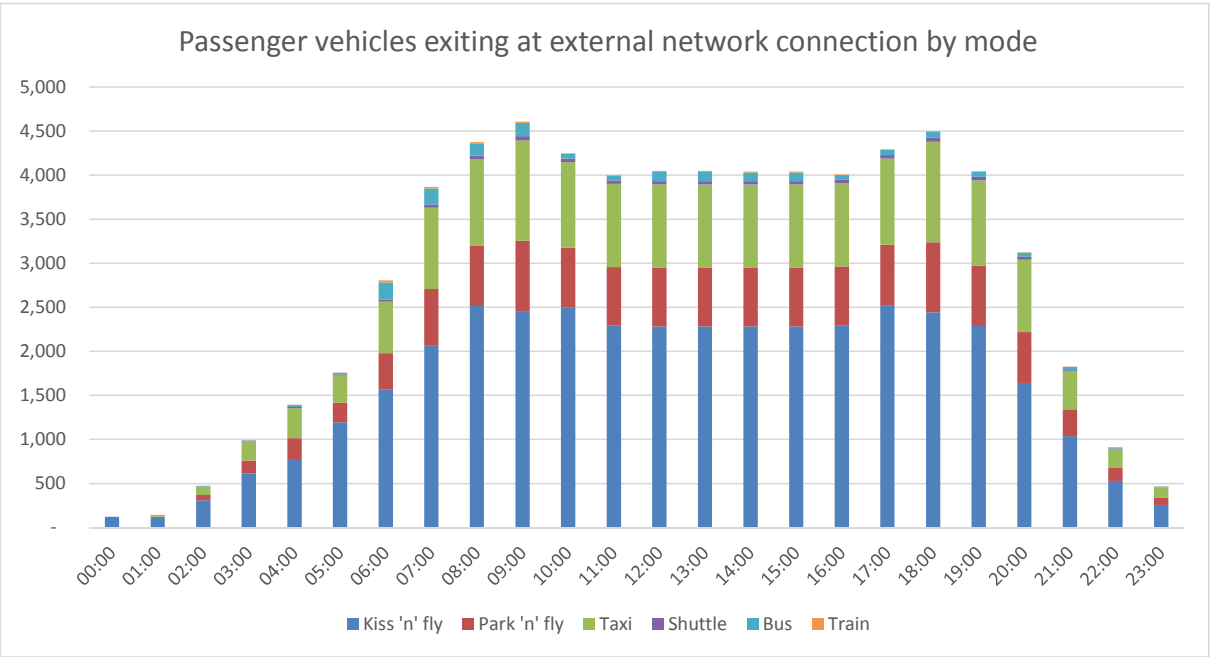


Figure 9-12 Passenger vehicles entering at the northern boundary by vehicle type

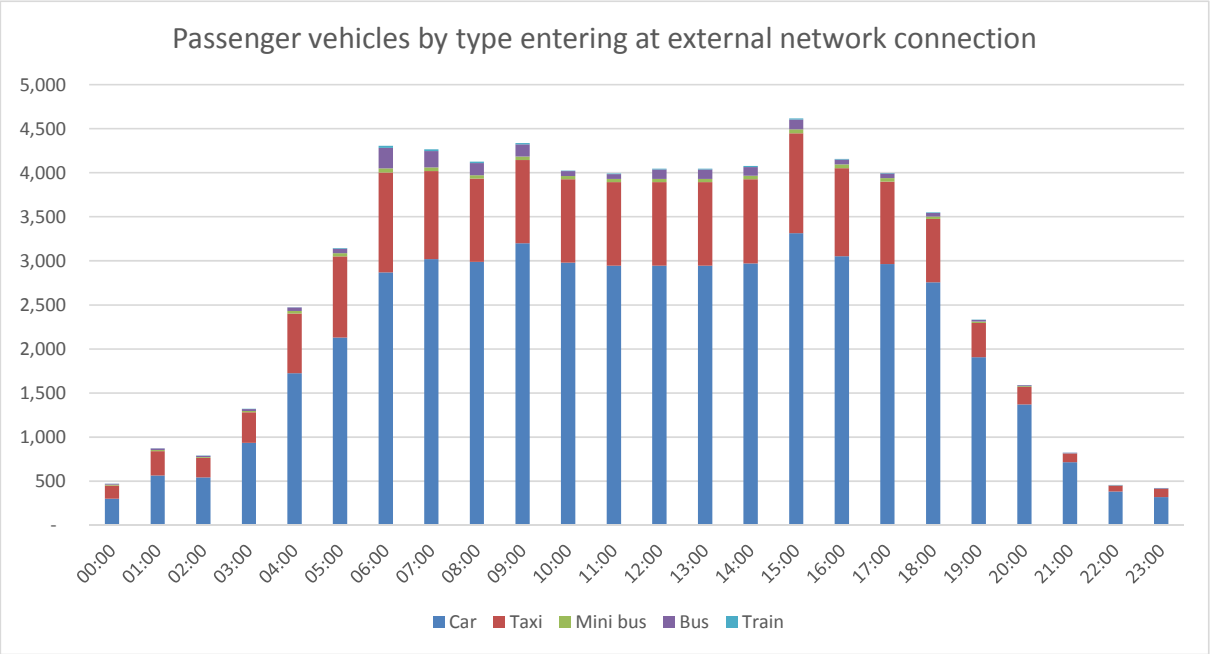


Figure 9-13 Passenger vehicles exiting at the northern boundary by vehicle type

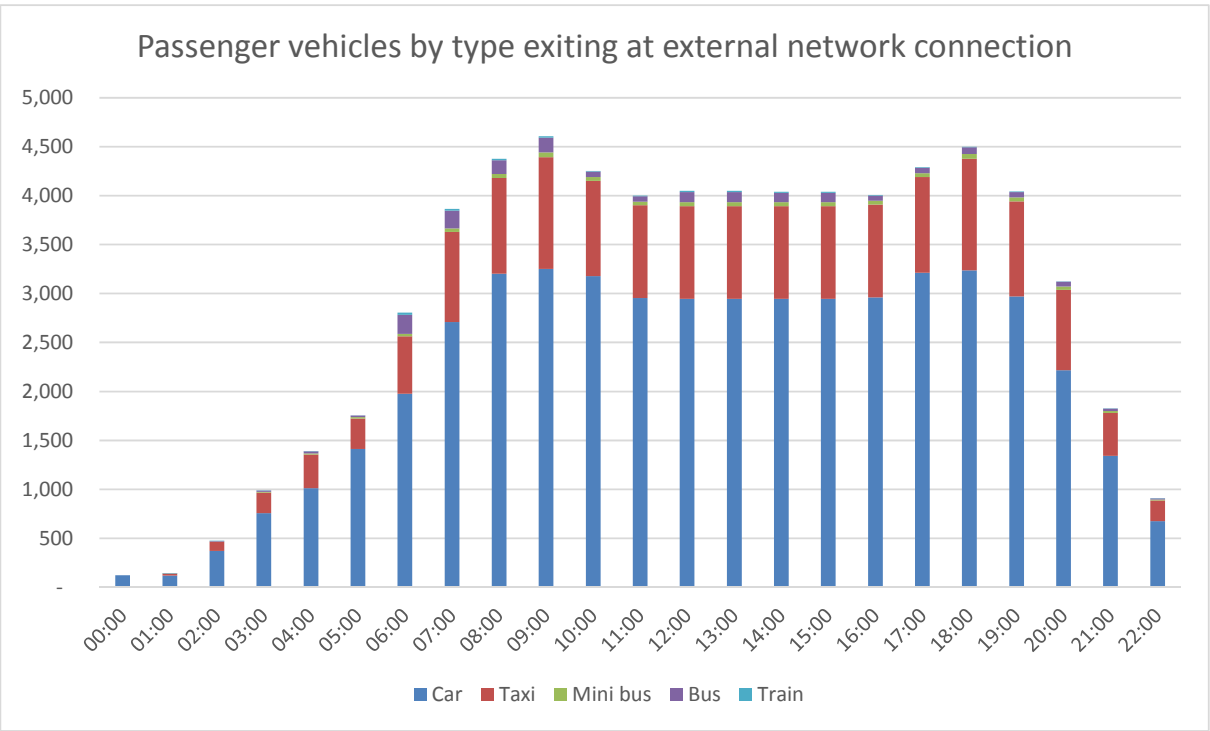


Figure 9-12 shows that the vehicle demand at 4,332 vehicles entering the proposed airport during the AM traffic peak on the external road network and 4,152 vehicles entering the proposed airport during the PM traffic peak on the external road network.

Figure 9-13 shows 4,361 leaving the proposed airport during the AM traffic peak on the external road network and 4,492 leaving the proposed airport during the PM traffic peak on the external road network.

In addition to the vehicles arriving at the boundary, the circulating movements of the taxis (as developed in 6.2 are added into the volumes to determine the internal traffic demand.

Figure 9-14 Passenger vehicles arriving at the terminal and car park entrances

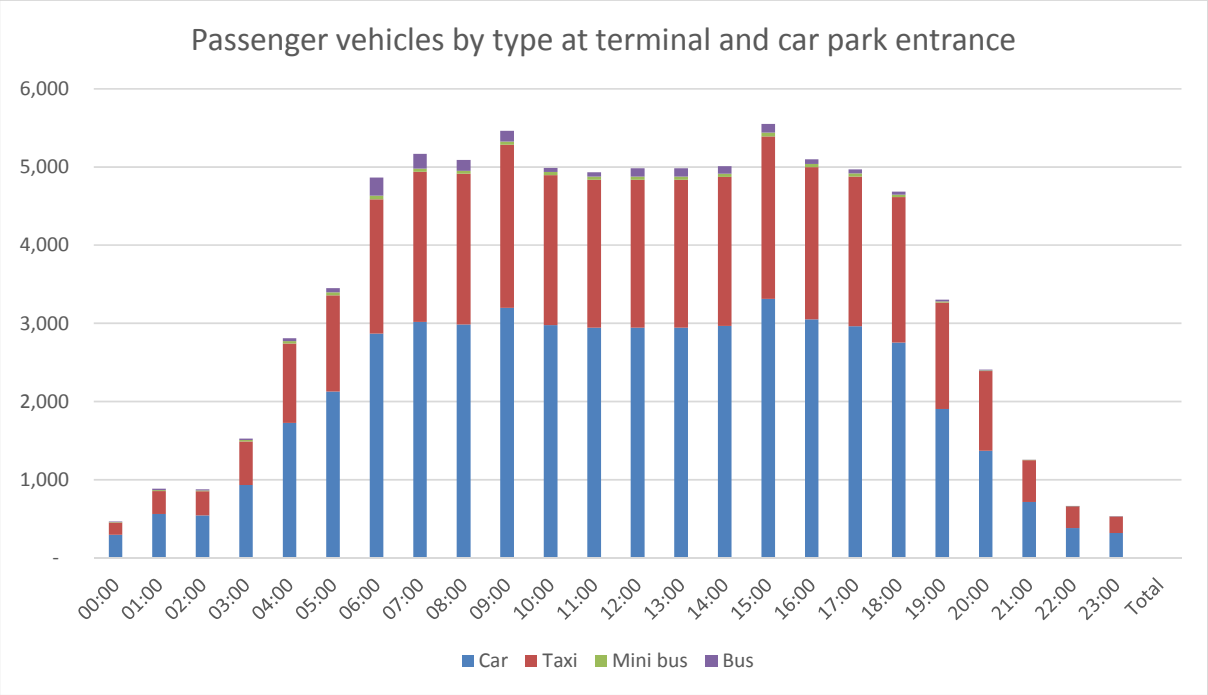


Figure 9-15 Passenger vehicles leaving at the terminal and car park exits

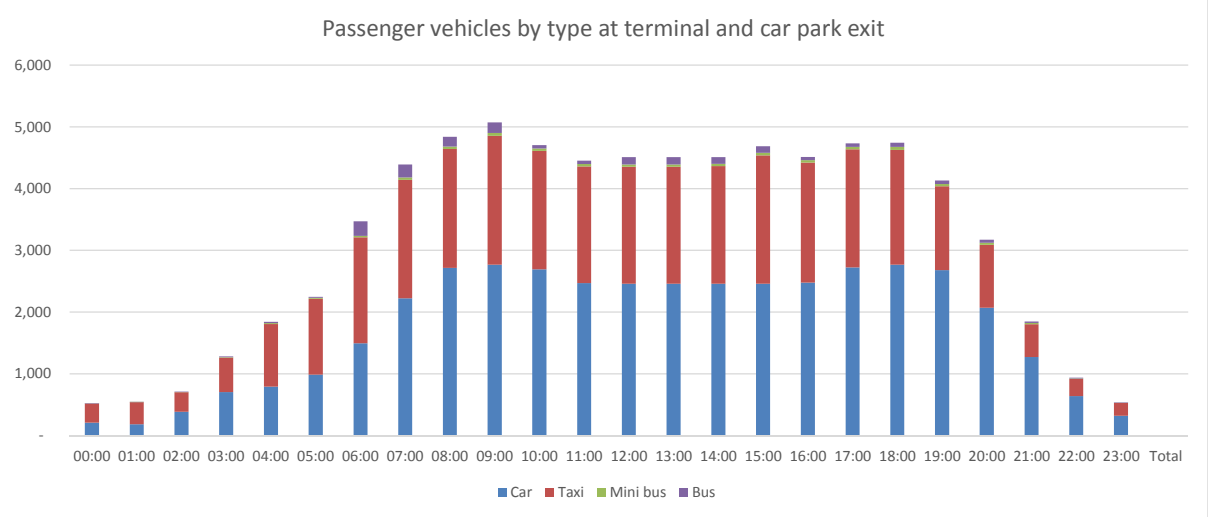


Figure 9-14 shows the vehicle demand entering the terminal area in the AM peak and vehicles entering the proposed airport during the PM peak.

Figure 9-15 shows the vehicle demand leaving the airport during the AM peak and leaving the proposed airport during the PM peak.

9.3 Employee trip generation

Employee trip generation has been determined using the same methods as outlined in section 6.

In 2063, a value of 80 million annual passenger movements has been used for the analysis. This results in a total staffing requirement of 59,500. Applying the same 80 per cent staff on site ratio as in section 6.3.2, 47,392 staff will be on site in any one day.

Table 9-5 shows how these staff will be broken into the 10 employee groups.

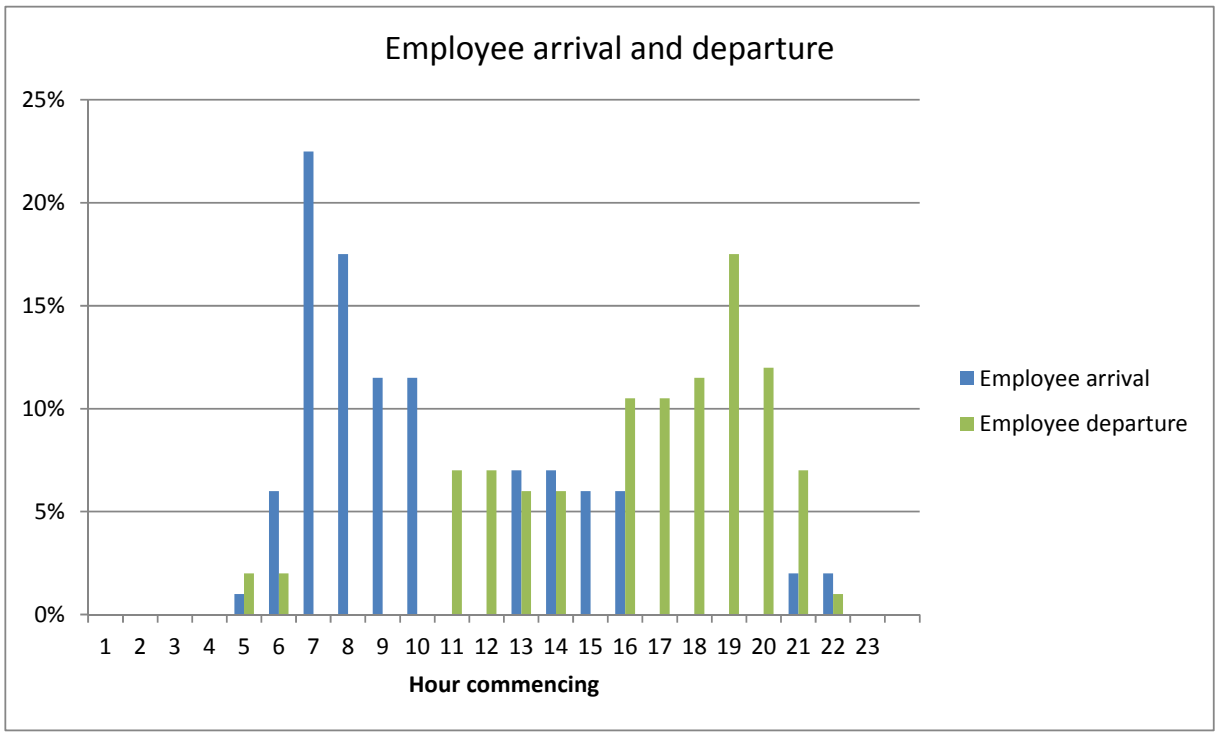
Table 9-5 Proposed WSA assumed 2063 shift profiles

Worker type	Start	Finish	Percent of total employees	No of employees on site
Airfield and terminal overnight	21:00	05:00	2	1,700
Airfield day	05:00	13:00	3	950
Airfield afternoon	13:00	21:00	3	950
Terminal support morning	06:00	13:00	10	4,760
Terminal support afternoon	13:00	20:00	10	5,712
Terminal supplementary morning	07:00	11:00	14	6,664
Terminal supplementary morning	15:00	17:00	14	5,712
Office early start	07:00	17:00	21	9,996
Office later start	09:00	19:00	23	10,948
		Total	**100**	**47,392**

9.3.1 Arrival and departure profiles

A synthetic profile for employee arrivals and departures prior to and after their shifts has been created to allow for some early and late starts and finishes for employees. For each shift, 50 percent of employees have been assumed to arrive in the hour before their shift starts and the remaining in the hour that the shift starts. A similar process has been developed for completion of shifts. This results in the profile shown in Figure 9-16.

Figure 9-16 Employee arrival and departure profile - percentage



This translates into the volume of employees arriving and departing in each hour as shown in Figure 9-17.

Figure 9-17 Employee arrival and departure profile - volume

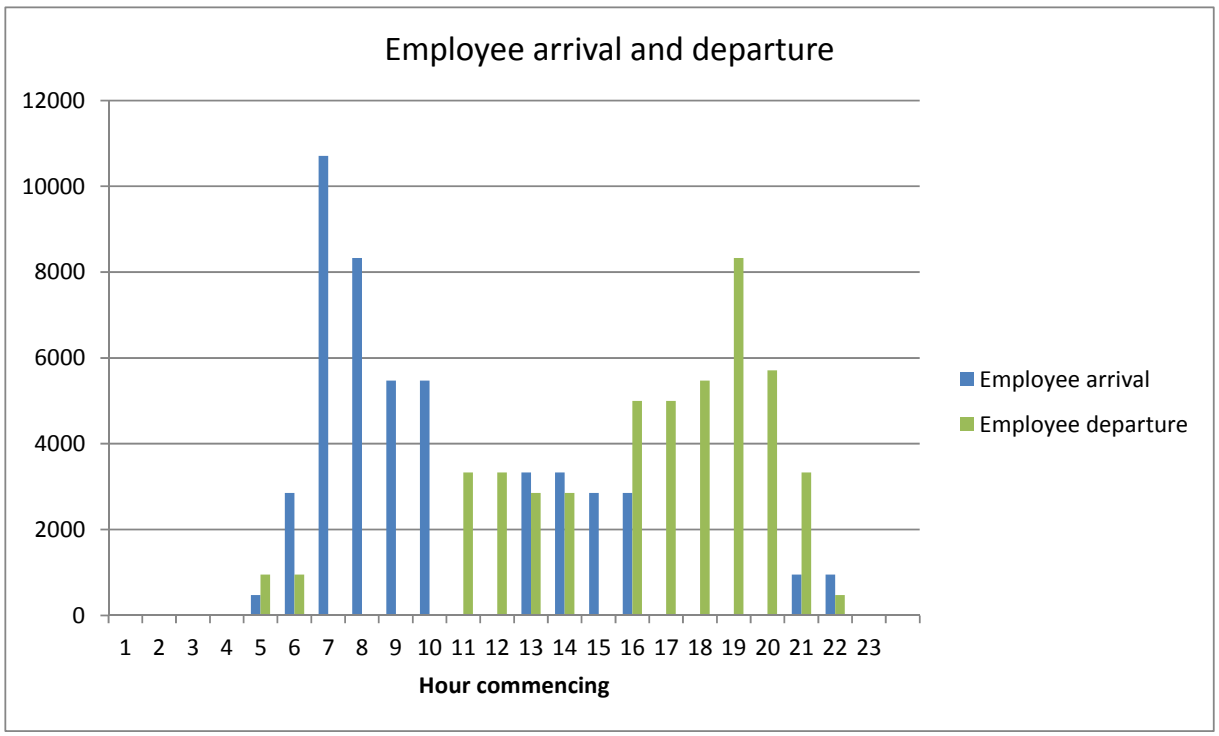


Figure 9-17 shows that the peak arrival for the AM peak period is 10,710 employees and the PM peak departure for employees is after the main transport network peak between 7 and 8 PM, with 8,330 employees leaving in this hour.

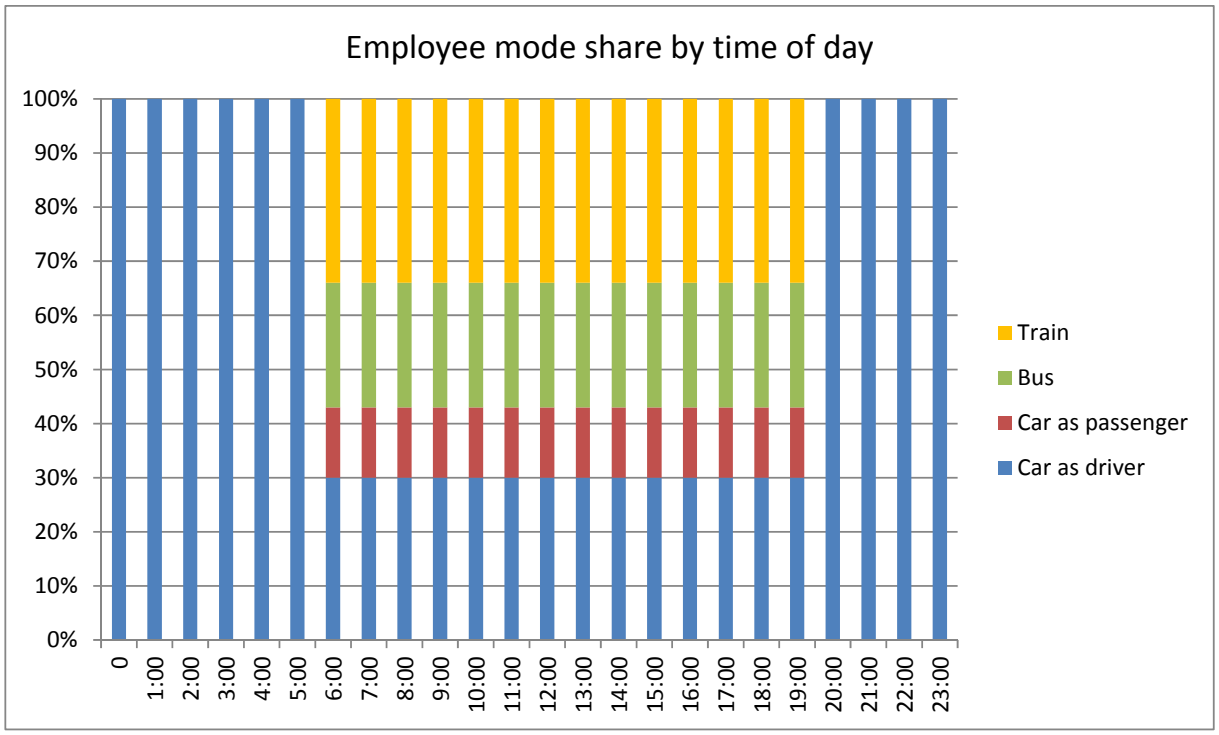
9.3.2 Mode split

The employee mode spilt for the longer term development was determined in the following way:

- a base mode split based on section 6.3.5 was determined, with the addition of the railway through the airport site;
- the mode split for car modes was modified down based on the capacity of a potential staff car park when the access road reaches its nominal capacity;
- workers arriving between 8 pm and 6 am are assumed to solely use cars, due to the lack of connectivity in the public transport system for counter-peak travel from residential areas in Western Sydney; and
- distributing the staff trips to bus and rail modes.

The resulting employee mode splits are shown in Figure 9-18.

Figure 9-18 2063 employee mode split by time of day



Using the distributions applied in the previous sections, the employee trips have been assigned to the employee modes. These are shown in Figure 9-19 and Figure 9-20 for arrivals and departures respectively.

Figure 9-19 Employee arrivals by mode by time of day

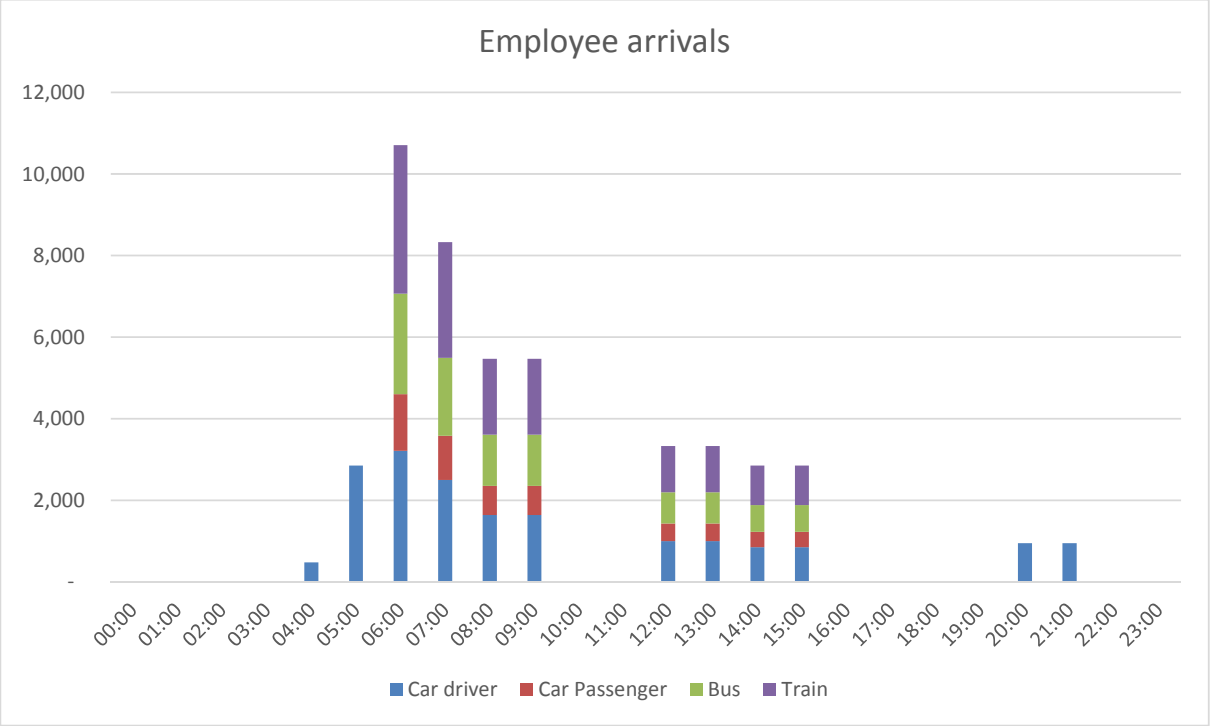


Figure 9-20 Employee departures by mode by time of day

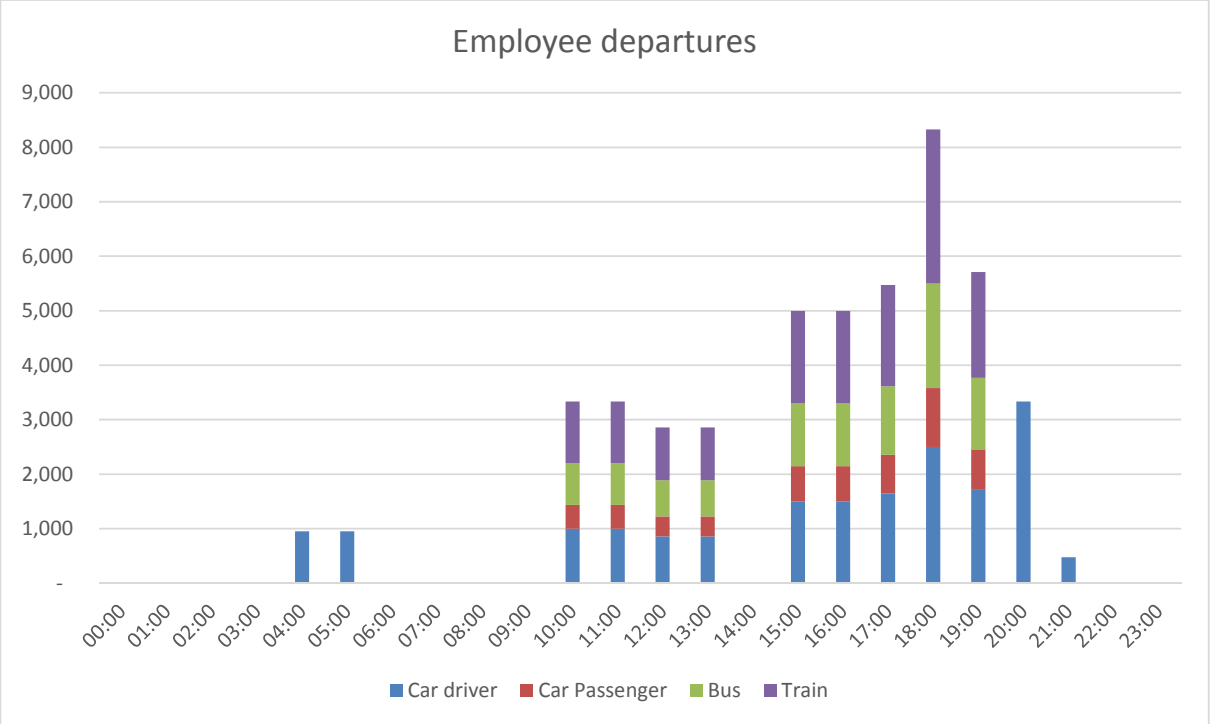


Figure 9-19 shows that the AM peak arrival volume for employees is 3,213 cars.

Figure 9-20 shows that the peak PM departure volume for employees is 3,332 cars.

9.3.3 Traffic generation

The traffic generation for employees is shown in Figure 9-21 and Figure 9-22.

Figure 9-21 2063 employee vehicle arrivals by mode

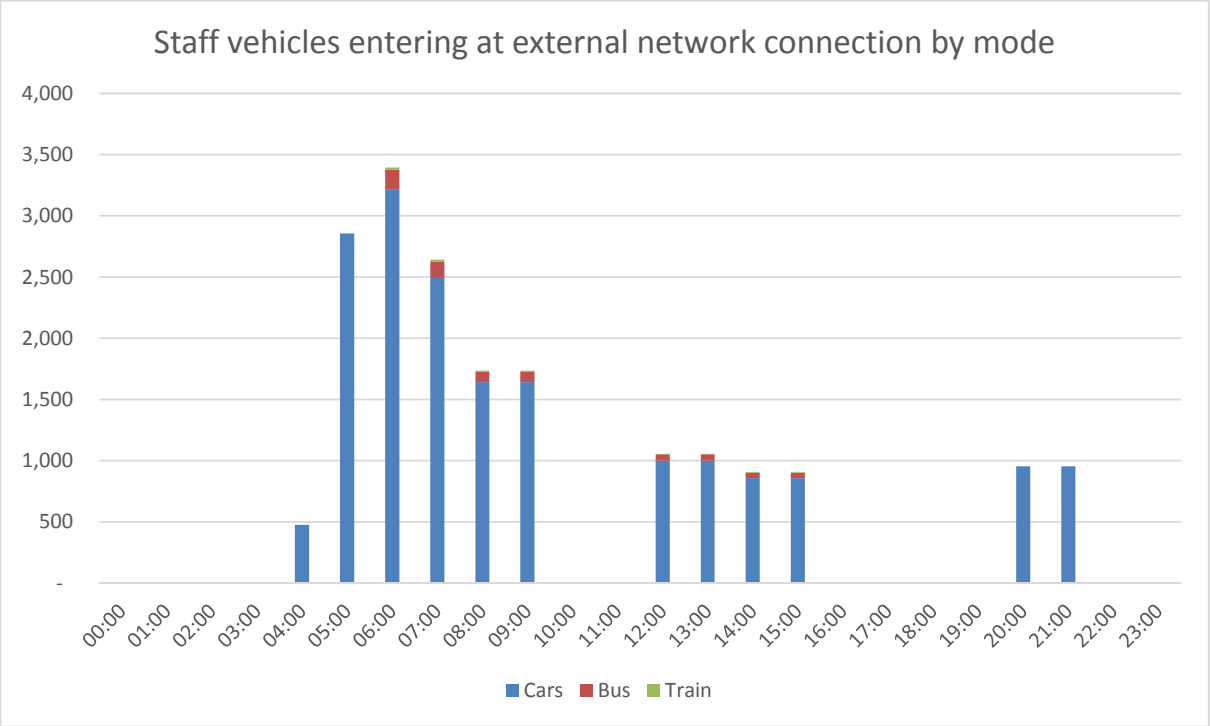


Figure 9-22 2063 employee vehicle departures by mode

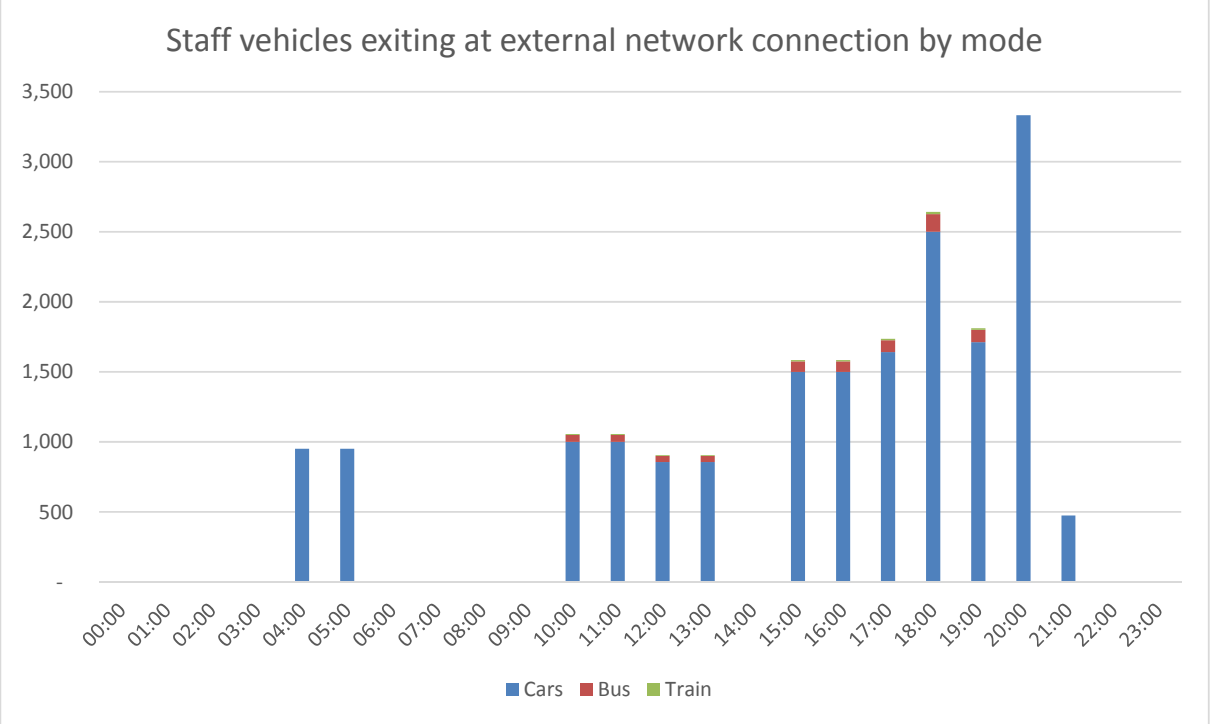


Figure 9-21 and Figure 9-22 show that the employee traffic generation peaks outside the main traffic peaks for the surrounding road network for both the arrival and departure of employees.

9.4 Combined air passenger and employee trip generation

The total employee trip generation for 2063 based on the total trips for each hour is shown in Figure 9-23 and Figure 9-24.

Figure 9-23 Total arrival trip generation by mode

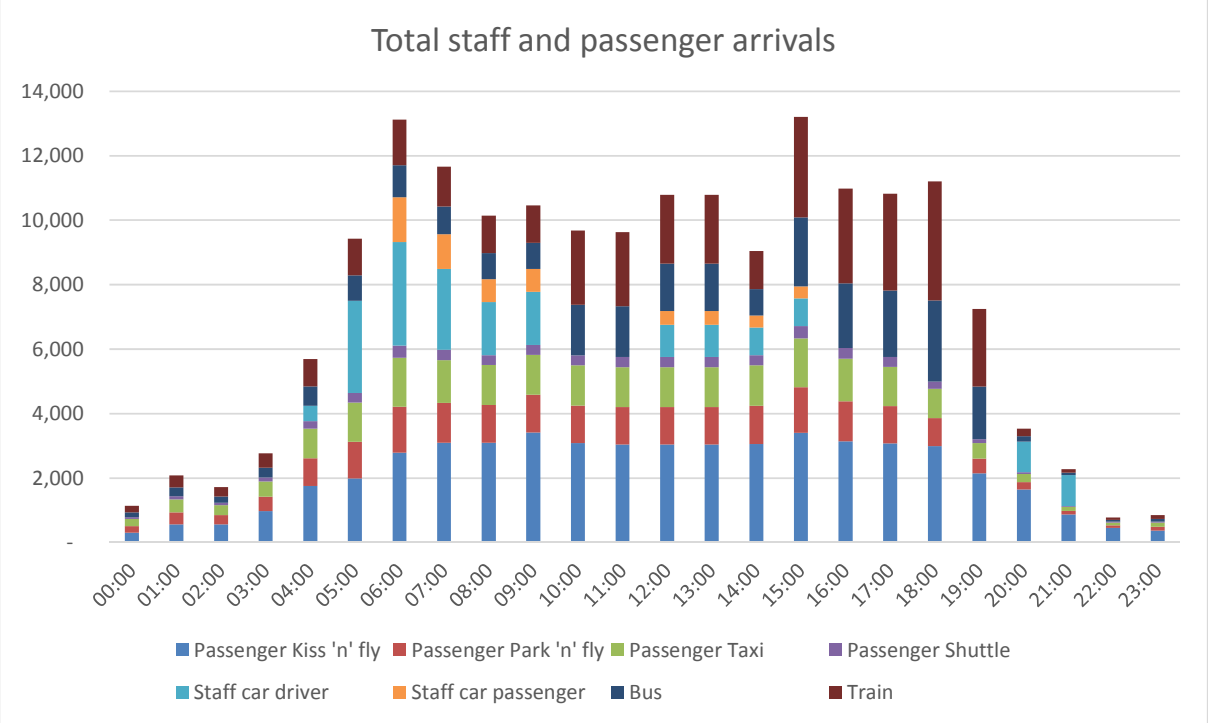


Figure 9-24 Total departure trip generation by mode

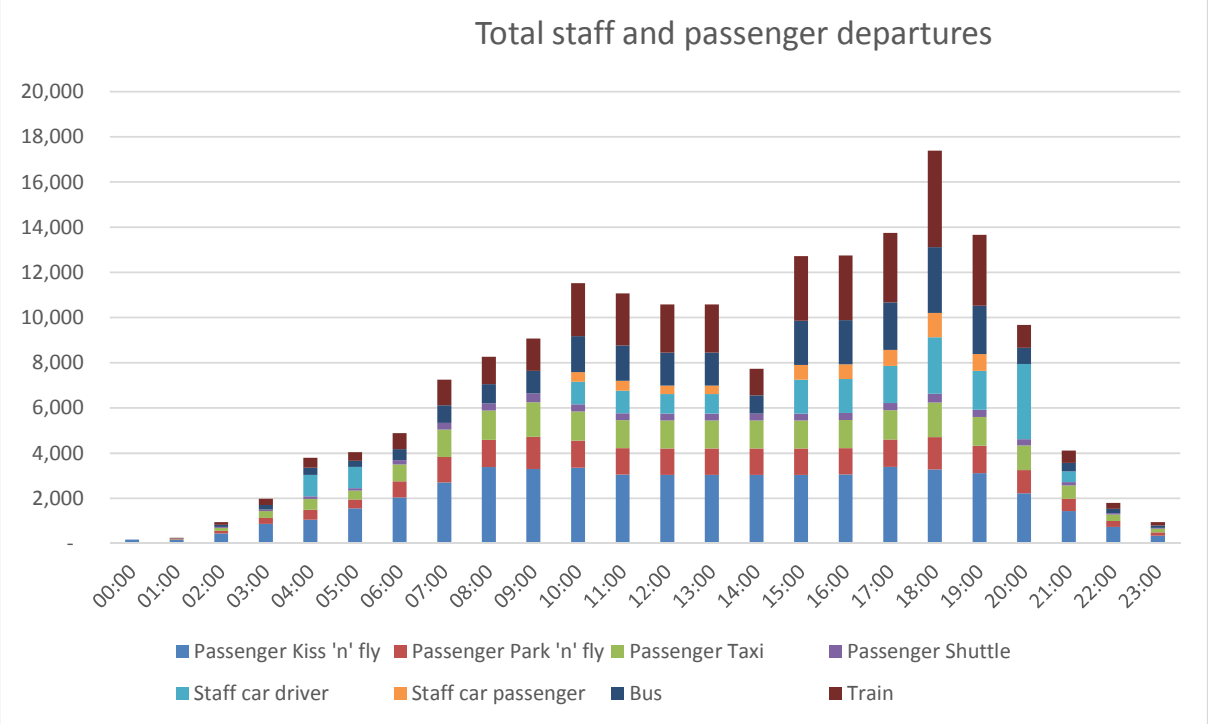
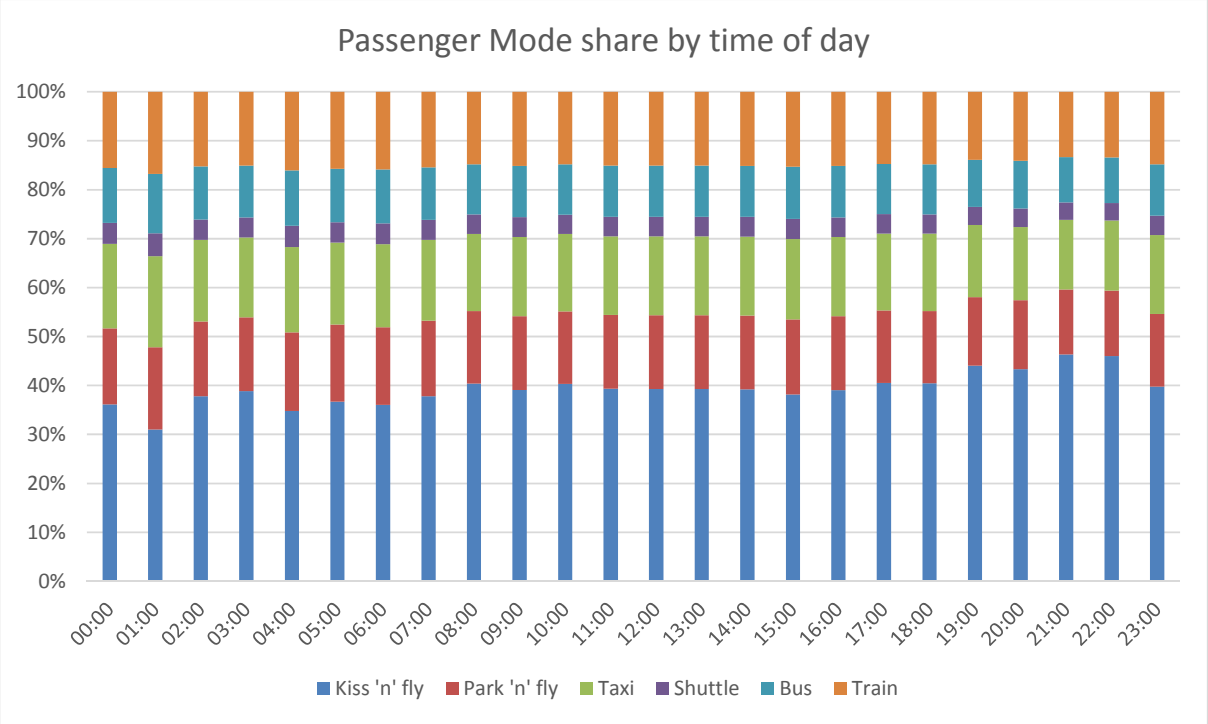


Figure 9-23 shows that the peak trip generation to the proposed airport occurs between 6 and 7 AM and is 13,122 trips.

Figure 9-24 shows that the peak trip generation from the proposed airport occurs between 6 and 7 pm and is 17,382 trips.

When the actual mode splits across the day are determined based on the preceding sections, the revealed mode split is as shown in Figure 9-25.

Figure 9-25 Mode split across the day



9.5 Total air passenger and employee traffic generation

The trips identified in sections 9.2 and 9.3 and converted into traffic trips to and from the proposed airport are shown in Figure 9-26 to Figure 9-29.

Figure 9-26 Traffic generation to the main airport entrance by mode

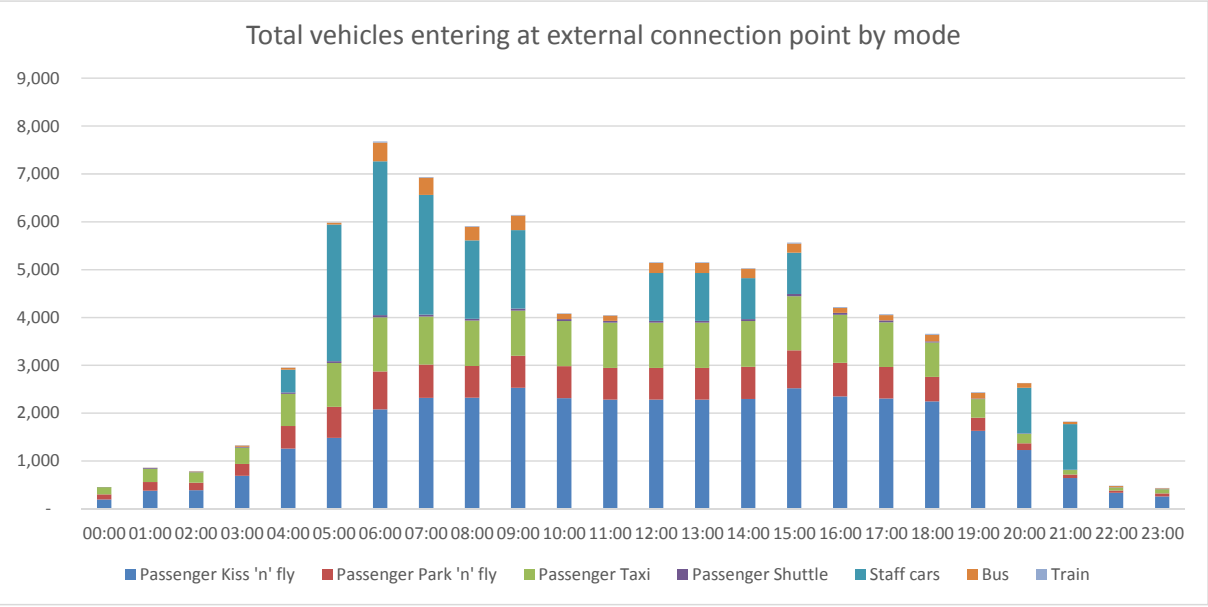


Figure 9-27 Traffic generation from the main airport entrance by mode

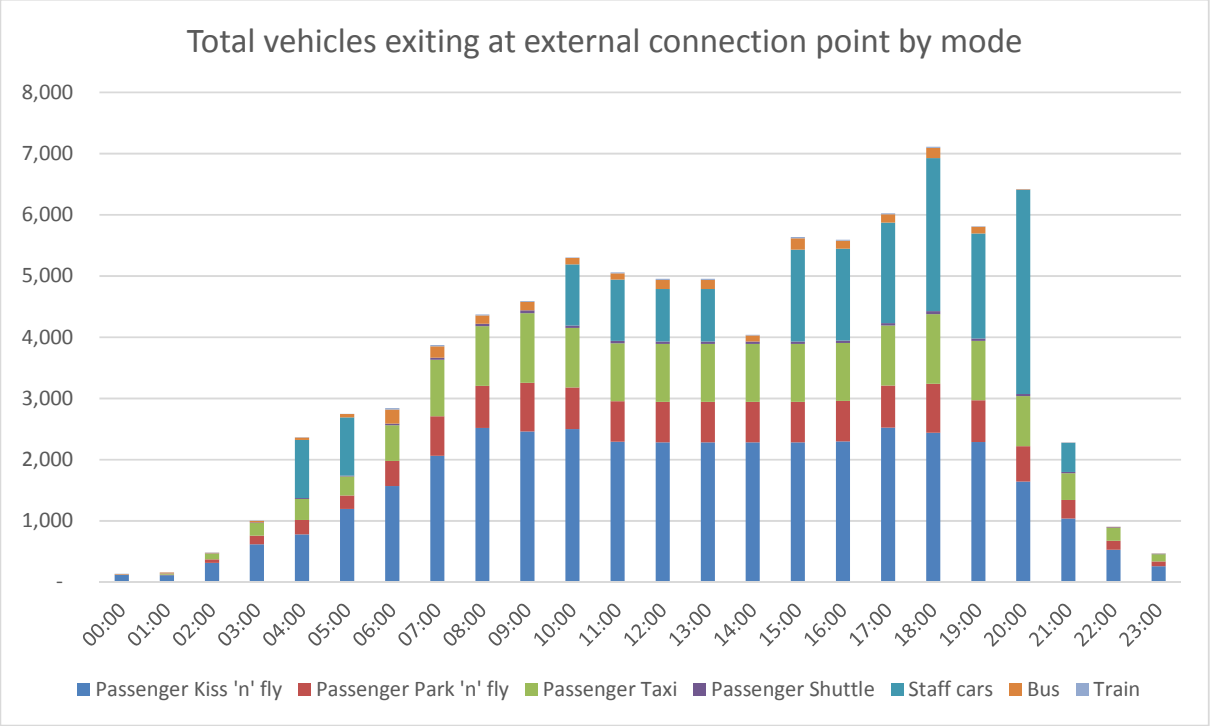


Figure 9-28 Traffic generation to the main airport entrance by vehicle type

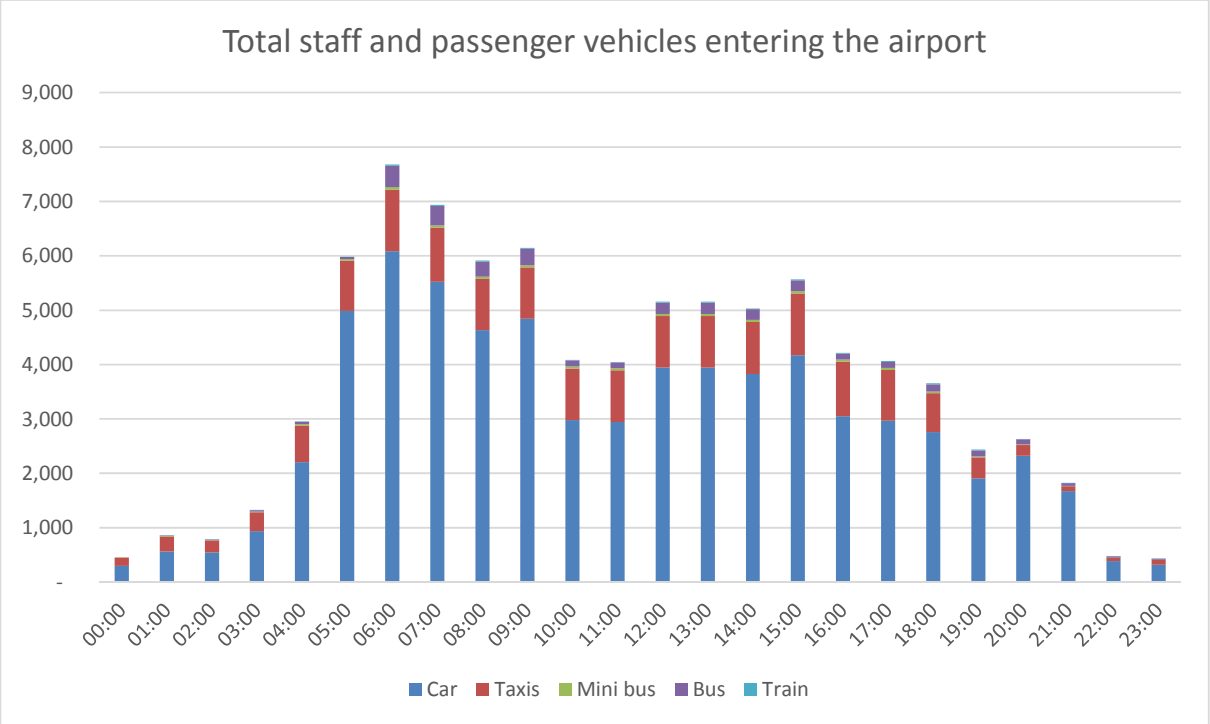


Figure 9-29 Traffic generation from the main airport entrance by vehicle type

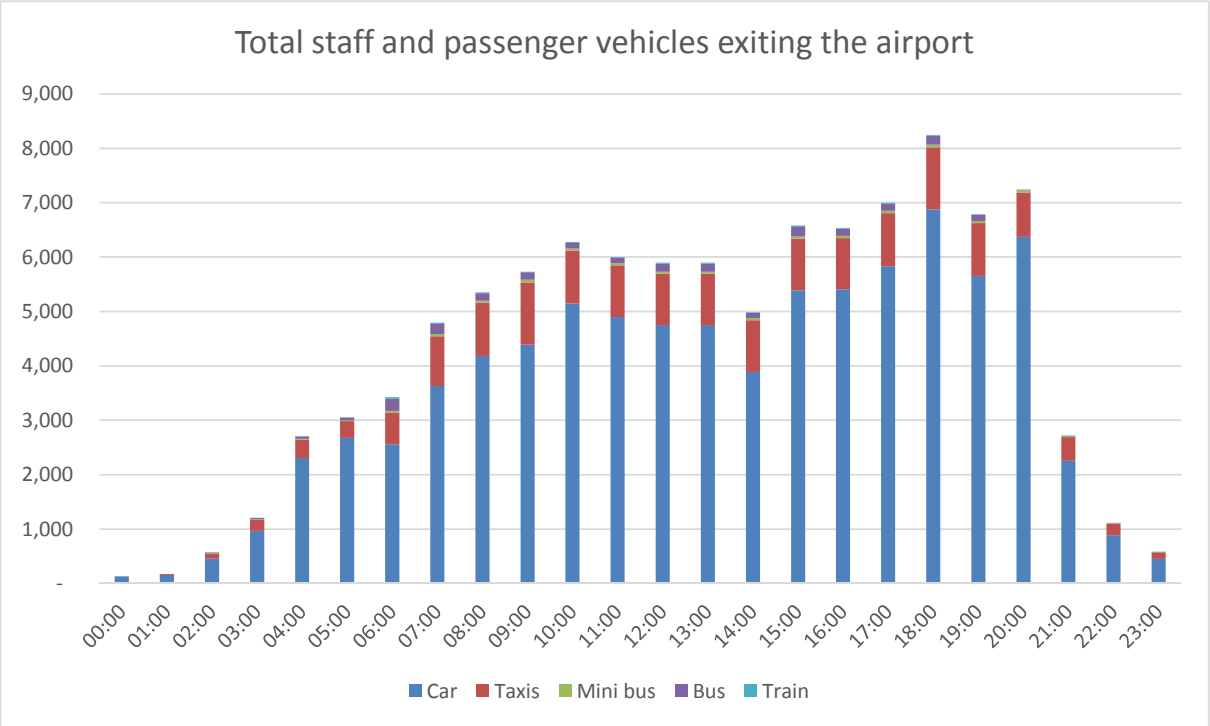


Figure 9-28 shows that the peak vehicle demand to the proposed airport is between 6 and 7 AM and is 7,608 vehicles per hour.

Figure 9-29 shows that the peak vehicle demand away from the proposed airport is between 6 and 7 PM and is 8,200 vehicles per hour.

9.6 Freight trip generation

Freight demand has been provided for air freight cargo to the proposed airport.

No delivery demand for airport consumables (e.g. food, retail items) or waste removal from the terminals at the proposed airport was available as both the location of these facilities within the terminal and the access arrangements are unknown at the time of writing it is not possible to determine the traffic impacts of this demand. It is not possible to determine these items without a detailed terminal plan.

9.6.1 Air freight

The freight demand for air cargo is estimated to be 1,021,210 tonnes in 2063.

In order to turn these cargo loads into freight trips, it has been assumed that the cargo freight arrives using the proportions of heavy rigid trucks, semi-trailers and B-doubles as shown in Table 9-6.

Each freight vehicle type, its carrying mass and percentage of the fleet are shown in Table 9-7.

Table 9-6 2063 freight vehicle expansion factors

Vehicle type	Percentage of vehicle fleet	Number of car equivalents (pcu)	Cargo mass carried (tonnes)
Heavy Rigid Truck (12.5 metres long)	65	2	12.5
Semi-Trailer (19 metres long)	25	3	40
B-Double (23 -26 metres long)	10	5	56

It is anticipated that a fuel pipeline to the proposed airport will be completed by 2063, significantly reducing the number of B-double movements each day.

Table 9-7 2063 two-way freight truck movements

Vehicle type	2063 Annual movements	2063 Daily movements	2063 Hourly movements	2063 Car equivalents (pcu) per hour
Heavy Rigid Truck (12.5 metres long)	112,603	308.50	12.85	25.71
Semi-Trailer (19 metres long)	13,534	37.08	1.54	4.63
B-Double (23 -26 metres long)	3,867	10.59	0.44	2.21

9.7 Total traffic trip generation estimate

The traffic generation calculations presented in this section are inserted into the traffic model to assess their impact. The figures are presented for the representative 2-hour periods used in STM3, with a 24 hour total. Table 9-8 provides the collation of traffic generation estimates developed in the section. The figures assume an operational rail line to the airport.

Table 9-8 Total modelled trips to/from the proposed airport in 2063

	AM Peak 2 hour	Interpeak 2 hour	PM Peak 2 hour	Evening 2 hour	24 Hour
Accessing Airport					
Passengers	8,034	7,969	8,351	7,345	66,504
Airport Workers	4,141	1,499	571	2,748	17,739
Freight (TNR)	26	79	39	171	834
Total (Accessing)	**12,201**	**9,547**	**8,962**	**10,263**	**85,077**
Egressing from Airport					
Passengers	7,887	8,121	8,071	7,342	66,385
Airport Workers	0	1,237	3,094	3,240	18,072
Freight (TNR)	26	79	39	171	834
Total (Egressing)	**7,914**	**9,437**	**11,205**	**10,753**	**85,291**

Note that the analysis excludes the trips to and from the proposed airport generated by associated commercial development or freight traffic for consumables.

The slight discrepancy in accessing and egressing totals is due to park-and-fly trips where access and egress profiles are calculated separately and external taxi trips where the inbound and outbound occupancy rates differ.

9.8 Airport traffic distribution

The traffic generated from the Airport was distributed using STM3. This calculates traffic distribution from first principles, by using the land use inputs combined with the generalised costs of travel from origin to destination zone. As such, this source is considered the best available for the proposed airport generation, considering the condensed timeframes for this stage of the study.

10. Operational impact assessment

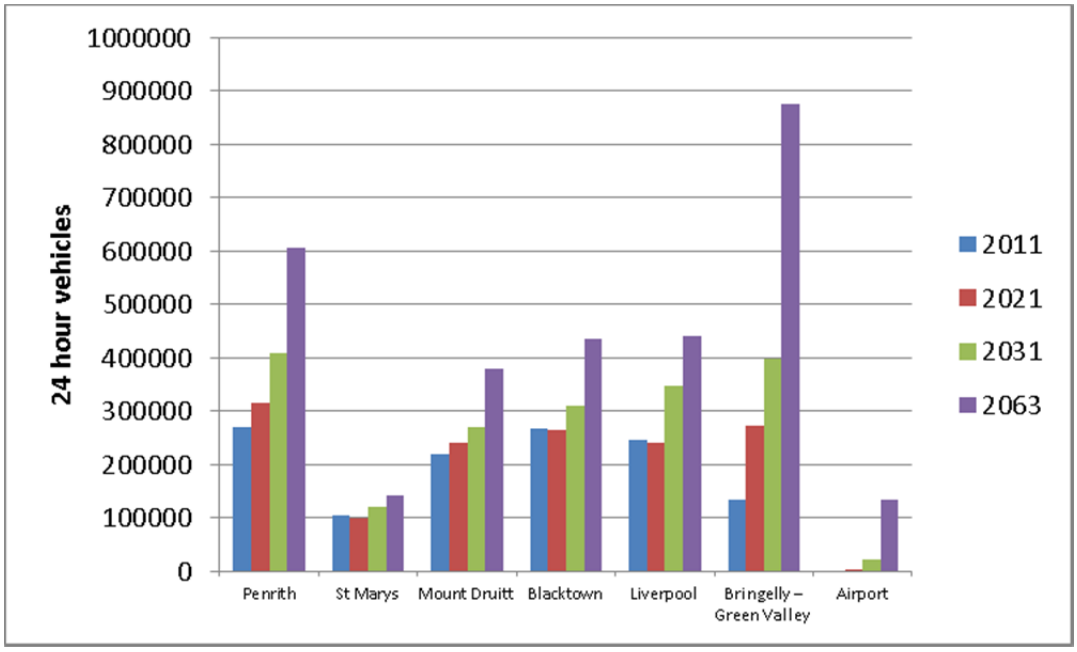
10.1 Background traffic growth

As a result of existing and future planned developments in Western Sydney, there is expected to be a considerable amount of development growth in the coming years, largely comprised of:

- South West Priority Growth Area
- Broader Western Sydney Employment Area
- Greater Macarthur Investigation Area
- the proposed Western Sydney Airport
- smaller growth centres.

Figure 10-1 provides a summary of the magnitude of trip making in the vicinity of the proposed airport and shows the expected growth to 2063. The data in Figure 10-1 assume the rail extension from Leppington to St Marys via the proposed airport is operational.

Figure 10-1 Vehicle movements originating within SA3 (24 hour)



Source: STM3 Model outputs

Figure 10-1 shows that the proposed airport represents a very small component of overall trip demand in 2031, but rises substantially between 2031 and 2063. Nevertheless, Figure 10-1 shows a more substantial increase in trip demand is forecast over the next half a century, in particular in the Greater MacArthur Investigation Area (Bringelly/Green Valley). Although the proposed airport is projected to produce approximately 130,000 trips in each direction by 2063, trip making from other areas are expected to grow substantially too.

For modelling purposes it is assumed that all passengers and workers at the proposed airport would access the airport site from the north, either using the M12 or Elizabeth Drive. Freight would access the site from the south, from The Northern Road.

10.2 Future road network performance

Figure 10-2 and Figure 10-3 show the changes in traffic volumes in 2063 between the Do Minimum and With Airport scenarios. The differences are in pcu for the 2 hour peak periods.

The data in Figure 10-2 and Figure 10-3 show:

- the opening of the M12 within the model attracts traffic from the M4 corridor. However, for Elizabeth Drive, Bringelly Road and Fifteenth Avenue, the additional traffic that would be generated by the proposed airport overrides the reduction in volumes as a consequence of the M12 to create, in general, a net increase in the volumes on these east-west routes.
- The Northern Road, Luddenham Road and Mamre Road carry a significant additional amount of traffic as a consequence of the proposed airport.
- the proposed airport increases the volume of traffic on the north-south routes in the study area, including The Northern Road and Mamre Road, where no additional infrastructure is currently assumed over that proposed as part of the Western Sydney Infrastructure Plan.

Figure 10-2 2063 AM Peak Traffic Volume Difference plot (2 hour)

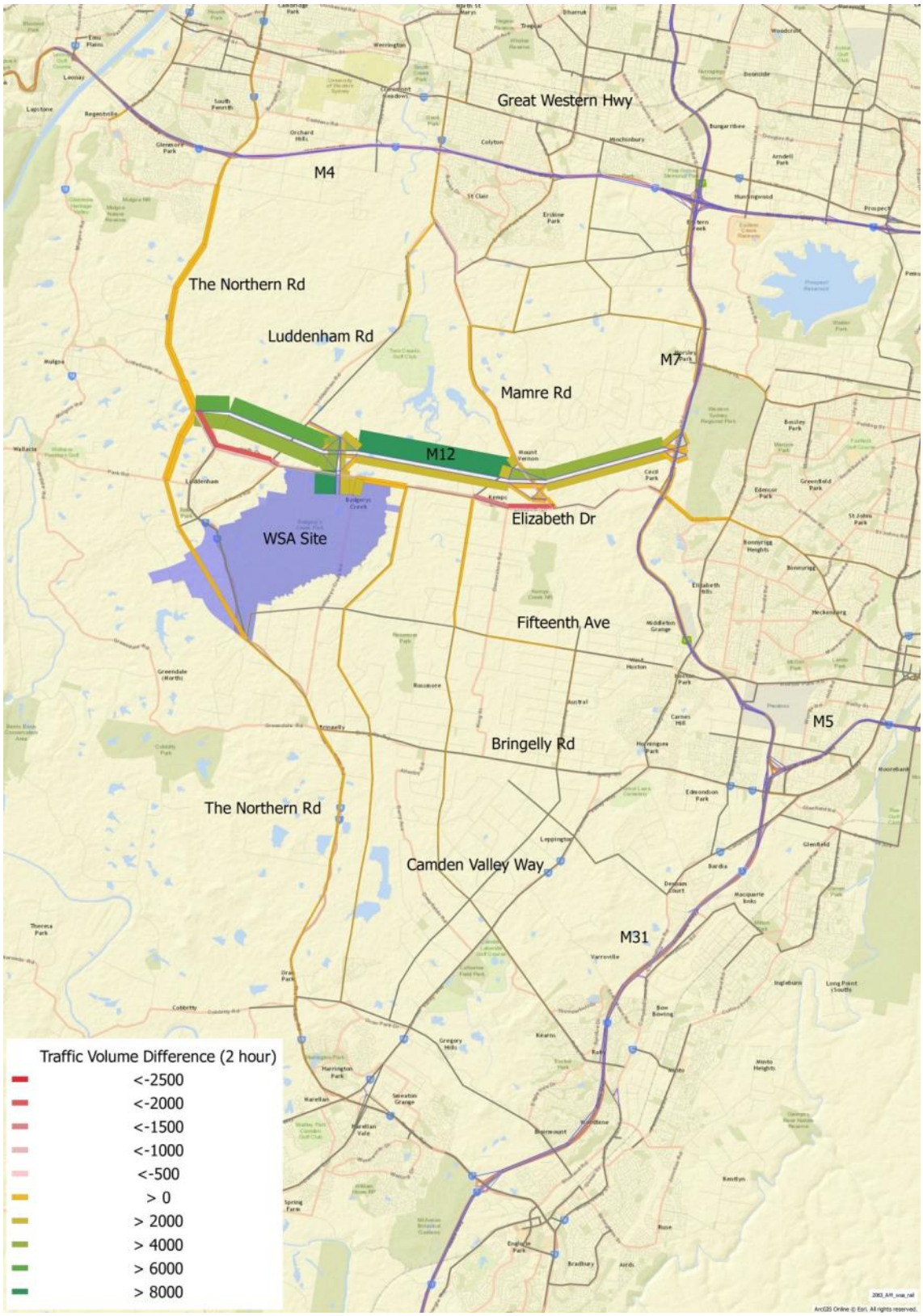
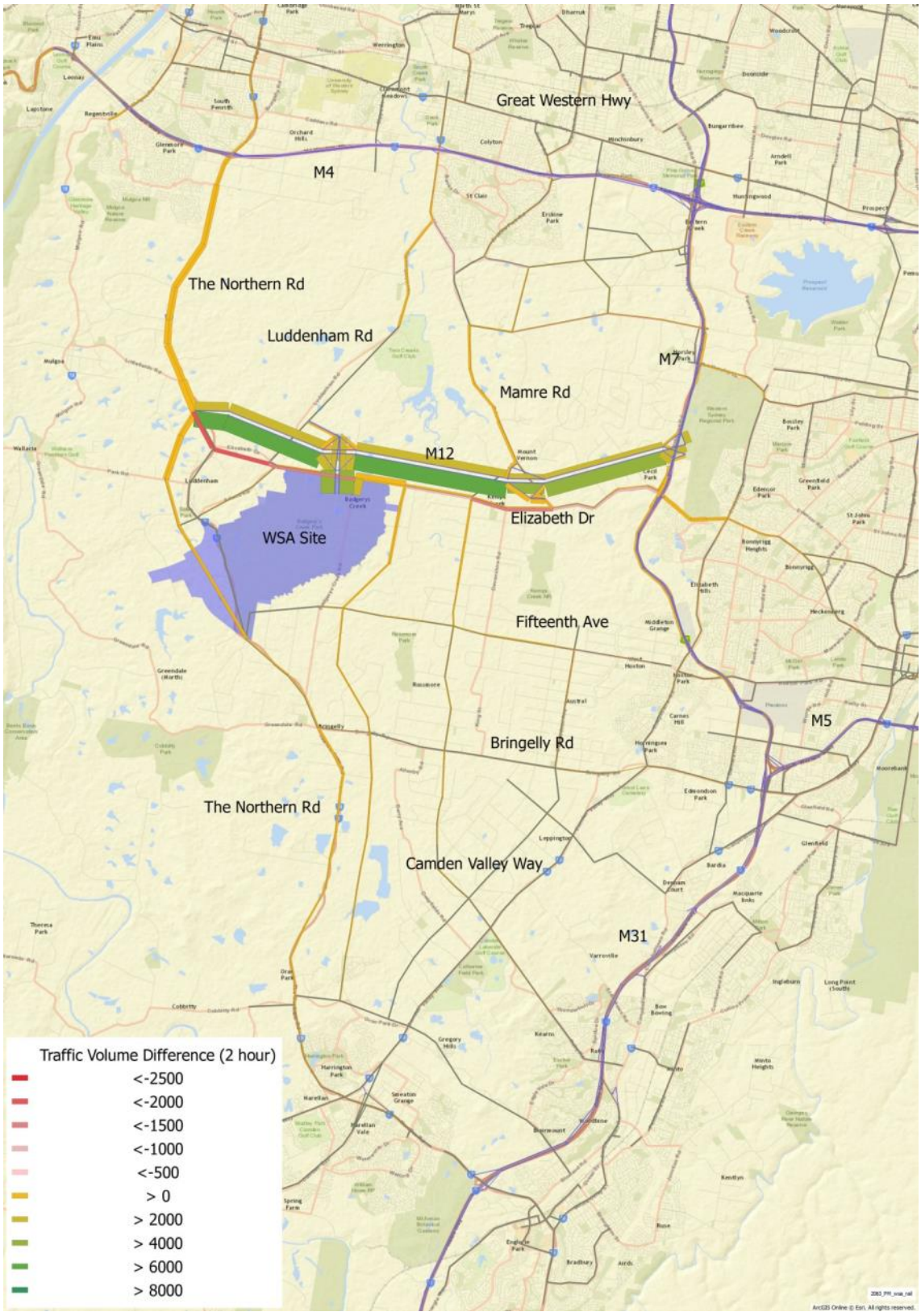


Figure 10-3 2063 PM Peak Traffic Volume Difference plot (2 hour)



10.3 Impacts on roads and access

An analysis has been carried out on the mid-block level of service for the Do Minimum and the With Airport scenarios. The Level of Service is shown figuratively in Figure 10-4, Figure 10-5 and Figure 10-6 for the AM and PM peaks respectively, which show the differences in volume/capacity for without (left) and with the proposed airport (right). A summary of the Level

of Service at key links in the network is provided in Table 10-1, with a map of the location of the key links provided in Figure 10-4.

Figure 10-4 Location of Tabulated Level of Service output

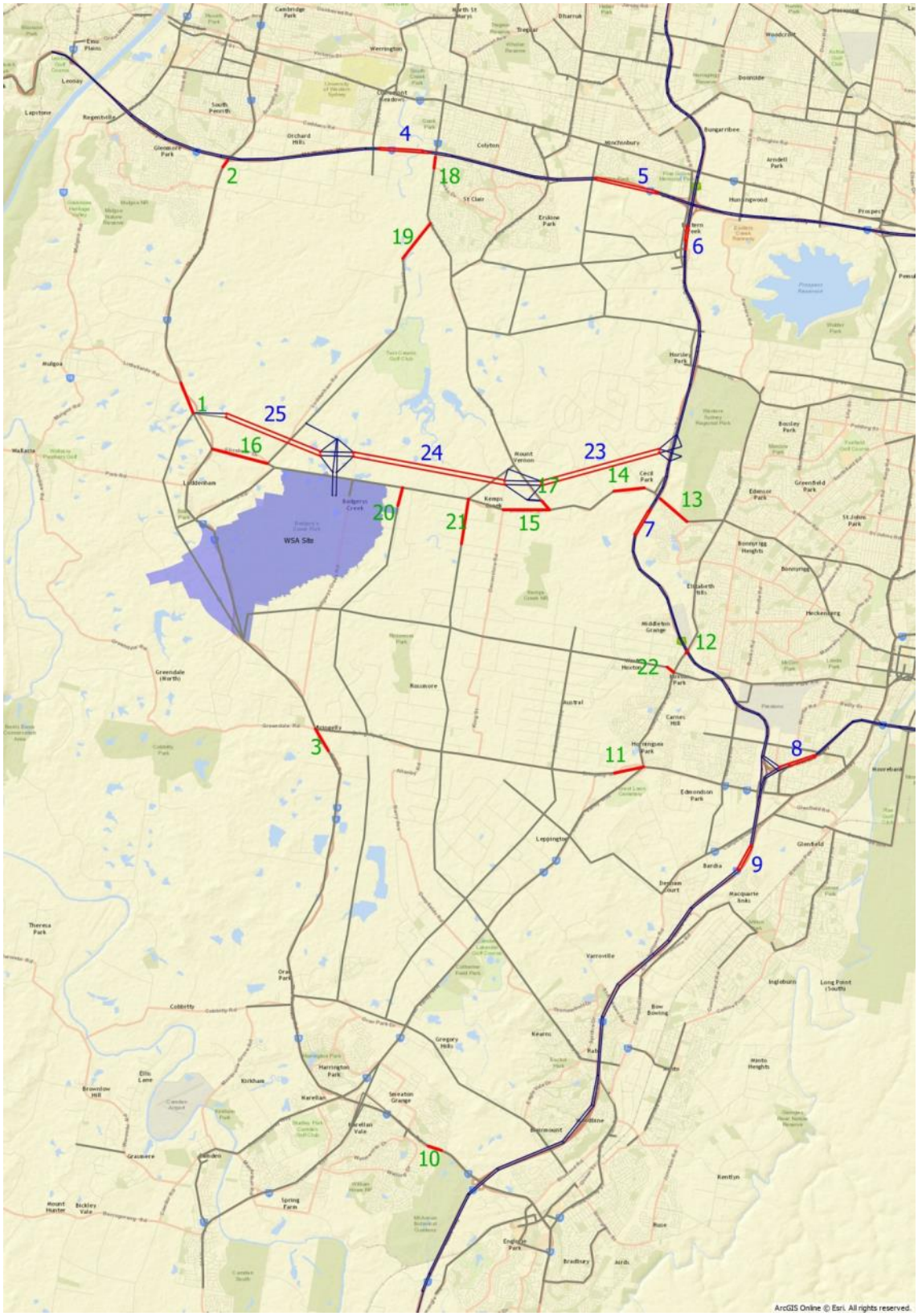


Table 10-1 Level of Service for 2063 With and Without Western Sydney Airport

Id	Road	Location	Baseline (Without WSA)				With WSA			
			AM Peak		PM Peak		AM Peak		PM Peak	
			Nbd/Ebd	Sbd/Wbd	Nbd/Ebd	Sbd/Wbd	Nbd/Ebd	Sbd/Wbd	Nbd/Ebd	Sbd/Wbd
1	The Northern Road	North of Elizabeth Dr	C	C	C	C	**F**	**F**	**E**	**E**
2	The Northern Road	South of M4	F	D	D	F	F	D	**F**	F
3	The Northern Road	South of Bringelly Rd	D	C	C	F	**E**	**D**	**D**	F
4	M4	West of Mamre Road	F	E	E	F	F	**D**	E	F
5	M4	West of M7	F	E	D	F	F	E	D	F
6	M7	South of M4	F	F	F	F	F	F	F	F
7	M7	South of Elizabeth Drive	F	E	D	F	F	**F**	**E**	F
8	M5	East of M7	F	F	F	F	F	F	F	F
9	M31	South of Campbelltown Road	F	F	F	F	F	F	F	F
10	Narellan Road	North of Tramway Dr	F	F	F	E	F	F	F	E
11	Bringelly Road	West of Cowpasture Road	F	D	D	F	F	D	D	F
12	Cowpasture Road	At M7	F	F	E	F	F	F	E	F
13	Elizabeth Dr	East of M7	F	F	E	E	F	F	**F**	**F**
14	Elizabeth Dr	West of M7	F	E	D	F	F	**D**	D	**D**
15	Elizabeth Dr	West of Mamre Road	F	C	C	F	F	C	C	**E**
16	Elizabeth Dr	East of the Northern Road	C	A	A	C	**B**	A	A	A
17	Mamre Road	North of Elizabeth Dr	F	C	C	F	F	**F**	**D**	F
18	Mamre Road	South of M4	F	F	F	E	F	F	F	E
19	Luddenham Dr	West of Mamre Road	F	C	C	F	F	**F**	**D**	F
20	Lawson Rd	South of Elizabeth Dr	F	A	B	F	F	**C**	**C**	F
21	Western Rd	South of Elizabeth Dr	F	B	C	F	F	**C**	C	F
22	Fifteenth Ave	West of Cowpasture Rd	F	B	B	E	F	B	B	E
23	M12	West of M7	-	-	-	-	B	A	A	C
24	M12	West of Mamre Road	-	-	-	-	D	A	A	C
25	M12	East of the Northern Road	-	-	-	-	C	C	A	C

Note: Bold text has been used to identify a change in LoS from the base case – whether this is an improvement or deterioration.

Figure 10-5 2063 AM Peak Volume/Capacity - Do Minimum (Left), with proposed Airport (Right)

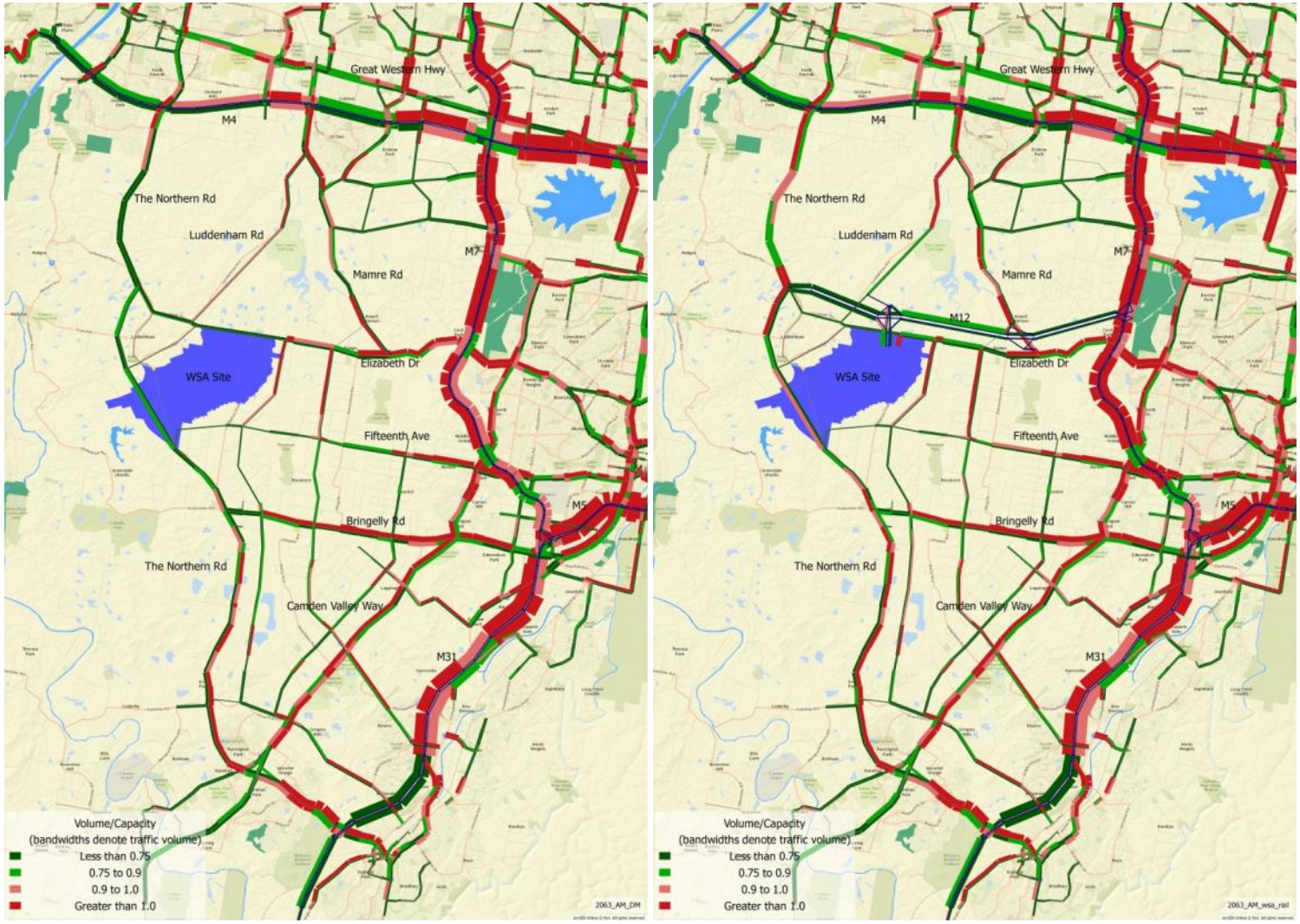
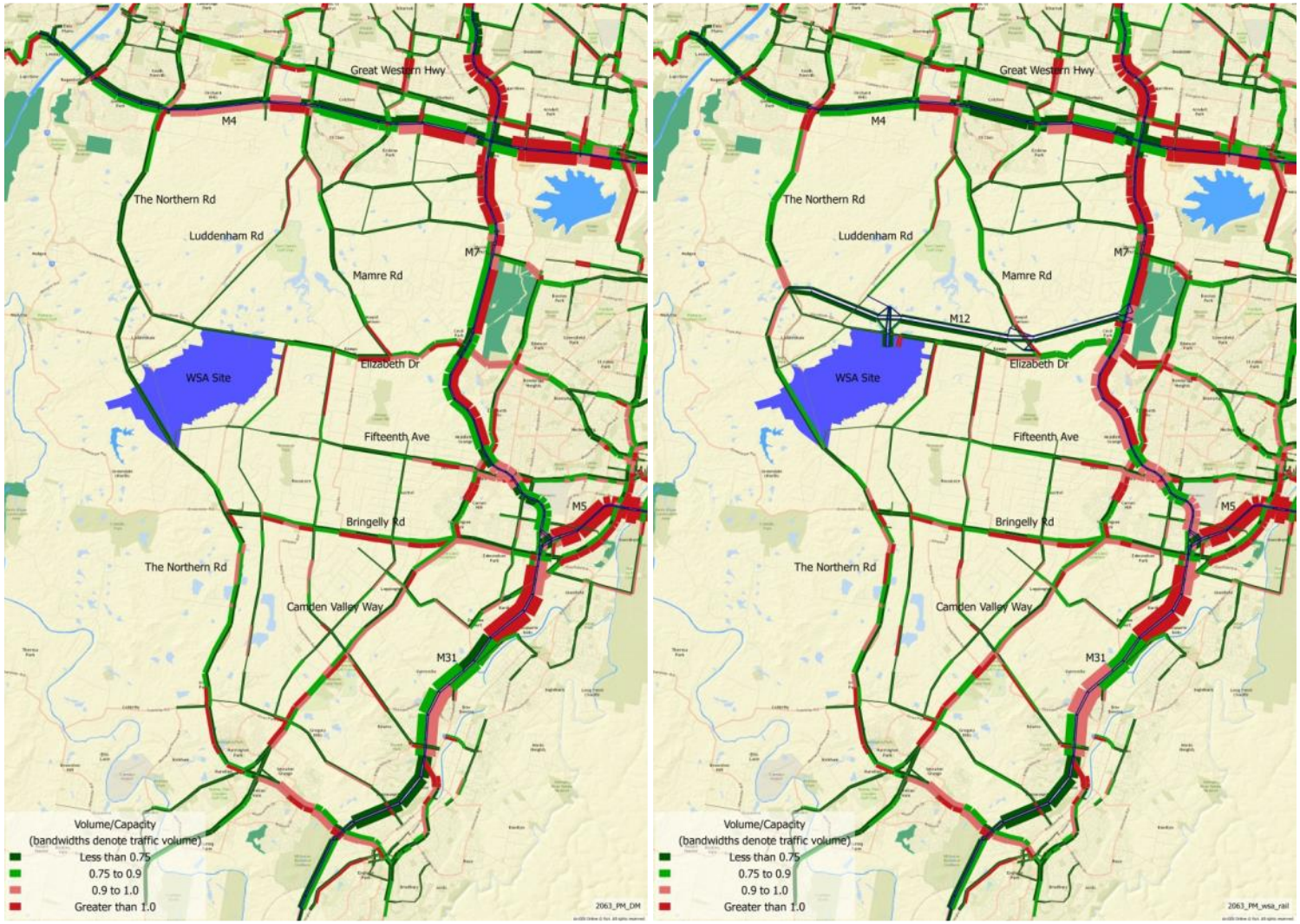


Figure 10-6 2063 PM Peak Volume/Capacity - Do Minimum (Left), with proposed Airport (Right)



By 2063, with or without the proposed airport, the road network is forecast to exhibit a considerable amount of congestion. The results indicate that:

- the M4, M5 and M7 have high volume/capacity ratios in both peak periods in both directions;
- Bringelly Road exhibits high levels of congestion eastbound in the AM peak and westbound in the PM peak; and
- Narellan Road is considerably more congested than in 2031.

With the addition of the airport traffic, the following changes are observed:

- North-south links between Elizabeth Drive and Fifteenth Avenue are more congested with the airport, rising to LoS F in both peak periods. These are important links that will be used to access the airport via Elizabeth Drive and have not been assumed to have been upgraded in this modelling analysis;
- The Northern Road carries more traffic with the airport and M12 in place, approximately an additional 1,000 vehicles per hour (with the additional two lanes in each direction supplied as part of the WSIP) in the PM peak, north of the intersection with the M12. By 2063, with the airport, it is reaching capacity;
- the M12 forms an important link to alleviate congestion on Elizabeth Drive. The M12 itself has spare capacity; and
- the M4 shows a lower LoS in certain sections as a result of diversion to the M12.

It should be noted that because of the significant time horizon being forecast and the lack of available information on the future road network in 2063, the 2063 airport demand forecasts have been assigned to a 2041 road network as road networks for a later horizon year are not available. As a result, it is reasonable to suggest this analysis is a worst-case scenario and that additional traffic capacity infrastructure would be provided in the 20 years between 2041 and 2063. In particular, if the proposed M9 is built, this would relieve some of the congestion identified from the current modelling.

10.4 Public transport impacts

No assessment of the changes to the capacity requirements for the longer term public transport network has been made. Due to the capacity constraints of the internal road system within the proposed airport, the mode split to public transport would need to increase over the longer term and suitable levels of service will be required.

10.5 Key findings

The following key findings concerning passenger and employee trip generation and freight trip generation have been identified:

- daily passenger and employee road vehicle trip generation of 87,575 vehicles to the airport and 102,785 vehicles from the proposed airport, with 242 trains per day.
- the peak passenger and employee vehicle demand to the proposed airport is between 7 and 8 AM and is 13,122 vehicles per hour.
- the peak passenger and employee vehicle demand away from the proposed airport is between 6 and 7 PM and is 17,382 vehicles per hour.
- daily freight vehicle trip generation is expected to be 85,077 vehicles to the proposed airport and 85,291 vehicles from the airport.
- peak AM (2 hour) vehicle demand is 12,201 to the proposed airport and 7,914 from the airport.
- peak PM (2 hour) vehicle demand is 10,263 to the proposed airport and 10,753 from the airport.

Due to the capacity constraints of the internal road system within the proposed airport, the mode split to public transport would need to increase over the longer term and suitable levels of service will be required.

As demonstrated, the longer term airport development and forecast growth in Western Sydney will have a significant combined impact on both the roads and public transport systems. The NSW and Australian governments have not commenced planning any road or transport upgrades beyond 2041.

Longer term airport operations will be reliant on the introduction of the South West Rail Link extension after 2031. Even with the South West Rail Link extension, the assessed increases in demand vs capacity for 2063 show that detailed planning is required to preserve additional corridors and transport upgrades to cater for the population and development growth associated with the airport and surrounding urban development.

It is recommended that more detailed planning is commenced to address this envisioned capacity shortfall such that potential future upgrades are not constrained by encroachment from surrounding development.

11. Summary and conclusions

11.1 Existing conditions

The existing land use in the vicinity of the airport site is generally rural /agricultural, consisting mainly of farming land and residential properties.

The existing traffic volumes on the surrounding road network are within the expected functional classification outlined by Roads and Maritime for arterial roads.

Bus routes 789 and 801 currently service the area in the vicinity of the airport site.

Pedestrian and cycling infrastructure is provided within the study area but is currently very limited.

The 2011 STM3 model for existing conditions shows capacity constraints on the M4 and M5 eastbound and in both directions on the M7 during the AM peak and in the PM peak, the westbound direction on the M4 and M5, as well as both directions on the M7. Therefore, although the immediate area around the airport site does not exhibit significant congestion, there are existing constraints on the strategic motorway network.

The crash history identified for the strategic road network is not out of character for these types of high volume roads. The following stands out in the analysis:

- there is a high representation of speed and fatigue in the roads analysed.
- there is a high number of rear end crashes on The Northern Road.
- there have been two fatalities at the intersection of Bringelly Road and Camden Valley Way.

The identified common crash types and themes should be considered in future proposed works.

11.2 Construction traffic impact

The construction of the proposed airport would generate an additional 1,254 vehicle movements per day on the surrounding road network during the construction period. This equates to around 314 peak hour vehicle movements which would occur during the AM peak period, which is not a significant value in the context of Western Sydney.

The construction stages for the proposed airport would not impact on the surrounding transport system with the exception of potential oversized vehicle movements for the earthworks. These movements may require temporary road closures or police escorts.

A CTMP would be developed in consultation with relevant stakeholders prior to the commencement of construction. The CTMP would provide the overall plan and staging for managing traffic through and around each work site and take into consideration major projects around the airport site.

An important measure relating to construction traffic impacts is the implementation of a community information awareness programme. This programme will be initiated prior to construction commencing and throughout the entire construction period to ensure that local residents are aware of the construction activities, with particular regard to construction traffic issues.

11.3 Initial airport development

The main access to the airport site from the north would be via the new M12 Motorway that is planned to run generally parallel to Elizabeth Drive. It is expected to include a grade separated interchange for the proposed airport access. The proposed access corridor within the airport site will be 100 m wide comprising of six traffic lanes, two bus lanes and a 40 metre rail reserve corridor (including provision for station(s) within the corridor).

Additional commercial development area access could be via Elizabeth Drive and Badgerys Creek Road.

Access to the airport site from the south-west will be via The Northern Road, which will be relocated and upgraded by others prior to the commencement of operations. This access point is anticipated as being primarily for secure commercial access to operational areas of the site, including cargo and maintenance. This access road is expected to consist of a 50 metre wide corridor allowing four trafficable lanes.

Parking would be provided for a minimum of 8,400 and up to 10,000 vehicles, consisting of short and long stay parking, employee and operational parking, commercial vehicle parking and storage, parking for rental cars, and emergency services vehicle parking.

Pedestrian and cycle access would be included in the terminal and ground transport precincts and parking areas, and pedestrian and cycle routes would be provided throughout the airport site.

11.4 Operational assessment of the proposed initial airport development

The following key findings concerning passenger and employee trip generation and freight trip generation:

- daily passenger and employee vehicle trip generation of 22,134 vehicles to the proposed airport and 24,857 vehicles from the airport;
- the peak passenger and employee vehicle demand to the proposed airport is between 7:00 and 8:00 am and is 2,406 vehicles per hour;
- the peak passenger and employee vehicle demand away from the proposed airport is between 6:00 and 7:00 pm and is 2,429 vehicles per hour;
- daily freight vehicle trip generation of 20,922 vehicles to the proposed airport and 20,936 vehicles from the airport;
- the freight AM peak (2 hour) vehicle demand is 3,966 to the proposed airport and 2,295 from the airport; and
- the freight PM peak (2 hour) vehicle demand is 1,905 to the proposed airport and 2,117 from the airport.

The introduction of the airport and the M12 has the following effects on the capacity of the major road network:

- a small increase in congestion at The Northern Road/M4 intersection;
- a small increase in congestion on Mamre Road; and
- overall, by 2031, the initial airport development would not generate the level of traffic required significantly to impact the operation of the surrounding road network.

The initial (Stage 1) airport operations would not have a significant impact on the capacity of the road network. This is primarily because the substantial package of road improvements proposed as part of the WSIP, in addition to those identified in the BWSEA and SWGC, will have sufficient capacity to cater for the expected passenger and employee traffic demand for the proposed airport in 2031.

The public transport and walking and cycling systems proposed by the NSW Government and local councils would also have sufficient capacity to cater to the expected passenger and employee demand at the proposed airport.

As such, no transport mitigation measures are considered to be required.

11.5 Operational assessment of the indicative longer term airport development

The following key findings concerning passenger and employee trip generation and freight trip generation have been identified:

- daily passenger and employee road vehicle trip generation of 87,575 vehicles to the proposed airport and 102,785 vehicles from the airport, with 242 trains per day.
- the peak passenger and employee vehicle demand to the proposed airport is between 7 and 8 AM and is 13,122 vehicles per hour
- the peak passenger and employee vehicle demand away from the proposed airport is between 6 and 7 PM and is 17,382 vehicles per hour
- daily freight vehicle trip generation Is expected to be 85,077 vehicles to the proposed airport and 85,291 vehicles from the airport
- peak AM (2 hour) vehicle demand is 12,201 to the proposed airport and 7,914 from the airport.
- peak PM (2 hour) vehicle demand is 10,263 to the proposed airport and 10,753 from the airport.

The assessment of the impact of public transport is limited to the forecast reduction in traffic volumes as a consequence of the proposed rail line from Leppington to St Marys via WSA.

As demonstrated, the indicative long term operations of the proposed airport together with forecast development growth in Western Sydney would have a significant combined effect on both the roads and transport systems. The NSW and Australian governments have not commenced planning any road or transport upgrades beyond 2041.

The indicative longer term operations of the proposed airport would be reliant on the introduction of the South West Rail Link extension after 2031. Even with the South West Rail Link extension, the identified increases in demand vs capacity for 2063 show that detailed planning is required to preserve additional corridors to cater for the population and travel growth associated with the airport and surrounding urban development.

It is recommended that more detailed planning is commenced to address this envisioned capacity shortfall such that potential future upgrades are not constrained by encroachment from the surrounding development.

12. References

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South West Growth Centre Structure Plan
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http://www.transitsystems.com.au/sydney/pdf/maps/801_Map.pdf

US Customs and Border Protection *Airport wait times (http://awt.cbp.gov/)*

US Transportation Security Administration *Security wait times (https://apps.tsa.dhs.gov/mytsa/wait_times_home.aspx)*

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Appendices

Appendix A - Traffic Volumes

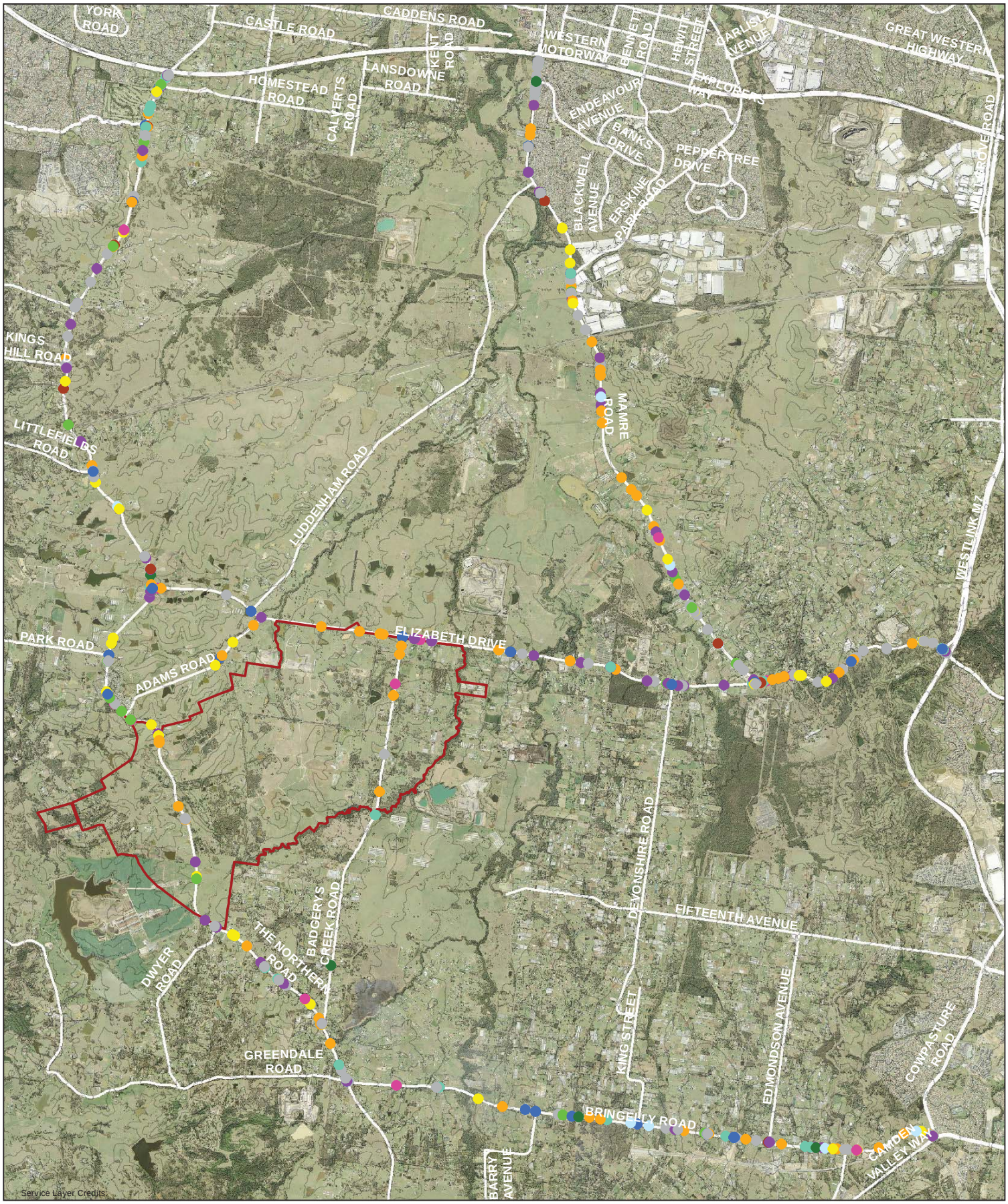
ID	Status	station	station	Location	Map	1991	1993	1996	1999	2002	2005	2005 flag	2005 factor	2005 converted	2005 converted flag
2340		64.014	64.014	BRINGELLY-N OF MR647,BRINGELLY RD	62	10591	11724	12224	15134	15790	17290	Axle Pair	0.98	16944	Vehicle
2341		64.015	64.015	LUDDENHAM-1K S OF EATON RD	55	9819	10060	12313	12951	13425	14885	Axle Pair	0.98	14587	Vehicle
2991		85.021	85.021	NARELLAN-1.5K W OF MR178,CAMDEN V'WY	75	8201	9119	9758	11857	15308	16369	Axle Pair	0.98	16042	Vehicle
2992		85.023	85.023	ORAN PARK-N OF WSTN. END COBBITY RD	69	8829						Axle Pair			Axle Pair
2993		85.024	85.024	BRINGELLY-S OF MR647,BRINGELLY RD	999	8291						Axle Pair			Axle Pair
3058		87.019	87.019	KINGSWOOD-N OF F4,WESTERN FWY	40	26964	31451	34120	41598	42786	44018	Axle Pair	0.98	43138	Vehicle
3059		87.020	87.020	KINGSWOOD-S OF F4,WESTERN FWY	47	16602	15268	21836	28531	30500	33069	Axle Pair	0.98	32408	Vehicle
3061		87.023	87.023	CAMBRIDGE PK-S OF SR2048,ANDREWS RD	40	28285	25546	27918	30601	27679	33961	Axle Pair	1.00	33961	Axle Pair
3063		87.026	87.026	LONDONDERRY-S OF SR2063,LONDOND'Y RD	32	10611	10690	12132	11813	12605	14329	Axle Pair	1.00	14329	Axle Pair
2994		85.026	85.026	BRINGELLY-S OF LOWES CK	62		9538	9775	12067	13212	14284	Axle Pair	0.98	13998	Vehicle
3060		87.021	87.021	LUDDENHAM-N OF MR535,ELIZABETH DR	55	12850	11643	13318	15501	14515	16902	Axle Pair	0.98	16564	Vehicle
3062		87.025	87.025	LONDONDERRY-E OF SR2063,LONDOND'Y RD	32	8342	9067	8975	10821	11255	10649	Axle Pair	1.00	10649	Axle Pair
2292	V	60.032	60.032	LIVERPOOL-AT CABRAMATTA CK BRIDGE	64	40651		45583	47878	49940	50281	Vehicle	1.00	50281	Vehicle
2301		60.092	60.092	LIVERPOOL-W OF SH 2,COPELAND ST	999							Axle Pair			Axle Pair
2302		60.093	60.093	LIVERPOOL-W OF MACQUARIE ST	64							Axle Pair			Axle Pair
2343		64.032	64.032	LUDDENHAM-E OF MR154,THE NORTHERN RD	55	6526	5446	5879	6753	6592	7311	Axle Pair	1.00	7311	Axle Pair
2344		64.033	64.033	CECIL PARK-W OF MR515,WALLGROVE RD	56	16980	15906	17274	19180	17910	17311	Axle Pair	1.00	17311	Axle Pair
2345		64.034	64.034	KEMPS CREEK-W OF MR536,MAMRE RD	56	10580	10943					Axle Pair			Axle Pair
2346		64.037	64.037	KEMPS CK-AT SOUTH CK BR	56			8041	9117	9098	9757	Axle Pair	1.00	9757	Axle Pair
2367		65.011	65.011	BONNYRIGG-S OF MR534,CABRAMATTA RD	57	23770	25621	25652	24412	24861	26122	Axle Pair	1.00	26122	Axle Pair
2368		65.012	65.012	BONNYRIGG-W OF MR534,CABRAMATTA RD	57	35698	35375					Axle Pair			Axle Pair
2371		65.022	65.022	BONNYR'G HTS-E OF MR648,COWPASTURE R	57			25920				Axle Pair			Axle Pair
2386	V	65.143	65.143	BONNYRIGG-W OF BONNYRIGG AV	57		32198	31504	28996	35506	36046	Vehicle	1.00	36046	Vehicle
2342	V	64.022	64.022	CECIL PARK-E OF MR515,WALLGROVE RD	56	21890		19755	23669	23303	M7 Roadwo	Vehicle	1.00		Vehicle
3032		86.041	86.041	ST MARYS-S OF SH5,GT WESTERN HWY	41							Axle Pair			Axle Pair
3049		86.165	86.165	ST CLAIR-N OF RAMPS TO WESTERN FWY	41		22282	28231	32143	32716	32534	Axle Pair	0.98	31883	Vehicle
3067		87.041	87.041	KEMPS CK-N OF MR535,ELIZABETH DR	56							Axle Pair			Axle Pair
3033		86.044	86.044	ERSKINE PK-AT WATER SUPPLY PIPELINE	48		9676	10859	12153	12446	14074	Axle Pair	0.98	13793	Vehicle
3038		86.084	86.084	KINGSWOOD-S OF SH5,GT WESTERN HWY	40							Axle Pair			Axle Pair
2358		64.099	64.099	PRESTONS-W OF MR620,CAMDEN VALLEY WY	63			7263			8900	Axle Pair	1.00	8900	Axle Pair
3008		85.092	85.092	AUSTRAL-E OF BROWNS AV	63	5558	5935		8484	8828	9449	Axle Pair	1.00	9449	Axle Pair
3012		85.099	85.099	BRINGELLY-E OF MR154,THE NORTHERN RD	62	3806	4874	4921	5841	6015	6212	Axle Pair	1.00	6212	Axle Pair
2356		64.097	64.097	AUSTRAL-AT SYDNEY WATER SUPPLY LINE	63	12412	12348	14554	15399	9363	8865	Axle Pair	1.00	8865	Axle Pair

Job No	N1840
Client	RMS
Road	The Northern Rd - north of Bringelly Rd
Location	Bringelly
Site No.	16
Start Date	16-Jun-15
Description	Volume Summary
Direction	Combined

Average Weekday	16,916
7 Day Average	15,593

Time	Day of Week							Ave W'day	7 Day Ave
	Mon	Tue	Wed	Thu	Fri	Sat	Sun		
	22-Jun	16-Jun	17-Jun	18-Jun	19-Jun	20-Jun	21-Jun		
AM Peak	1735	1699	1630	1595	1516	1024	1049		
PM Peak	1642	1543	1523	1671	1581	1015	1123		
0:00	39	42	44	45	44	102	146	43	66
1:00	23	33	33	25	28	53	59	28	36
2:00	44	39	37	28	34	40	42	36	38
3:00	88	78	69	66	73	44	33	75	64
4:00	215	180	188	194	195	99	52	194	160
5:00	689	591	587	590	553	219	98	602	475
6:00	1451	1399	1304	1280	1106	432	152	1308	1018
7:00	1735	1699	1630	1595	1516	542	263	1635	1283
8:00	1328	1240	1277	1260	1166	618	442	1254	1047
9:00	913	875	897	879	913	805	658	895	849
10:00	772	777	755	762	847	920	875	783	815
11:00	691	828	719	778	796	1024	1049	762	841
12:00	741	850	796	799	872	978	958	812	856
13:00	781	862	804	798	968	1015	958	843	884
14:00	1037	957	953	1019	1120	972	970	1017	1004
15:00	1406	1323	1338	1431	1436	988	1037	1387	1280
16:00	1642	1543	1523	1671	1581	1006	1123	1592	1441
17:00	1592	1451	1469	1555	1575	971	948	1528	1366
18:00	948	839	898	850	987	679	635	904	834
19:00	412	363	411	456	514	373	385	431	416
20:00	240	240	244	304	358	274	296	277	279
21:00	193	212	161	277	254	279	213	219	227
22:00	124	158	212	175	286	301	141	191	200
23:00	71	68	130	70	148	241	63	97	113
Total	17175	16647	16479	16907	17370	12975	11596	16916	15593
7-19	13586	13244	13059	13397	13777	10518	9916	13413	12500
6-22	15882	15458	15179	15714	16009	11876	10962	15648	14440
6-24	16077	15684	15521	15959	16443	12418	11166	15937	14753
0-24	17175	16647	16479	16907	17370	12975	11596	16916	15593

Appendix B – Crash data



LEGEND

- Airport site
- Adjacent Direction
- Manoeuvring
- Miscellanous
- Off carriageway on bend
- Off carriageway on straight
- On path
- Opposing Direction
- Out of Control
- Overtaking
- Same direction - lane changing
- Same direction - rear end

Paper Size A3

0 500 1,000 2,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Job Number	21-24265
Revision	A
Date	10 Jul 2015

Location of crashes (5 years)

Figure 7

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 33]

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Data source: Created by: afoddy

Summary Crash Report

# Crash Type		
Car Crash	281	92.4%
Light Truck Crash	67	22.0%
Rigid Truck Crash	11	3.6%
Articulated Truck Crash	8	2.6%
'Heavy Truck Crash	(19)	(6.3%)
Bus Crash	4	1.3%
"Heavy Vehicle Crash	(21)	(6.9%)
Emergency Vehicle Crash	2	0.7%
Motorcycle Crash	20	6.6%
Pedal Cycle Crash	4	1.3%
Pedestrian Crash	1	0.3%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	157	51.6%
Non intersection	147	48.4%

* Up to 10 metres from an intersection
~ 07:30-09:30 or 14:30-17:00 on school days

Collision Type		
Single Vehicle	51	16.8%
Multi Vehicle	253	83.2%

Road Classification		
Freeway/Motorway	1	0.3%
State Highway	0	0.0%
Other Classified Road	303	99.7%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	32	10.5%
Fatigue	25	8.2%
Alcohol	7	2.3%

Weather		
Fine	230	75.7%
Rain	41	13.5%
Overcast	26	8.6%
Fog or mist	5	1.6%
Other	1	0.3%

Road Surface Condition		
Wet	56	18.4%
Dry	248	81.6%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	18	5.9%
Daylight	200	65.8%
Dusk	28	9.2%
Darkness	58	19.1%

Crash Movement		
Intersection, adjacent approaches	29	9.5%
Head-on (not overtaking)	20	6.6%
Opposing vehicles; turning	28	9.2%
U-turn	4	1.3%
Rear-end	141	46.4%
Lane change	13	4.3%
Parallel lanes; turning	2	0.7%
Vehicle leaving driveway	5	1.6%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	1	0.3%
Permanent obstruction on road	0	0.0%
Hit animal	2	0.7%
Off road, on straight	1	0.3%
Off road on straight, hit object	23	7.6%
Out of control on straight	4	1.3%
Off road, on curve	1	0.3%
Off road on curve, hit object	14	4.6%
Out of control on curve	1	0.3%
Other crash type	15	4.9%

Speed Limit				
40 km/h or less	0	0.0%	80 km/h zone	97	31.9%
50 km/h zone	7	2.3%	90 km/h zone	0	0.0%
60 km/h zone	42	13.8%	100 km/h zone	0	0.0%
70 km/h zone	156	51.3%	110 km/h zone	2	0.7%
~ 40km/h or less	0	0.0%			

CRASHES	304	
Fatal crash	4	1.3%
Injury crash	130	42.8%
Non-casualty crash	170	55.9%

Time Group		% of Day	
00:01 - 02:59	6	2.0%	12.5%
03:00 - 04:59	7	2.3%	8.3%
05:00 - 05:59	15	4.9%	4.2%
06:00 - 06:59	19	6.3%	4.2%
07:00 - 07:59	23	7.6%	4.2%
08:00 - 08:59	25	8.2%	4.2%
09:00 - 09:59	9	3.0%	4.2%
10:00 - 10:59	11	3.6%	4.2%
11:00 - 11:59	21	6.9%	4.2%
12:00 - 12:59	14	4.6%	4.2%
13:00 - 13:59	11	3.6%	4.2%
14:00 - 14:59	15	4.9%	4.2%
15:00 - 15:59	22	7.2%	4.2%
16:00 - 16:59	29	9.5%	4.2%
17:00 - 17:59	34	11.2%	4.2%
18:00 - 18:59	19	6.3%	4.2%
19:00 - 19:59	11	3.6%	4.2%
20:00 - 21:59	9	3.0%	8.3%
22:00 - 24:00	4	1.3%	8.3%

Street Lighting Off/Nil		% of Dark
13	of 58 in Dark	22.4%

CASUALTIES	190	
Killed	4	2.1%
Injured	186	97.9%
^ Unrestrained	1	0.5%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Crashes		Casualties
49	2013	24
49	2012	43
73	2011	41
85	2010	54
48	2009	28

~ School Travel Time		
Involvement	73	24.0%

McLean Periods			% Week
A	81	26.6%	17.9%
B	8	2.6%	7.1%
C	57	18.8%	17.9%
D	11	3.6%	3.5%
E	13	4.3%	3.6%
F	52	17.1%	10.7%
G	46	15.1%	7.1%
H	24	7.9%	7.1%
I	3	1.0%	12.5%
J	9	3.0%	10.7%

Day of the Week						# Holiday Periods		
Monday	55	18.1%	Thursday	52	17.1%	Sunday	35	11.5%
Tuesday	34	11.2%	Friday	54	17.8%	WEEKDAY	241	79.3%
Wednesday	46	15.1%	Saturday	28	9.2%	WEEKEND	63	20.7%

New Year	2	0.7%	Queen's BD	2	0.7%	Easter SH	8	2.6%
Aust. Day	1	0.3%	Labour Day	2	0.7%	June/July SH	11	3.6%
Easter	0	0.0%	Christmas	3	1.0%	Sept./Oct. SH	16	5.3%
Anzac Day	2	0.7%	January SH	9	3.0%	December SH	8	2.6%

Crashid dataset 6169 - The Northern Road from Maxwell Street to Mersey Road - Jan09 to Dec13
Note: 6169 - The Northern Road from Maxwell Street to Mersey Road - Jan09 to Dec13

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Summary Crash Report

# Crash Type		
Car Crash	106	93.8%
Light Truck Crash	23	20.4%
Rigid Truck Crash	6	5.3%
Articulated Truck Crash	3	2.7%
'Heavy Truck Crash	(9)	(8.0%)
Bus Crash	1	0.9%
"Heavy Vehicle Crash	(10)	(8.8%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	5	4.4%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	2	1.8%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	72	63.7%
Non intersection	41	36.3%

* Up to 10 metres from an intersection

Collision Type		
Single Vehicle	25	22.1%
Multi Vehicle	88	77.9%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	0	0.0%
Other Classified Road	34	30.1%
Unclassified Road	79	69.9%

Contributing Factors		
Speeding	8	7.1%
Fatigue	7	6.2%
Alcohol	1	0.9%

Weather		
Fine	96	85.0%
Rain	9	8.0%
Overcast	6	5.3%
Fog or mist	2	1.8%
Other	0	0.0%

Road Surface Condition		
Wet	12	10.6%
Dry	101	89.4%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	6	5.3%
Daylight	66	58.4%
Dusk	5	4.4%
Darkness	36	31.9%

Crash Movement		
Intersection, adjacent approaches	34	30.1%
Head-on (not overtaking)	1	0.9%
Opposing vehicles; turning	7	6.2%
U-turn	5	4.4%
Rear-end	29	25.7%
Lane change	1	0.9%
Parallel lanes; turning	2	1.8%
Vehicle leaving driveway	1	0.9%
Overtaking; same direction	2	1.8%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	1	0.9%
Permanent obstruction on road	0	0.0%
Hit animal	1	0.9%
Off road, on straight	1	0.9%
Off road on straight, hit object	14	12.4%
Out of control on straight	1	0.9%
Off road, on curve	1	0.9%
Off road on curve, hit object	3	2.7%
Out of control on curve	0	0.0%
Other crash type	9	8.0%

Speed Limit					
40 km/h or less	0	0.0%	80 km/h zone	59	52.2%
50 km/h zone	0	0.0%	90 km/h zone	0	0.0%
60 km/h zone	29	25.7%	100 km/h zone	0	0.0%
70 km/h zone	25	22.1%	110 km/h zone	0	0.0%

~ 07:30-09:30 or 14:30-17:00 on school days	~ 40km/h or less	0	0.0%	~ School Travel Time Involvement	27	23.9%

CRASHES	113	
Fatal crash	2	1.8%
Injury crash	61	54.0%
Non-casualty crash	50	44.2%

Self Reported Crash	0	0%

Time Group		% of Day	
00:01 - 02:59	1	0.9%	12.5%
03:00 - 04:59	1	0.9%	8.3%
05:00 - 05:59	2	1.8%	4.2%
06:00 - 06:59	6	5.3%	4.2%
07:00 - 07:59	2	1.8%	4.2%
08:00 - 08:59	6	5.3%	4.2%
09:00 - 09:59	2	1.8%	4.2%
10:00 - 10:59	8	7.1%	4.2%
11:00 - 11:59	2	1.8%	4.2%
12:00 - 12:59	7	6.2%	4.2%
13:00 - 13:59	6	5.3%	4.2%
14:00 - 14:59	8	7.1%	4.2%
15:00 - 15:59	10	8.8%	4.2%
16:00 - 16:59	9	8.0%	4.2%
17:00 - 17:59	7	6.2%	4.2%
18:00 - 18:59	10	8.8%	4.2%
19:00 - 19:59	4	3.5%	4.2%
20:00 - 21:59	12	10.6%	8.3%
22:00 - 24:00	10	8.8%	8.3%

Street Lighting Off/Nil		% of Dark
16	of 36 in Dark	44.4%

CASUALTIES	94	
Killed	2	2.1%
Injured	92	97.9%
^ Unrestrained	1	1.1%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Crashes		Casualties
16	2014	16
19	2013	14
24	2012	15
25	2011	22
19	2010	20
10	2009	7

McLean Periods			% Week
A	15	13.3%	17.9%
B	2	1.8%	7.1%
C	20	17.7%	17.9%
D	6	5.3%	3.5%
E	7	6.2%	3.6%
F	23	20.4%	10.7%
G	16	14.2%	7.1%
H	4	3.5%	7.1%
I	12	10.6%	12.5%
J	8	7.1%	10.7%

Day of the Week						# Holiday Periods		
Monday	13	11.5%	Thursday	13	11.5%	Sunday	11	9.7%
Tuesday	26	23.0%	Friday	22	19.5%	WEEKDAY	86	76.1%
Wednesday	12	10.6%	Saturday	16	14.2%	WEEKEND	27	23.9%

New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	6	5.3%
Aust. Day	0	0.0%	Labour Day	1	0.9%	June/July SH	4	3.5%
Easter	1	0.9%	Christmas	2	1.8%	Sept./Oct. SH	2	1.8%
Anzac Day	0	0.0%	January SH	3	2.7%	December SH	2	1.8%

Crashid dataset 6470 - Bringelly Rd - The Northern Rd to Camden Valley Way - July09 to June14

Note: Crash self reporting, including self reported injuries began in Oct 2014. Trends from 2014 are expected to vary from previous years. More unknowns are expected in self reported data. For further information refer to Data Manual or report provider.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Summary Crash Report

# Crash Type		
Car Crash	137	87.3%
Light Truck Crash	43	27.4%
Rigid Truck Crash	14	8.9%
Articulated Truck Crash	10	6.4%
'Heavy Truck Crash	(24)	(15.3%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(24)	(15.3%)
Emergency Vehicle Crash	1	0.6%
Motorcycle Crash	8	5.1%
Pedal Cycle Crash	1	0.6%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	86	54.8%
Non intersection	71	45.2%

* Up to 10 metres from an intersection

Collision Type		
Single Vehicle	38	24.2%
Multi Vehicle	119	75.8%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	0	0.0%
Other Classified Road	157	100.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	21	13.4%
Fatigue	14	8.9%

Weather		
Fine	116	73.9%
Rain	22	14.0%
Overcast	14	8.9%
Fog or mist	4	2.5%
Other	0	0.0%

Road Surface Condition		
Wet	39	24.8%
Dry	118	75.2%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	6	3.8%
Daylight	103	65.6%
Dusk	7	4.5%
Darkness	41	26.1%

Crash Movement		
Intersection, adjacent approaches	32	20.4%
Head-on (not overtaking)	12	7.6%
Opposing vehicles; turning	5	3.2%
U-turn	1	0.6%
Rear-end	50	31.8%
Lane change	11	7.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	1	0.6%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	4	2.5%
Off road, on straight	2	1.3%
Off road on straight, hit object	21	13.4%
Out of control on straight	2	1.3%
Off road, on curve	4	2.5%
Off road on curve, hit object	3	1.9%
Out of control on curve	0	0.0%
Other crash type	9	5.7%

Speed Limit				
40 km/h or less	1	0.6%	80 km/h zone	89	57.1%
50 km/h zone	2	1.3%	90 km/h zone	0	0.0%
60 km/h zone	34	21.8%	100 km/h zone	0	0.0%
70 km/h zone	30	19.2%	110 km/h zone	0	0.0%

~ 07:30-09:30 or 14:30-17:00 on school days	~ 40km/h or less		~ School Travel Time Involvement	
	0	0.0%	33	21.0%

CRASHES	157	
Fatal crash	2	1.3%
Injury crash	75	47.8%
Non-casualty crash	80	51.0%

Self Reported Crash	0	0%

Time Group		% of Day	
00:01 - 02:59	6	3.8%	12.5%
03:00 - 04:59	10	6.4%	8.3%
05:00 - 05:59	3	1.9%	4.2%
06:00 - 06:59	6	3.8%	4.2%
07:00 - 07:59	7	4.5%	4.2%
08:00 - 08:59	12	7.6%	4.2%
09:00 - 09:59	7	4.5%	4.2%
10:00 - 10:59	5	3.2%	4.2%
11:00 - 11:59	10	6.4%	4.2%
12:00 - 12:59	5	3.2%	4.2%
13:00 - 13:59	9	5.7%	4.2%
14:00 - 14:59	7	4.5%	4.2%
15:00 - 15:59	8	5.1%	4.2%
16:00 - 16:59	17	10.8%	4.2%
17:00 - 17:59	14	8.9%	4.2%
18:00 - 18:59	8	5.1%	4.2%
19:00 - 19:59	4	2.5%	4.2%
20:00 - 21:59	10	6.4%	8.3%
22:00 - 24:00	9	5.7%	8.3%

Street Lighting Off/Nil			% of Dark
25	of	41 in Dark	61.0%

CASUALTIES	101	
Killed	2	2.0%
Injured	99	98.0%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Crashes		Casualties
18	2014	14
26	2013	12
31	2012	21
24	2011	15
40	2010	28
18	2009	11

McLean Periods			% Week
A	35	22.3%	17.9%
B	3	1.9%	7.1%
C	33	21.0%	17.9%
D	4	2.5%	3.5%
E	6	3.8%	3.6%
F	27	17.2%	10.7%
G	20	12.7%	7.1%
H	6	3.8%	7.1%
I	10	6.4%	12.5%
J	13	8.3%	10.7%

Day of the Week						# Holiday Periods		
Monday	26	16.6%	Thursday	40	25.5%	Sunday	13	8.3%
Tuesday	18	11.5%	Friday	17	10.8%	WEEKDAY	130	82.8%
Wednesday	29	18.5%	Saturday	14	8.9%	WEEKEND	27	17.2%

New Year	0	0.0%	Queen's BD	1	0.6%	Easter SH	3	1.9%
Aust. Day	1	0.6%	Labour Day	0	0.0%	June/July SH	6	3.8%
Easter	1	0.6%	Christmas	3	1.9%	Sept./Oct. SH	4	2.5%
Anzac Day	0	0.0%	January SH	12	7.6%	December SH	8	5.1%

Crashid dataset 6454 - Reported crashes on Elizabeth Dr between the Northern Rd & M7 - 1 Jul 09 to 30 Jun 14

Note: Crash self reporting, including self reported injuries began in Oct 2014. Trends from 2014 are expected to vary from previous years. More unknowns are expected in self reported data. For further information refer to Data Manual or report provider.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Summary Crash Report

# Crash Type		
Car Crash	144	90.6%
Light Truck Crash	21	13.2%
Rigid Truck Crash	14	8.8%
Articulated Truck Crash	8	5.0%
'Heavy Truck Crash	(22)	(13.8%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(22)	(13.8%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	8	5.0%
Pedal Cycle Crash	2	1.3%
Pedestrian Crash	1	0.6%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	67	42.1%
Non intersection	92	57.9%

* Up to 10 metres from an intersection

Collision Type		
Single Vehicle	43	27.0%
Multi Vehicle	116	73.0%

Road Classification		
Freeway/Motorway	1	0.6%
State Highway	0	0.0%
Other Classified Road	157	98.7%
Unclassified Road	1	0.6%

Contributing Factors		
Speeding	14	8.8%
Fatigue	14	8.8%

Weather		
Fine	114	71.7%
Rain	22	13.8%
Overcast	15	9.4%
Fog or mist	7	4.4%
Other	0	0.0%

Road Surface Condition		
Wet	33	20.8%
Dry	126	79.2%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	16	10.1%
Daylight	98	61.6%
Dusk	3	1.9%
Darkness	42	26.4%

Crash Movement		
Intersection, adjacent approaches	24	15.1%
Head-on (not overtaking)	11	6.9%
Opposing vehicles; turning	10	6.3%
U-turn	3	1.9%
Rear-end	50	31.4%
Lane change	4	2.5%
Parallel lanes; turning	1	0.6%
Vehicle leaving driveway	4	2.5%
Overtaking; same direction	2	1.3%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	1	0.6%
Permanent obstruction on road	0	0.0%
Hit animal	3	1.9%
Off road, on straight	4	2.5%
Off road on straight, hit object	22	13.8%
Out of control on straight	2	1.3%
Off road, on curve	1	0.6%
Off road on curve, hit object	6	3.8%
Out of control on curve	0	0.0%
Other crash type	11	6.9%

Speed Limit				
40 km/h or less	0	0.0%	80 km/h zone	97	61.0%
50 km/h zone	4	2.5%	90 km/h zone	0	0.0%
60 km/h zone	42	26.4%	100 km/h zone	0	0.0%
70 km/h zone	16	10.1%	110 km/h zone	0	0.0%

~ 07:30-09:30 or 14:30-17:00 on school days	~ 40km/h or less			~ School Travel Time Involvement		
	0	0.0%		37	23.3%	

CRASHES	159	
Fatal crash	1	0.6%
Injury crash	79	49.7%
Non-casualty crash	79	49.7%

Self Reported Crash	0	0%

Time Group		% of Day	
00:01 - 02:59	8	5.0%	12.5%
03:00 - 04:59	4	2.5%	8.3%
05:00 - 05:59	12	7.5%	4.2%
06:00 - 06:59	14	8.8%	4.2%
07:00 - 07:59	13	8.2%	4.2%
08:00 - 08:59	10	6.3%	4.2%
09:00 - 09:59	4	2.5%	4.2%
10:00 - 10:59	6	3.8%	4.2%
11:00 - 11:59	5	3.1%	4.2%
12:00 - 12:59	4	2.5%	4.2%
13:00 - 13:59	9	5.7%	4.2%
14:00 - 14:59	12	7.5%	4.2%
15:00 - 15:59	12	7.5%	4.2%
16:00 - 16:59	11	6.9%	4.2%
17:00 - 17:59	10	6.3%	4.2%
18:00 - 18:59	6	3.8%	4.2%
19:00 - 19:59	2	1.3%	4.2%
20:00 - 21:59	4	2.5%	8.3%
22:00 - 24:00	13	8.2%	8.3%

Street Lighting Off/Nil		% of Dark
11	of 42 in Dark	26.2%

CASUALTIES	106	
Killed	1	0.9%
Injured	105	99.1%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Crashes		Casualties
13	2014	8
38	2013	29
33	2012	22
30	2011	17
32	2010	21
13	2009	9

McLean Periods			% Week
A	48	30.2%	17.9%
B	5	3.1%	7.1%
C	30	18.9%	17.9%
D	5	3.1%	3.5%
E	5	3.1%	3.6%
F	18	11.3%	10.7%
G	13	8.2%	7.1%
H	12	7.5%	7.1%
I	12	7.5%	12.5%
J	11	6.9%	10.7%

Day of the Week						# Holiday Periods					
Monday	23	14.5%	Thursday	22	13.8%	Sunday	20	12.6%	New Year	0	0.0%	Queen's BD	1	0.6%	Easter SH	1	0.6%
Tuesday	18	11.3%	Friday	24	15.1%	WEEKDAY	125	78.6%	Aust. Day	0	0.0%	Labour Day	2	1.3%	June/July SH	4	2.5%
Wednesday	38	23.9%	Saturday	14	8.8%	WEEKEND	34	21.4%	Easter	0	0.0%	Christmas	2	1.3%	Sept./Oct. SH	6	3.8%
									Anzac Day	0	0.0%	January SH	15	9.4%	December SH	3	1.9%

Crashid dataset 6467 - Reported crashes on Mamre Rd between Elizabeth Dr & M4 Mtwy - 1 Jul 09 to 30 Jun 14

Note: Crash self reporting, including self reported injuries began in Oct 2014. Trends from 2014 are expected to vary from previous years. More unknowns are expected in self reported data. For further information refer to Data Manual or report provider.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Summary Crash Report

# Crash Type		
Car Crash	5	83.3%
Light Truck Crash	0	0.0%
Rigid Truck Crash	1	16.7%
Articulated Truck Crash	0	0.0%
'Heavy Truck Crash	(1)	(16.7%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(1)	(16.7%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	1	16.7%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	1	16.7%
Non intersection	5	83.3%

* Up to 10 metres from an intersection

Collision Type		
Single Vehicle	5	83.3%
Multi Vehicle	1	16.7%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	0	0.0%
Other Classified Road	0	0.0%
Unclassified Road	6	100.0%

Contributing Factors		
Speeding	4	66.7%
Fatigue	1	16.7%

Weather		
Fine	5	83.3%
Rain	0	0.0%
Overcast	1	16.7%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	1	16.7%
Dry	5	83.3%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	0	0.0%
Daylight	4	66.7%
Dusk	0	0.0%
Darkness	2	33.3%

Crash Movement		
Intersection, adjacent approaches	1	16.7%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	0	0.0%
U-turn	0	0.0%
Rear-end	0	0.0%
Lane change	0	0.0%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	0	0.0%
Off road, on straight	0	0.0%
Off road on straight, hit object	2	33.3%
Out of control on straight	0	0.0%
Off road, on curve	1	16.7%
Off road on curve, hit object	1	16.7%
Out of control on curve	1	16.7%
Other crash type	0	0.0%

Speed Limit				
40 km/h or less	0	0.0%	80 km/h zone	0	0.0%
50 km/h zone	0	0.0%	90 km/h zone	0	0.0%
60 km/h zone	2	33.3%	100 km/h zone	0	0.0%
70 km/h zone	4	66.7%	110 km/h zone	0	0.0%

~ 07:30-09:30 or 14:30-17:00 on school days	~ 40km/h or less	0	0.0%	~ School Travel Time Involvement	0	0.0%

CRASHES	6	
Fatal crash	0	0.0%
Injury crash	4	66.7%
Non-casualty crash	2	33.3%

Self Reported Crash	0	0%

Time Group		% of Day
00:01 - 02:59	0	0.0% 12.5%
03:00 - 04:59	0	0.0% 8.3%
05:00 - 05:59	0	0.0% 4.2%
06:00 - 06:59	0	0.0% 4.2%
07:00 - 07:59	0	0.0% 4.2%
08:00 - 08:59	1	16.7% 4.2%
09:00 - 09:59	0	0.0% 4.2%
10:00 - 10:59	0	0.0% 4.2%
11:00 - 11:59	1	16.7% 4.2%
12:00 - 12:59	1	16.7% 4.2%
13:00 - 13:59	1	16.7% 4.2%
14:00 - 14:59	0	0.0% 4.2%
15:00 - 15:59	0	0.0% 4.2%
16:00 - 16:59	0	0.0% 4.2%
17:00 - 17:59	0	0.0% 4.2%
18:00 - 18:59	1	16.7% 4.2%
19:00 - 19:59	0	0.0% 4.2%
20:00 - 21:59	0	0.0% 8.3%
22:00 - 24:00	1	16.7% 8.3%

Street Lighting Off/Nil		% of Dark
1	of 2 in Dark	50.0%

CASUALTIES	6	
Killed	0	0.0%
Injured	6	100.0%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Crashes		Casualties
2	2014	1
2	2013	2
1	2012	0
1	2009	3

McLean Periods			% Week
A	0	0.0%	17.9%
B	1	16.7%	7.1%
C	2	33.3%	17.9%
D	1	16.7%	3.5%
E	0	0.0%	3.6%
F	0	0.0%	10.7%
G	1	16.7%	7.1%
H	0	0.0%	7.1%
I	1	16.7%	12.5%
J	0	0.0%	10.7%

Day of the Week						# Holiday Periods		
Monday	1	16.7%	Thursday	0	0.0%	Sunday	1	16.7%
Tuesday	0	0.0%	Friday	1	16.7%	WEEKDAY	4	66.7%
Wednesday	2	33.3%	Saturday	1	16.7%	WEEKEND	2	33.3%

New Year	0	0.0%	Queen's BD	1	16.7%	Easter SH	0	0.0%
Aust. Day	0	0.0%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	1	16.7%
Anzac Day	0	0.0%	January SH	0	0.0%	December SH	0	0.0%

Crashid dataset 6493 - Reported crashes on Adams Rd between Elizabeth Dr & The Northern Rd - 1 Jul 09 to 30 Jun 14

Note: Crash self reporting, including self reported injuries began in Oct 2014. Trends from 2014 are expected to vary from previous years. More unknowns are expected in self reported data. For further information refer to Data Manual or report provider.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Summary Crash Report

# Crash Type		
Car Crash	22	91.7%
Light Truck Crash	5	20.8%
Rigid Truck Crash	1	4.2%
Articulated Truck Crash	0	0.0%
'Heavy Truck Crash	(1)	(4.2%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(1)	(4.2%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	0	0.0%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	17	70.8%
Non intersection	7	29.2%

* Up to 10 metres from an intersection

Collision Type		
Single Vehicle	8	33.3%
Multi Vehicle	16	66.7%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	0	0.0%
Other Classified Road	16	66.7%
Unclassified Road	8	33.3%

Contributing Factors		
Speeding	6	25.0%
Fatigue	3	12.5%

Weather		
Fine	17	70.8%
Rain	3	12.5%
Overcast	4	16.7%
Fog or mist	0	0.0%
Other	0	0.0%

Road Surface Condition		
Wet	3	12.5%
Dry	21	87.5%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	2	8.3%
Daylight	17	70.8%
Dusk	1	4.2%
Darkness	4	16.7%

Crash Movement		
Intersection, adjacent approaches	12	50.0%
Head-on (not overtaking)	0	0.0%
Opposing vehicles; turning	1	4.2%
U-turn	0	0.0%
Rear-end	2	8.3%
Lane change	1	4.2%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	1	4.2%
Off road, on straight	1	4.2%
Off road on straight, hit object	4	16.7%
Out of control on straight	0	0.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	1	4.2%
Out of control on curve	0	0.0%
Other crash type	1	4.2%

CRASHES	24	
Fatal crash	0	0.0%
Injury crash	9	37.5%
Non-casualty crash	15	62.5%

Self Reported Crash	0	0%

Time Group		% of Day	
00:01 - 02:59	0	0.0%	12.5%
03:00 - 04:59	1	4.2%	8.3%
05:00 - 05:59	0	0.0%	4.2%
06:00 - 06:59	3	12.5%	4.2%
07:00 - 07:59	4	16.7%	4.2%
08:00 - 08:59	2	8.3%	4.2%
09:00 - 09:59	1	4.2%	4.2%
10:00 - 10:59	2	8.3%	4.2%
11:00 - 11:59	0	0.0%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	1	4.2%	4.2%
15:00 - 15:59	2	8.3%	4.2%
16:00 - 16:59	3	12.5%	4.2%
17:00 - 17:59	1	4.2%	4.2%
18:00 - 18:59	2	8.3%	4.2%
19:00 - 19:59	0	0.0%	4.2%
20:00 - 21:59	2	8.3%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil		% of Dark
4	of 4 in Dark	100.0%

CASUALTIES	12	
Killed	0	0.0%
Injured	12	100.0%
^ Unrestrained	1	8.3%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Crashes		Casualties
5	2014	3
4	2013	1
2	2012	0
5	2011	3
3	2010	3
5	2009	2

Speed Limit				
40 km/h or less	0	0.0%	80 km/h zone	11	45.8%
50 km/h zone	3	12.5%	90 km/h zone	0	0.0%
60 km/h zone	7	29.2%	100 km/h zone	0	0.0%
70 km/h zone	3	12.5%	110 km/h zone	0	0.0%

~ 07:30-09:30 or 14:30-17:00 on school days	~ 40km/h or less			~ School Travel Time Involvement		
		0	0.0%		8	33.3%

McLean Periods			% Week
A	9	37.5%	17.9%
B	1	4.2%	7.1%
C	3	12.5%	17.9%
D	1	4.2%	3.5%
E	0	0.0%	3.6%
F	6	25.0%	10.7%
G	4	16.7%	7.1%
H	0	0.0%	7.1%
I	0	0.0%	12.5%
J	0	0.0%	10.7%

Day of the Week						# Holiday Periods		
Monday	6	25.0%	Thursday	6	25.0%	Sunday	0	0.0%
Tuesday	2	8.3%	Friday	2	8.3%	WEEKDAY	22	91.7%
Wednesday	6	25.0%	Saturday	2	8.3%	WEEKEND	2	8.3%

New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	1	4.2%
Aust. Day	1	4.2%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	0	0.0%
Anzac Day	1	4.2%	January SH	2	8.3%	December SH	0	0.0%

Crashid dataset 6493 - Reported crashes on Badgerys Creek Rd between Elizabeth Dr & The Northern Rd - 1 Jul 09 to 30 Jun 14

Note: Crash self reporting, including self reported injuries began in Oct 2014. Trends from 2014 are expected to vary from previous years. More unknowns are expected in self reported data. For further information refer to Data Manual or report provider.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Summary Crash Report

# Crash Type		
Car Crash	14	87.5%
Light Truck Crash	4	25.0%
Rigid Truck Crash	1	6.3%
Articulated Truck Crash	1	6.3%
'Heavy Truck Crash	(2)	(12.5%)
Bus Crash	0	0.0%
"Heavy Vehicle Crash	(2)	(12.5%)
Emergency Vehicle Crash	0	0.0%
Motorcycle Crash	2	12.5%
Pedal Cycle Crash	0	0.0%
Pedestrian Crash	0	0.0%

' Rigid or Artic. Truck " Heavy Truck or Heavy Bus
These categories are NOT mutually exclusive

Location Type		
*Intersection	5	31.3%
Non intersection	11	68.8%

* Up to 10 metres from an intersection

Collision Type		
Single Vehicle	7	43.8%
Multi Vehicle	9	56.3%

Road Classification		
Freeway/Motorway	0	0.0%
State Highway	0	0.0%
Other Classified Road	16	100.0%
Unclassified Road	0	0.0%

Contributing Factors		
Speeding	4	25.0%
Fatigue	5	31.3%

Weather		
Fine	11	68.8%
Rain	2	12.5%
Overcast	2	12.5%
Fog or mist	1	6.3%
Other	0	0.0%

Road Surface Condition		
Wet	3	18.8%
Dry	13	81.3%
Snow or ice	0	0.0%

Natural Lighting		
Dawn	2	12.5%
Daylight	11	68.8%
Dusk	2	12.5%
Darkness	1	6.3%

Crash Movement		
Intersection, adjacent approaches	0	0.0%
Head-on (not overtaking)	2	12.5%
Opposing vehicles; turning	1	6.3%
U-turn	1	6.3%
Rear-end	4	25.0%
Lane change	1	6.3%
Parallel lanes; turning	0	0.0%
Vehicle leaving driveway	0	0.0%
Overtaking; same direction	0	0.0%
Hit parked vehicle	0	0.0%
Hit railway train	0	0.0%
Hit pedestrian	0	0.0%
Permanent obstruction on road	0	0.0%
Hit animal	1	6.3%
Off road, on straight	0	0.0%
Off road on straight, hit object	3	18.8%
Out of control on straight	0	0.0%
Off road, on curve	0	0.0%
Off road on curve, hit object	3	18.8%
Out of control on curve	0	0.0%
Other crash type	0	0.0%

Speed Limit				
40 km/h or less	0	0.0%	80 km/h zone	12	75.0%
50 km/h zone	0	0.0%	90 km/h zone	0	0.0%
60 km/h zone	4	25.0%	100 km/h zone	0	0.0%
70 km/h zone	0	0.0%	110 km/h zone	0	0.0%

~ 07:30-09:30 or 14:30-17:00 on school days	~ 40km/h or less	0	0.0%	~ School Travel Time Involvement	4	25.0%

CRASHES	16	
Fatal crash	1	6.3%
Injury crash	6	37.5%
Non-casualty crash	9	56.3%

Self Reported Crash	0	0%

Time Group		% of Day	
00:01 - 02:59	1	6.3%	12.5%
03:00 - 04:59	0	0.0%	8.3%
05:00 - 05:59	2	12.5%	4.2%
06:00 - 06:59	0	0.0%	4.2%
07:00 - 07:59	1	6.3%	4.2%
08:00 - 08:59	0	0.0%	4.2%
09:00 - 09:59	2	12.5%	4.2%
10:00 - 10:59	1	6.3%	4.2%
11:00 - 11:59	0	0.0%	4.2%
12:00 - 12:59	0	0.0%	4.2%
13:00 - 13:59	0	0.0%	4.2%
14:00 - 14:59	4	25.0%	4.2%
15:00 - 15:59	2	12.5%	4.2%
16:00 - 16:59	1	6.3%	4.2%
17:00 - 17:59	1	6.3%	4.2%
18:00 - 18:59	0	0.0%	4.2%
19:00 - 19:59	1	6.3%	4.2%
20:00 - 21:59	0	0.0%	8.3%
22:00 - 24:00	0	0.0%	8.3%

Street Lighting Off/Nil			% of Dark
1	of	1 in Dark	100.0%

CASUALTIES	9	
Killed	1	11.1%
Injured	8	88.9%
^ Unrestrained	0	0.0%

^ Belt fitted but not worn, No restraint fitted to position OR No helmet worn

Crashes		Casualties
3	2014	0
2	2013	0
4	2012	4
4	2011	3
2	2010	1
1	2009	1

McLean Periods			% Week
A	2	12.5%	17.9%
B	1	6.3%	7.1%
C	5	31.3%	17.9%
D	2	12.5%	3.5%
E	0	0.0%	3.6%
F	3	18.8%	10.7%
G	1	6.3%	7.1%
H	1	6.3%	7.1%
I	1	6.3%	12.5%
J	0	0.0%	10.7%

Day of the Week						# Holiday Periods		
Monday	3	18.8%	Thursday	0	0.0%	Sunday	2	12.5%
Tuesday	3	18.8%	Friday	3	18.8%	WEEKDAY	12	75.0%
Wednesday	3	18.8%	Saturday	2	12.5%	WEEKEND	4	25.0%

New Year	0	0.0%	Queen's BD	0	0.0%	Easter SH	1	6.3%
Aust. Day	1	6.3%	Labour Day	0	0.0%	June/July SH	0	0.0%
Easter	0	0.0%	Christmas	0	0.0%	Sept./Oct. SH	0	0.0%
Anzac Day	2	12.5%	January SH	2	12.5%	December SH	0	0.0%

Crashid dataset 6493 - Reported crashes on The Northern Rd between Badgerys Creek Rd & Mersey Rd - 1 Jul 09 to 30 Jun 14

Note: Crash self reporting, including self reported injuries began in Oct 2014. Trends from 2014 are expected to vary from previous years. More unknowns are expected in self reported data. For further information refer to Data Manual or report provider.

Percentages are percentages of all crashes. Unknown values for each category are not shown on this report.

Detailed Crash Report

NOTES: Reported crashes on Adams Rd between Elizabeth Dr & The Northern Rd - 1 Jul 09 to 30 Jun 14

Crash No.	Data Source	Date	Day of Week	Time	Distance		ID Feature	Loc Type	Alignment	Weather	Surface Condition	Speed Limit	No. of Tus	Tu Type/Obj	Age/Sex	Street Travelling	Speed Travelling	Manoeuvre	Degree of Crash	Killed	Injured	Factors
																						S F
Sydney Region																						
Liverpool LGA																						
Luddenham																						
Adams Rd																						
685110	P	07/10/2009	Wed	11:20		at	ANTON RD	TJN	STR	Fine	Dry	70	2	CAR	F41	N in ANTON RD	10	Turning right	I	0	3	
E39087277								RUM: 13	Right near					LOR	M32	W in ADAMS RD	60	Proceeding in lane				
838660	P	17/05/2013	Fri	18:20	140 m	W	ANTON RD	2WY	CRV	Fine	Dry	60	1	M/C	M19	W in ADAMS RD	60	Proceeding in lane	I	0	1	S
E52318939								RUM: 88	Out of cont on bend													
1030690	P	07/06/2014	Sat	13:50	200 m	S	ELIZABETH DR	2WY	STR	Fine	Dry	70	1	CAR	M34	S in ADAMS RD	60	Proceeding in lane	I	0	1	F
E106028601								RUM: 71	Off rd left => obj					Tree/bush								
828100	P	24/02/2013	Sun	08:35	650 m	S	ELIZABETH DR	2WY	CRV	Overcast	Wet	60	1	CAR	M41	S in ADAMS RD	50	Turning right	I	0	1	S
E52546780								RUM: 87	Off lft/lft bnd=>obj					Tree/bush								
1024162	P	17/03/2014	Mon	23:10	1.8 km	E	THE NORTHERN RD	2WY	CRV	Fine	Dry	70	1	CAR	M35	E in ADAMS RD	Unk	Proceeding in lane	N	0	0	S
E54546762								RUM: 82	Off right/right bend													
807193	P	15/08/2012	Wed	12:30	2 km	E	THE NORTHERN RD	2WY	STR	Fine	Dry	70	1	CAR	F53	W in ADAMS RD	75	Proceeding in lane	N	0	0	S
E48779912								RUM: 71	Off rd left => obj					Utility pole								

Report Totals: Total Crashes: 6 Fatal Crashes: 0 Injury Crashes: 4 Killed: 0 Injured: 6

Crashid dataset 6493 - Reported crashes on Adams Rd between Elizabeth Dr & The Northern Rd - 1 Jul 09 to 30 Jun 14

Crash self reporting, including self reported injuries began in Oct 2014. Trends from 2014 are expected to vary from previous years. More unknowns are expected in self reported data. For further information refer to Data Manual or report provider.

Detailed Crash Report

NOTES: Reported crashes on Badgerys Creek Rd between Elizabeth Dr & The Northern Rd - 1 Jul 09 to 30 Jun 14

Crash No.	Data Source	Date	Day of Week	Time	Distance		ID Feature	Loc Type	Alignment	Weather	Surface Condition	Speed Limit	No. of Tus	Tu Type/Obj	Age/Sex	Street Travelling	Speed Travelling	Manoeuvre	Degree of Crash	Killed	Injured	Factors
																						S F
Sydney Region																						
Liverpool LGA																						
Badgerys Creek																						
Badgerys Creek Rd																						
1030027	P	31/05/2014	Sat	06:50	150 m	S	ELIZABETH DR	2WY	STR	Overcast	Dry	50	1	CAR	M56	S in BADGERYS CREEK RD	60	Proceeding in lane	N	0	0	S
E56747487								RUM: 73	Off rd rght => obj					Tree/bush								
1013301	P	26/02/2014	Wed	20:20	300 m	S	ELIZABETH DR	2WY	STR	Raining	Wet	50	1	CAR	M37	N in BADGERYS CREEK RD	60	Proceeding in lane	I	0	1	S F
E54704563								RUM: 71	Off rd left => obj					Tree/bush								
682922	P	19/08/2009	Wed	18:50	800 m	S	ELIZABETH DR	2WY	STR	Fine	Dry	60	1	CAR	F49	N in BADGERYS CREEK RD	50	Proceeding in lane	I	0	1	
E38246676								RUM: 67	Struck animal					Riderless horse								
1020452	P	09/04/2014	Wed	20:49	1 km	S	ELIZABETH DR	2WY	STR	Fine	Dry	50	1	CAR	M34	N in BADGERYS CREEK RD	60	Proceeding in lane	N	0	0	S
E55293839								RUM: 73	Off rd rght => obj					Tree/bush								
777159	P	21/11/2011	Mon	07:00	290 m	S	JAGELMAN RD	2WY	CRV	Fine	Dry	80	2	LOR	U 49	S in BADGERYS CREEK RD	70	Proceeding in lane	I	0	1	
E46498019								RUM: 33	Lane sideswipe					R A	F21	S in BADGERYS CREEK RD		Proceeding in lane				
846686	P	01/08/2013	Thu	16:15		at	LEGGO ST	TJN	STR	Fine	Dry	70	2	CAR	F23	N in BADGERYS CREEK RD	60	Proceeding in lane	I	0	1	
E53043608								RUM: 30	Rear end					4WD	M56	N in BADGERYS CREEK RD	10	Proceeding in lane				
683225	P	23/09/2009	Wed	08:45	1 km	S	LONGLEYS RD	2WY	STR	Overcast	Dry	60	1	CAR	F23	N in BADGERYS CREEK RD	50	Proceeding in lane	N	0	0	
E39038151								RUM: 70	Off road to left													
Elizabeth Dr																						
691666	P	03/12/2009	Thu	08:10		at	BADGERYS CREEK RD	TJN	STR	Fine	Dry	80	2	CAR	F38	N in BADGERYS CREEK RD	Unk	Turning right	N	0	0	
E39315561								RUM: 13	Right near					CAR	M21	W in ELIZABETH DR	Unk	Proceeding in lane				
692496	P	14/12/2009	Mon	16:15		at	BADGERYS CREEK RD	TJN	STR	Overcast	Dry	70	2	WAG	F63	N in BADGERYS CREEK RD	Unk	Turning right	I	0	1	S
E39905267								RUM: 13	Right near					TRK	M21	W in ELIZABETH DR	80	Proceeding in lane				
696715	P	07/01/2010	Thu	10:45		at	BADGERYS CREEK RD	TJN	STR	Overcast	Dry	80	2	CAR	M25	N in BADGERYS CREEK RD	Unk	Turning right	I	0	1	
E148038095								RUM: 13	Right near					4WD	M65	W in ELIZABETH DR	75	Proceeding in lane				
731447	P	04/11/2010	Thu	15:45		at	BADGERYS CREEK RD	TJN	STR	Raining	Wet	80	2	TRK	M43	N in BADGERYS CREEK RD	10	Turning right	N	0	0	
E43263178								RUM: 13	Right near					CAR	F49	W in ELIZABETH DR	80	Proceeding in lane				
734079	P	03/12/2010	Fri	06:40		at	BADGERYS CREEK RD	TJN	STR	Fine	Dry	80	2	CAR	M41	N in BADGERYS CREEK RD	Unk	Turning right	I	0	2	
E45416386								RUM: 13	Right near					CAR	M24	W in ELIZABETH DR	Unk	Proceeding in lane				
770981	P	12/10/2011	Wed	07:15		at	BADGERYS CREEK RD	TJN	STR	Fine	Dry	80	2	CAR	M24	N in BADGERYS CREEK RD	20	Turning right	N	0	0	
E45871747								RUM: 13	Right near					CAR	F69	W in ELIZABETH DR	70	Proceeding in lane				

Detailed Crash Report

Crash No.	Data Source	Date	Day of Week	Time	Distance		ID Feature	Loc Type	Alignment	Weather	Surface Condition	Speed Limit	No. of Tus	Tu Type/Obj	Age/Sex	Street Travelling	Speed Travelling	Manoeuvre	Degree of Crash	Killed	Injured	Factors
																						S F
807223	P	16/08/2012	Thu	07:20		at	BADGERYS CREEK RD	TJN	STR	Fine	Dry	80	2	CAR	F30	N in BADGERYS CREEK RD	5	Turning right	N	0	0	
E49369267								RUM: 13	Right near					CAR	F61	W in ELIZABETH DR	75	Proceeding in lane				
819701	P	10/12/2012	Mon	17:38		at	BADGERYS CREEK RD	TJN	STR	Fine	Dry	70	2	UTE	M U	N in BADGERYS CREEK RD	70	Turning right	N	0	0	
E50343379								RUM: 13	Right near					TRK	M39	W in ELIZABETH DR	50	Proceeding in lane				
839238	P	31/05/2013	Fri	16:30		at	BADGERYS CREEK RD	TJN	STR	Fine	Dry	60	2	4WD	M17	N in BADGERYS CREEK RD	Unk	Turning right	N	0	0	
E52077528								RUM: 13	Right near					CAR	M45	W in ELIZABETH DR	Unk	Proceeding in lane				
1003651	P	04/11/2013	Mon	09:25		at	BADGERYS CREEK RD	TJN	STR	Fine	Dry	80	2	WAG	M51	N in BADGERYS CREEK RD	Unk	Turning right	N	0	0	
E53523043								RUM: 13	Right near					TRK	F38	W in ELIZABETH DR	70	Proceeding in lane				
1014639	P	20/02/2014	Thu	18:00		at	BADGERYS CREEK RD	TJN	STR	Fine	Dry	80	2	CAR	F41	N in BADGERYS CREEK RD	20	Proceeding in lane	I	0	2	
E54600969								RUM: 10	Cross traffic					CAR	M25	W in ELIZABETH DR	80	Proceeding in lane				
1029759	P	24/06/2014	Tue	06:20		at	BADGERYS CREEK RD	TJN	STR	Fine	Dry	80	2	UTE	M64	N in BADGERYS CREEK RD	10	Proceeding in lane	N	0	0	
E55438858								RUM: 10	Cross traffic					CAR	M28	W in ELIZABETH DR	75	Proceeding in lane				
Bringelly																						
Badgerys Creek Rd																						
679756	P	03/08/2009	Mon	04:00	1 km	N	THE NORTHERN RD	2WY	STR	Fine	Dry	60	1	CAR	M28	N in BADGERYS CREEK RD	80	Other forward	N	0	0	S
E38270412								RUM: 79	Other straight													
The Northern Rd																						
751938	P	26/04/2011	Tue	15:00		at	BADGERYS CREEK RD	RDB	CRV	Fine	Dry	60	1	CAR	M74	W in THE NORTHERN RD	Unk	Proceeding in lane	I	0	2	S F
E44265205								RUM: 81	Off left/rt bnd=>obj					Body of water								
773894	P	29/10/2011	Sat	14:50		at	BADGERYS CREEK RD	RDB	STR	Fine	Dry	60	1	TRK	M38	N in THE NORTHERN RD	60	Proceeding in lane	N	0	0	F
E46047247								RUM: 71	Off rd left => obj					Utility pole								
772511	P	02/11/2011	Wed	07:45		at	BADGERYS CREEK RD	RDB	CRV	Fine	Dry	60	2	CAR	M59	N in THE NORTHERN RD	15	Turning right	N	0	0	
E45991827								RUM: 21	Right through					CAR	F22	S in THE NORTHERN RD	15	Proceeding in lane				
826214	P	28/01/2013	Mon	10:55		at	BADGERYS CREEK RD	RDB	STR	Raining	Wet	80	2	4WD	U U	S in THE NORTHERN RD	Unk	Proceeding in lane	N	0	0	
E50730562								RUM: 30	Rear end					CAR	F41	S in THE NORTHERN RD	40	Proceeding in lane				

Report Totals: Total Crashes: 24 Fatal Crashes: 0 Injury Crashes: 9 Killed: 0 Injured: 12

Crashid dataset 6493 - Reported crashes on Badgerys Creek Rd between Elizabeth Dr & The Northern Rd - 1 Jul 09 to 30 Jun 14

Crash self reporting, including self reported injuries began in Oct 2014. Trends from 2014 are expected to vary from previous years. More unknowns are expected in self reported data. For further information refer to Data Manual or report provider.

Detailed Crash Report

NOTES: Reported crashes on The Northern Rd between Badgerys Creek Rd & Mersey Rd - 1 Jul 09 to 30 Jun 14

Crash No.	Data Source	Date	Day of Week	Time	Distance		ID Feature	Loc Type	Alignment	Weather	Surface Condition	Speed Limit	No. of Tus	Tu Type/Obj	Age/Sex	Street Travelling	Speed Travelling	Manoeuvre	Degree of Crash	Killed	Injured	Factors
																						S F
Sydney Region																						
Liverpool LGA																						
Bringelly																						
The Northern Rd																						
1004381	P	23/10/2013	Wed	09:00	100 m	N	AVON RD	2WY	STR	Fine	Dry	80	2	CAR	F25	N in THE NORTHERN RD	80	Proceeding in lane	N	0	0	
E52617652								RUM: 32	Right rear					WAG	M36	N in THE NORTHERN RD	80	Turning right				
The Northern Rd																						
699084	P	06/02/2010	Sat	14:30	100 m	N	AVON RD	2WY	STR	Overcast	Dry	80	2	TRK	M16	S in THE NORTHERN RD	5	Perform U-turn	I	0	1	
E149013195								RUM: 40	U turn					PAN	M56	S in THE NORTHERN RD	75	Proceeding in lane				
1022901	P	05/05/2014	Mon	05:00	235 m	S	AVON RD	2WY	STR	Fine	Dry	80	2	TRK	M34	S in THE NORTHERN RD	80	Proceeding in lane	N	0	0	
E216800695								RUM: 30	Rear end					4WD	M21	S in THE NORTHERN RD	50	Proceeding in lane				
751938	P	26/04/2011	Tue	15:00		at	BADGERYS CREEK RD	RDB	CRV	Fine	Dry	60	1	CAR	M74	W in THE NORTHERN RD	Unk	Proceeding in lane	I	0	2	S F
E44265205								RUM: 81	Off left/rt bnd=>obj					Body of water								
773894	P	29/10/2011	Sat	14:50		at	BADGERYS CREEK RD	RDB	STR	Fine	Dry	60	1	TRK	M38	N in THE NORTHERN RD	60	Proceeding in lane	N	0	0	F
E46047247								RUM: 71	Off rd left => obj					Utility pole								
772511	P	02/11/2011	Wed	07:45		at	BADGERYS CREEK RD	RDB	CRV	Fine	Dry	60	2	CAR	M59	N in THE NORTHERN RD	15	Turning right	N	0	0	
E45991827								RUM: 21	Right through					CAR	F22	S in THE NORTHERN RD	15	Proceeding in lane				
826214	P	28/01/2013	Mon	10:55		at	BADGERYS CREEK RD	RDB	STR	Raining	Wet	80	2	4WD	U U	S in THE NORTHERN RD	Unk	Proceeding in lane	N	0	0	
E50730562								RUM: 30	Rear end					CAR	F41	S in THE NORTHERN RD	40	Proceeding in lane				
1015736	P	07/03/2014	Fri	14:20	100 m	N	BADGERYS CREEK RD	2WY	STR	Overcast	Wet	60	1	CAR	F45	S in THE NORTHERN RD	80	Proceeding in lane	N	0	0	S F
E53592370								RUM: 73	Off rd rght => obj					Tree/bush								
798869	P	22/05/2012	Tue	16:00	500 m	N	BADGERYS CREEK RD	2WY	CRV	Fine	Dry	80	1	4WD	M43	N in THE NORTHERN RD	Unk	Proceeding in lane	I	0	2	S
E47943154								RUM: 87	Off lft/lft bnd=>obj					Tree/bush								
1026438	P	14/05/2014	Wed	01:00	500 m	N	BADGERYS CREEK RD	2WY	CRV	Fog or mist	Dry	80	1	WAG	F39	S in THE NORTHERN RD	70	Proceeding in lane	N	0	0	
E55099673								RUM: 67	Struck animal					Straying stock								
791904	P	23/03/2012	Fri	14:00	2 km	N	BRINGELLY RD	2WY	STR	Fine	Dry	80	3	CAR	F25	S in THE NORTHERN RD	80	Incorrect side	I	0	1	F
E47597966								RUM: 20	Head on					VAN	M52	N in THE NORTHERN RD	80	Proceeding in lane				
														LOR	M28	S in THE NORTHERN RD	80	Proceeding in lane				
681913	P	13/09/2009	Sun	17:15	100 m	W	DERWENT RD	2WY	STR	Fine	Dry	80	2	M/C	M66	W in THE NORTHERN RD	70	Proceeding in lane	I	0	1	
E40725083								RUM: 30	Rear end					4WD	M54	W in THE NORTHERN RD	0	Stationary				

Detailed Crash Report

Crash No.	Data Source	Date	Day of Week	Time	Distance		ID Feature	Loc Type	Alignment	Weather	Surface Condition	Speed Limit	No. of Tus	Tu Type/Obj	Age/Sex	Street Travelling	Speed Travelling	Manoeuvre	Degree of Crash	Killed	Injured	Factors
																						S F
772636	P	13/01/2012	Fri	19:30	1 km	S	DWYER RD	2WY	CRV	Fine	Dry	80	2	M/C	M29	S in THE NORTHERN RD	Unk	Incorrect side	F	1	0	
E46455217								RUM: 20	Head on					SEM	M39	N in THE NORTHERN RD	80	Proceeding in lane				
746680	P	29/03/2011	Tue	09:55	2.1 km	S	DWYER RD	2WY	CRV	Fine	Dry	80	1	CAR	F36	S in THE NORTHERN RD	80	Proceeding in lane	I	0	1	S F
E44926908								RUM: 81	Off left/rt bnd=>obj					Tree/bush								
707861	P	25/04/2010	Sun	05:00		at	MERSEY RD	TJN	STR	Raining	Wet	80	1	CAR	M19	E in THE NORTHERN RD	75	Proceeding in lane	N	0	0	
E41377778								RUM: 73	Off rd rght => obj					Utility pole								
821266	P	12/11/2012	Mon	15:20		at	NUMBER 1455 HN	2WY	STR	Fine	Dry	80	3	TRK	M55	W in THE NORTHERN RD	80	Veering right	N	0	0	
E49418652								RUM: 34	Lane change right					CAR	M44	W in THE NORTHERN RD	80	Proceeding in lane				
														TRK	M42	W in THE NORTHERN RD	80	Proceeding in lane				

Report Totals: Total Crashes: 16 Fatal Crashes: 1 Injury Crashes: 6 Killed: 1 Injured: 8

Crashid dataset 6493 - Reported crashes on The Northern Rd between Badgerys Creek Rd & Mersey Rd - 1 Jul 09 to 30 Jun 14

Crash self reporting, including self reported injuries began in Oct 2014. Trends from 2014 are expected to vary from previous years. More unknowns are expected in self reported data. For further information refer to Data Manual or report provider.

Appendix C – Initial airport development traffic generation

Initial airport development

Traffic generation tables

Table 1 2031 passenger trip generation to the airport

Hr comm.	Domestic air departures	International air departures	Hourly total
00:00	-	-	-
01:00	-	-	-
02:00	-	-	-
03:00	-	208	208
04:00	71	378	449
05:00	436	541	976
06:00	780	792	1,572
07:00	1,246	760	2,006
08:00	1,064	756	1,820
09:00	975	736	1,711
10:00	697	658	1,354
11:00	625	631	1,257
12:00	577	593	1,171
13:00	595	700	1,295
14:00	796	736	1,532
15:00	913	865	1,778
16:00	1,285	818	2,103
17:00	1,046	683	1,730
18:00	762	518	1,280
19:00	390	419	809
20:00	128	162	290
21:00	40	124	164
22:00	-	35	35
23:00	-	-	-
Total	**12,425**	**11,113**	**23,539**

Table 2 2031 passenger trip generation from the airport

Hr comm.	Domestic air arrivals	International air arrivals	Hourly total
00:00	-	-	-
01:00	-	-	-
02:00	-	-	-
03:00	-	-	-
04:00	16	16	31
05:00	121	204	325
06:00	419	757	1,175
07:00	855	1,453	2,308
08:00	1,122	1,885	3,007
09:00	1,243	2,144	3,387
10:00	854	1,691	2,545
11:00	745	1,480	2,225
12:00	578	1,206	1,783
13:00	577	1,163	1,740
14:00	637	1,237	1,874
15:00	758	1,404	2,162
16:00	1,009	1,747	2,756
17:00	1,123	1,958	3,081
18:00	1,180	2,075	3,254
19:00	693	1,497	2,190
20:00	350	887	1,237
21:00	146	538	685
22:00	0	187	188
23:00	-	11	11
Total	**12,425**	**23,539**	**35,964**

Table 3 Passenger trip generation to the airport

Hr Comm.	Kiss'n'fly	Park'n'fly	Taxi	Shuttle	Bus	Train	Hourly total
00:00	-	-	-	-	-	-	-
01:00	-	-	-	-	-	-	-
02:00	-	-	-	-	-	-	-
03:00	83	62	42	10	10	-	208
04:00	173	138	90	22	26	-	449
05:00	347	315	195	49	71	-	976
06:00	675	448	276	69	104	-	1,572
07:00	890	558	336	84	138	-	2,006
08:00	940	440	267	67	106	-	1,820
09:00	964	374	227	57	90	-	1,711
10:00	764	295	181	45	70	-	1,354
11:00	692	282	173	43	66	-	1,257
12:00	608	281	173	43	65	-	1,171
13:00	648	323	200	50	73	-	1,295
14:00	729	401	246	61	94	-	1,532
15:00	842	468	287	72	109	-	1,778
16:00	991	556	335	84	138	-	2,103
17:00	918	406	245	61	100	-	1,730
18:00	809	235	141	35	58	-	1,280
19:00	548	130	80	20	31	-	809
20:00	266	12	7	2	3	-	290
21:00	164	-	-	-	-	-	164
22:00	35	-	-	-	-	-	35
23:00	-	-	-	-	-	-	-
Total	**12,085**	**5,727**	**3,499**	**875**	**1,353**	**-**	**23,539**

Table 4 Passenger trip generation from the airport

Hr Comm.	Kiss 'n' fly	Park 'n' fly	Taxi	Shuttle	Bus	Train	Hourly total
00:00	-	-	-	-	-	-	-
01:00	-	-	-	-	-	-	-
02:00	-	-	-	-	-	-	-
03:00	-	-	-	-	-	-	-
04:00	16	-	-	-	-	-	16
05:00	204	-	-	-	-	-	204
06:00	402	177	110	27	40	-	757
07:00	825	314	191	48	76	-	1,453
08:00	929	478	288	72	118	-	1,885
09:00	1,026	559	339	85	135	-	2,144
10:00	841	425	260	65	100	-	1,691
11:00	746	367	225	56	86	-	1,480
12:00	634	286	176	44	66	-	1,206
13:00	611	276	169	42	64	-	1,163
14:00	669	284	174	44	66	-	1,237
15:00	751	327	199	50	78	-	1,404
16:00	931	408	249	62	97	-	1,747
17:00	971	493	298	75	120	-	1,958
18:00	966	555	336	84	134	-	2,075
19:00	734	382	234	59	89	-	1,497
20:00	426	231	143	36	51	-	887
21:00	259	139	89	22	29	-	538
22:00	135	26	17	4	4	-	187
23:00	11	-	-	-	-	-	11
Total	**12,085**	**5,727**	**3,499**	**875**	**1,353**	**-**	**23,539**

Table 5 Total hourly passenger traffic generation to the airport

Hr comm.	Car	Taxi	Mini bus	Bus	Hourly total
00:00	-	-	-	-	-
01:00	-	-	-	-	-
02:00	-	-	-	-	-
03:00	87	28	1	1	116
04:00	194	63	3	2	261
05:00	446	151	6	5	608
06:00	785	303	9	16	1,113
07:00	1,054	431	10	16	1,512
08:00	1,017	453	8	12	1,490
09:00	991	459	7	11	1,467
10:00	771	351	6	5	1,133
11:00	704	316	5	4	1,030
12:00	636	275	5	7	924
13:00	686	290	6	8	990
14:00	806	334	8	9	1,156
15:00	934	387	9	10	1,340
16:00	1,130	475	10	9	1,625
17:00	983	444	8	7	1,441
18:00	791	389	4	4	1,188
19:00	502	249	2	2	755
20:00	210	117	0	0	328
21:00	119	65	-	-	184
22:00	23	12	-	-	35
23:00	-	-	-	-	-
Total	**12,868**	**5,592**	**109**	**127**	**18,696**

Table 6 Total hourly passenger traffic generation from the airport

Hr comm.	Car	Taxi	Mini bus	Bus	Hourly total
00:00	-	-	-	-	-
01:00	-	-	-	-	-
02:00	-	-	-	-	-
03:00	-	28	-	-	28
04:00	14	63	-	-	77
05:00	165	151	-	-	317
06:00	430	303	3	12	749
07:00	852	431	6	12	1,301
08:00	1,029	453	9	13	1,503
09:00	1,153	459	11	14	1,636
10:00	902	351	8	7	1,269
11:00	795	316	7	6	1,124
12:00	656	275	5	7	944
13:00	637	290	5	7	939
14:00	692	334	5	7	1,039
15:00	786	387	6	8	1,187
16:00	992	475	8	6	1,481
17:00	1,064	444	9	8	1,525
18:00	1,095	389	11	9	1,504
19:00	782	249	7	6	1,044
20:00	449	117	4	3	574
21:00	263	65	3	2	333
22:00	103	12	1	0	116
23:00	7	-	-	-	7
Total	**12,868**	**5,592**	**109**	**127**	**18,696**

Table 7 Shift profiles

Worker type	Start	Finish	Percent of total employees	No of employees
Airfield overnight	21:00	05:00	2	220
Airfield day	05:00	13:00	3	123
Airfield afternoon	13:00	21:00	3	123
Terminal support morning	06:00	13:00	10	616
Terminal support afternoon	13:00	20:00	10	739
Terminal supplementary morning	06:00	11:00	14	862
Terminal supplementary morning	15:00	17:00	14	739
Office early start	07:00	17:00	21	1,293
Office later start	09:00	19:00	21	1,416
			Total	**6,158**

Table 8 Hourly arrival and departure volumes

Hr comm.	Arrival	Departure	Hourly total
00:00	-	-	-
01:00	-	-	-
02:00	-	-	-
03:00	-	-	-
04:00	61	110	171
05:00	369	110	479
06:00	1,386	-	1,386
07:00	1,078	-	1,078
08:00	708	-	708
09:00	708	-	708
10:00	-	431	431
11:00	-	431	431
12:00	431	369	800
13:00	431	369	800
14:00	370	-	370
15:00	370	647	1,016
16:00	-	647	647
17:00	-	708	708
18:00	-	1,078	1,078
19:00	-	739	739
20:00	110	431	541
21:00	110	61	171
22:00	-	-	-
23:00	-	-	-
Total	**6,132**	**6,132**	**12,263**

Table 9 Employee volumes arriving at the airport by mode

Hr Comm.	Car driver	Car Passenger	Bus	Train	Hourly total
00:00	-	-	-	-	-
01:00	-	-	-	-	-
02:00	-	-	-	-	-
03:00	-	-	-	-	-
04:00	61	-	-	-	61
05:00	369	-	-	-	369
06:00	1,067	180	139	-	1,386
07:00	830	140	108	-	1,078
08:00	545	92	71	-	708
09:00	545	92	71	-	708
10:00	-	-	-	-	-
11:00	-	-	-	-	-
12:00	332	56	43	-	431
13:00	332	56	43	-	431
14:00	285	48	37	-	370
15:00	285	48	37	-	370
16:00	-	-	-	-	-
17:00	-	-	-	-	-
18:00	-	-	-	-	-
19:00	-	-	-	-	-
20:00	110	-	-	-	110
21:00	110	-	-	-	110
22:00	-	-	-	-	-
23:00	-	-	-	-	-
Total	**4,871**	**713**	**548**	**-**	**6,132**

Table 10 Employee volumes arriving at the airport by mode

Hr Comm.	Car driver	Car Passenger	Bus	Train	Hourly total
00:00	-	-	-	-	-
01:00	-	-	-	-	-
02:00	-	-	-	-	-
03:00	-	-	-	-	-
04:00	110	-	-	-	110
05:00	110	-	-	-	110
06:00	-	-	-	-	-
07:00	-	-	-	-	-
08:00	-	-	-	-	-
09:00	-	-	-	-	-
10:00	332	56	43	-	431
11:00	332	56	43	-	431
12:00	284	48	37	-	369
13:00	284	48	37	-	369
14:00	-	-	-	-	-
15:00	498	84	65	-	647
16:00	498	84	65	-	647
17:00	545	92	71	-	708
18:00	830	140	108	-	1,078
19:00	569	96	74	-	739
20:00	431	-	-	-	431
21:00	61	-	-	-	61
22:00	-	-	-	-	-
23:00	-	-	-	-	-
Total	**4,885**	**705**	**542**	**-**	**6,132**

Table 11 Employee traffic generation to the airport

Hr Comm.	Cars	Bus	Train	Hourly total
00:00	-	-	-	-
01:00	-	-	-	0
02:00	-	-	-	0
03:00	-	-	-	-
04:00	62	-	-	62
05:00	370	-	-	370
06:00	1,067	9	-	1,076
07:00	830	7	-	837
08:00	545	5	-	550
09:00	545	5	-	550
10:00	-	-	-	-
11:00	-	-	-	-
12:00	332	3	-	335
13:00	332	3	-	335
14:00	285	2	-	287
15:00	285	2	-	287
16:00	-	-	-	-
17:00	-	-	-	-
18:00	-	-	-	-
19:00	-	-	-	-
20:00	123	-	-	123
21:00	123	-	-	123
22:00	-	-	-	-
23:00	-	-	-	-
Total	**4,898**	**37**	**-**	**4,935**

Table 12 Employee traffic generation from the airport

Hr Comm.	Cars	Bus	Train	Hourly total
00:00	-	-	-	-
01:00	-	-	-	0
02:00	-	-	-	0
03:00	-	-	-	-
04:00	123	-	-	123
05:00	123	-	-	123
06:00	-	-	-	-
07:00	-	-	-	-
08:00	-	-	-	-
09:00	-	-	-	-
10:00	332	3	-	335
11:00	332	3	-	335
12:00	285	2	-	287
13:00	285	2	-	287
14:00	-	-	-	-
15:00	498	4	-	502
16:00	498	4	-	502
17:00	545	5	-	550
18:00	830	7	-	837
19:00	569	5	-	574
20:00	431	-	-	431
21:00	62	-	-	62
22:00	-	-	-	-
23:00	-	-	-	-
Total	**4,912**	**36**	**-**	**4,948**

Table 13 All day trip generation and mode share

	Passenger Kiss 'n' fly	Passenger Park 'n' fly	Passenger Taxi	Passenger Shuttle	Staff car driver	Staff car passenger	Bus	Train
Mode share	39%	18%	11%	3%	20%	3%	7%	0%
No. trips	24,170	11,453	6,998	1,750	12,195	1,771	4,060	-

Table 14 AM peak trip generation and mode share

AM peak	Passenger Kiss 'n' fly	Passenger Park 'n' fly	Passenger Taxi	Passenger Shuttle	Staff car driver	Staff car passenger	Bus	Train

Mode share	37%	19%	11%	3%	22%	4%	5%	0%
No. trips	1,715	872	527	132	1,037	175	214	-

Table 15 PM peak trip generation and mode share

PM peak	Passenger Kiss 'n' fly	Passenger Park 'n' fly	Passenger Taxi	Passenger Shuttle	Staff car driver	Staff car passenger	Bus	Train
Mode share	37%	16%	10%	2%	21%	4%	10%	0%
No. trips	1,775	790	478	119	1,037	175	462	-

Table 16 Airport traffic generation to airport

Hr comm.	Car	Taxis	Mini bus	Bus	Road vehicles	Trains
00:00	-	-	-	-	-	-
01:00	-	-	-	-	-	-
02:00	-	-	-	-	-	-
03:00	87	28	1	-	116	-
04:00	270	63	3	-	337	-
05:00	907	151	6	-	1,065	-
06:00	2,119	218	9	28	2,374	-
07:00	2,092	276	10	28	2,406	-
08:00	1,698	216	8	27	1,951	-
09:00	1,672	184	7	30	1,893	-
10:00	771	144	6	13	934	-
11:00	704	137	5	11	858	-
12:00	1,051	137	5	16	1,209	-
13:00	1,101	156	6	16	1,279	-
14:00	1,162	196	8	15	1,380	-
15:00	1,289	228	9	16	1,542	-
16:00	1,130	276	10	13	1,429	-
17:00	983	201	8	16	1,207	-
18:00	791	117	4	18	930	-
19:00	502	63	2	12	579	-
20:00	348	6	0	7	361	-
21:00	256	-	-	4	260	-
22:00	23	-	-	1	24	-
23:00	-	-	-	-	-	-
Total	**18,957**	**2,796**	**109**	**272**	**22,134**	**-**

Table 17 Airport traffic generation from airport

Hr comm.	Car	Taxis	Mini bus	Bus	Road vehicles	Trains
00:00	-	-	-	-	-	-
01:00	-	-	-	-	-	-
02:00	-	-	-	-	-	-
03:00	-	-	-	1	1	-
04:00	152	-	-	2	153	-
05:00	303	-	-	5	308	-
06:00	516	85	3	18	623	-
07:00	1,007	154	6	18	1,185	-
08:00	1,265	236	9	13	1,523	-
09:00	1,427	275	11	12	1,725	-
10:00	1,525	207	8	8	1,748	-
11:00	1,389	179	7	8	1,583	-
12:00	1,150	139	5	11	1,306	-
13:00	1,126	134	5	12	1,277	-
14:00	830	138	5	9	983	-
15:00	1,568	160	6	16	1,750	-
16:00	1,814	200	8	15	2,036	-
17:00	1,989	243	9	13	2,254	-
18:00	2,406	273	11	13	2,702	-
19:00	1,678	185	7	8	1,879	-
20:00	1,099	111	4	0	1,214	-
21:00	405	65	3	-	474	-
22:00	115	12	1	-	127	-
23:00	7	-	-	-	7	-
Total	**21,771**	**2,796**	**109**	**181**	**24,857**	**-**

Appendix D – Longer term airport development traffic generation

Longer term airport development

Traffic generation tables

Table 1 Passenger trip generation to the airport

Hr comm.	Domestic air departures	International air departures	Hourly total
00:00	-	1,142	1,142
01:00	63	2,013	2,076
02:00	309	1,405	1,715
03:00	660	2,106	2,766
04:00	1,320	3,899	5,219
05:00	2,408	4,166	6,574
06:00	2,808	5,708	8,517
07:00	2,964	5,118	8,082
08:00	2,965	4,826	7,790
09:00	2,965	5,142	8,107
10:00	2,965	4,812	7,777
11:00	2,965	4,763	7,727
12:00	2,965	4,763	7,727
13:00	2,965	4,763	7,727
14:00	2,965	4,850	7,814
15:00	2,965	6,161	9,126
16:00	2,965	5,167	8,132
17:00	2,965	4,739	7,703
18:00	2,845	3,611	6,456
19:00	1,897	2,090	3,987
20:00	1,109	1,473	2,582
21:00	559	768	1,327
22:00	287	491	779
23:00	125	727	852
Total	**47,002**	**84,703**	**131,705**

Table 2 Passenger trip generation from the airport

Hr comm.	Domestic air arrivals	International air arrivals	Hourly total
00:00	5	177	182
01:00	10	244	253
02:00	65	881	945
03:00	304	1,676	1,980
04:00	656	2,188	2,844
05:00	1,303	1,788	3,091
06:00	2,188	2,703	4,890
07:00	2,954	4,305	7,258
08:00	2,965	5,293	8,257
09:00	2,965	6,105	9,070
10:00	2,965	5,224	8,189
11:00	2,965	4,776	7,740
12:00	2,965	4,763	7,727
13:00	2,965	4,763	7,727
14:00	2,965	4,763	7,727
15:00	2,965	4,763	7,727
16:00	2,965	4,785	7,750
17:00	2,965	5,305	8,270
18:00	2,947	6,105	9,052
19:00	2,753	5,201	7,954
20:00	2,145	4,201	6,346
21:00	1,084	2,557	3,641
22:00	543	1,251	1,794
23:00	273	675	947
Total	**46,873**	**84,491**	**131,364**

Table 3 Passenger trip generation to the airport by mode

Hr Comm.	Kiss 'n' fly	Park 'n' fly	Taxi	Shuttle	Bus	Train	Hourly total
00:00	297	205	228	57	148	205	639
01:00	561	369	409	102	266	369	1,146
02:00	564	283	308	77	200	283	867
03:00	976	442	477	119	310	442	1,349
04:00	1,758	855	922	231	599	855	2,607
05:00	1,983	1,140	1,217	304	791	1,140	3,452
06:00	2,789	1,418	1,522	380	989	1,418	4,309
07:00	3,090	1,239	1,323	331	860	1,239	3,753
08:00	3,098	1,166	1,242	311	807	1,166	3,526
09:00	3,414	1,166	1,242	311	807	1,166	3,526
10:00	3,084	1,166	1,242	311	807	1,166	3,526
11:00	3,035	1,166	1,242	311	807	1,166	3,526
12:00	3,035	1,166	1,242	311	807	1,166	3,526
13:00	3,035	1,166	1,242	311	807	1,166	3,526
14:00	3,057	1,182	1,259	315	819	1,182	3,575
15:00	3,398	1,418	1,522	380	989	1,418	4,309
16:00	3,140	1,239	1,323	331	860	1,239	3,753
17:00	3,075	1,151	1,225	306	796	1,151	3,478
18:00	2,990	867	912	228	593	867	2,599
19:00	2,141	463	484	121	315	463	1,383
20:00	1,638	237	248	62	161	237	707
21:00	866	116	121	30	78	116	345
22:00	452	81	86	22	56	81	245
23:00	364	119	131	33	85	119	368
Total	**51,841**	**19,822**	**21,168**	**5,292**	**13,759**	**19,822**	**60,042**

Table 4 Passenger trip generation from the airport by mode

Hr Comm.	Kiss 'n' fly	Park 'n' fly	Taxi	Shuttle	Bus	Train	Hourly total
00:00	182	-	-	-	-	-	-
01:00	161	22	25	6	16	22	70
02:00	442	122	136	34	88	122	381
03:00	868	273	299	75	194	273	840
04:00	1,048	441	481	120	313	441	1,355
05:00	1,564	380	403	101	262	380	1,146
06:00	2,041	711	752	188	489	711	2,139
07:00	2,708	1,132	1,204	301	782	1,132	3,418
08:00	3,386	1,210	1,290	323	839	1,210	3,662
09:00	3,297	1,429	1,534	383	997	1,429	4,343
10:00	3,356	1,200	1,280	320	832	1,200	3,632
11:00	3,048	1,166	1,242	311	807	1,166	3,526
12:00	3,035	1,166	1,242	311	807	1,166	3,526
13:00	3,035	1,166	1,242	311	807	1,166	3,526
14:00	3,035	1,166	1,242	311	807	1,166	3,526
15:00	3,035	1,166	1,242	311	807	1,166	3,526
16:00	3,057	1,166	1,242	311	807	1,166	3,526
17:00	3,398	1,210	1,290	323	839	1,210	3,662
18:00	3,280	1,429	1,534	383	997	1,429	4,343
19:00	3,122	1,200	1,280	320	832	1,200	3,632
20:00	2,228	1,021	1,092	273	710	1,021	3,097
21:00	1,435	547	586	146	381	547	1,660
22:00	731	264	282	71	183	264	800
23:00	352	147	158	40	103	147	448
Total	**51,841**	**19,738**	**21,077**	**5,269**	**13,700**	**19,738**	**59,785**

Table 5 Traffic generation to the airport

Hr comm.	Car	Taxi	Mini bus	Bus	Train	Hourly total
00:00	301	152	7	10	1	471
01:00	564	276	13	18	2	872
02:00	545	220	10	13	1	789
03:00	936	348	15	21	2	1,321
04:00	1,728	674	29	40	4	2,475
05:00	2,130	919	38	53	6	3,145
06:00	2,871	1,132	48	230	25	4,306
07:00	3,020	1,000	41	185	20	4,266
08:00	2,989	946	39	138	15	4,126
09:00	3,200	946	39	138	15	4,337
10:00	2,979	946	39	54	6	4,024
11:00	2,947	946	39	54	6	3,991
12:00	2,947	946	39	105	11	4,048
13:00	2,947	946	39	105	11	4,048
14:00	2,969	957	39	98	11	4,075
15:00	3,315	1,132	48	110	12	4,616
16:00	3,053	1,000	41	57	6	4,158
17:00	2,966	934	38	53	6	3,997
18:00	2,756	720	28	40	4	3,549
19:00	1,907	389	15	21	2	2,334
20:00	1,372	198	8	11	1	1,590
21:00	717	97	4	5	1	824
22:00	384	66	3	4	0	457
23:00	321	91	4	6	1	422
Total	**49,861**	**15,981**	**662**	**1,567**	**171**	**68,242**

Table 6 Traffic generation from the airport

Hr comm.	Car	Taxi	Mini bus	Bus	Train	Hourly total
00:00	122	-	-	-	-	122
01:00	121	17	1	1	0	139
02:00	371	91	4	6	1	473
03:00	758	209	9	13	1	990
04:00	1,013	341	15	21	2	1,392
05:00	1,414	311	13	17	2	1,756
06:00	1,978	584	23	197	22	2,805
07:00	2,709	920	38	180	20	3,866
08:00	3,202	978	40	140	15	4,376
09:00	3,253	1,140	48	150	16	4,608
10:00	3,178	971	40	55	6	4,250
11:00	2,955	946	39	54	6	3,999
12:00	2,947	946	39	105	11	4,048
13:00	2,947	946	39	105	11	4,048
14:00	2,947	946	39	98	11	4,040
15:00	2,947	946	39	98	11	4,040
16:00	2,962	946	39	54	6	4,006
17:00	3,211	978	40	56	6	4,291
18:00	3,237	1,140	48	66	7	4,499
19:00	2,970	971	40	55	6	4,042
20:00	2,217	821	34	47	5	3,125
21:00	1,343	437	18	25	3	1,826
22:00	676	211	9	12	1	910
23:00	337	117	5	7	1	467
Total	**49,813**	**15,913**	**659**	**1,563**	**171**	**68,118**

Table 7 Hourly arrival and departure volumes

Hr comm.	Arrival	Departure	Hourly total
00:00	-	-	-
01:00	-	-	-
02:00	-	-	-
03:00	-	-	-
04:00	476	952	1,428
05:00	2,856	952	3,808
06:00	10,710	-	10,710
07:00	8,330	-	8,330
08:00	5,474	-	5,474
09:00	5,474	-	5,474
10:00	-	3,332	3,332
11:00	-	3,332	3,332
12:00	3,332	2,856	6,188
13:00	3,332	2,856	6,188
14:00	2,856	-	2,856
15:00	2,856	4,998	7,854
16:00	-	4,998	4,998
17:00	-	5,474	5,474
18:00	-	8,330	8,330
19:00	-	5,712	5,712
20:00	952	3,332	4,284
21:00	952	476	1,428
22:00	-	-	-
23:00	-	-	-
Total	**47,599**	**47,599**	**95,199**

Table 8 Employee volumes arriving at the airport by mode

Hr Comm.	Car driver	Car Passenger	Bus	Train	Hourly total
00:00	-	-	-	-	-
01:00	-	-	-	-	-
02:00	-	-	-	-	-
03:00	-	-	-	-	-
04:00	476	-	-	-	476
05:00	2,856	-	-	-	2,856
06:00	3,213	1,392	2,463	3,641	10,710
07:00	2,499	1,083	1,916	2,832	8,330
08:00	1,642	712	1,259	1,861	5,474
09:00	1,642	712	1,259	1,861	5,474
10:00	-	-	-	-	-
11:00	-	-	-	-	-
12:00	1,000	433	766	1,133	3,332
13:00	1,000	433	766	1,133	3,332
14:00	857	371	657	971	2,856
15:00	857	371	657	971	2,856
16:00	-	-	-	-	-
17:00	-	-	-	-	-
18:00	-	-	-	-	-
19:00	-	-	-	-	-
20:00	952	-	-	-	952
21:00	952	-	-	-	952
22:00	-	-	-	-	-
23:00	-	-	-	-	-
Total	**17,945**	**5,507**	**9,744**	**14,404**	**47,599**

Table 9 Employee volumes arriving at the airport by mode

Hr Comm.	Car driver	Car Passenger	Bus	Train	Hourly total
00:00	-	-	-	-	-
01:00	-	-	-	-	-
02:00	-	-	-	-	-
03:00	-	-	-	-	-
04:00	952	-	-	-	952
05:00	952	-	-	-	952
06:00	-	-	-	-	-
07:00	-	-	-	-	-
08:00	-	-	-	-	-
09:00	-	-	-	-	-
10:00	1,000	433	766	1,133	3,332
11:00	1,000	433	766	1,133	3,332
12:00	857	371	657	971	2,856
13:00	857	371	657	971	2,856
14:00	-	-	-	-	-
15:00	1,499	650	1,150	1,699	4,998
16:00	1,499	650	1,150	1,699	4,998
17:00	1,642	712	1,259	1,861	5,474
18:00	2,499	1,083	1,916	2,832	8,330
19:00	1,714	743	1,314	1,942	5,712
20:00	3,332	-	-	-	3,332
21:00	476	-	-	-	476
22:00	-	-	-	-	-
23:00	-	-	-	-	-
Total	**18,278**	**5,445**	**9,634**	**14,242**	**47,599**

Table 10 Employee traffic generation to the airport

Hr Comm.	Cars	Bus	Train	Hourly total
00:00	-	-	-	-
01:00	-	-	-	-
02:00	-	-	-	-
03:00	-	-	-	-
04:00	476	-	-	476
05:00	2,856	-	-	2,856
06:00	3,213	164	18	3,395
07:00	2,499	128	14	2,641
08:00	1,642	84	9	1,735
09:00	1,642	84	9	1,735
10:00	-	-	-	-
11:00	-	-	-	-
12:00	1,000	51	6	1,056
13:00	1,000	51	6	1,056
14:00	857	44	5	905
15:00	857	44	5	905
16:00	-	-	-	-
17:00	-	-	-	-
18:00	-	-	-	-
19:00	-	-	-	-
20:00	952	-	-	952
21:00	952	-	-	952
22:00	-	-	-	-
23:00	-	-	-	-
Total	**17,945**	**650**	**72**	**18,667**

Table 11 Employee traffic generation from the airport

Hr Comm.	Cars	Bus	Train	Hourly total
00:00	-	-	-	-
01:00	-	-	-	-
02:00	-	-	-	-
03:00	-	-	-	-
04:00	952	-	-	952
05:00	952	-	-	952
06:00	-	-	-	-
07:00	-	-	-	-
08:00	-	-	-	-
09:00	-	-	-	-
10:00	1,000	51	6	1,056
11:00	1,000	51	6	1,056
12:00	857	44	5	905
13:00	857	44	5	905
14:00	-	-	-	-
15:00	1,499	77	8	1,585
16:00	1,499	77	8	1,585
17:00	1,642	84	9	1,735
18:00	2,499	128	14	2,641
19:00	1,714	88	10	1,811
20:00	3,332	-	-	3,332
21:00	476	-	-	476
22:00	-	-	-	-
23:00	-	-	-	-
Total	**18,278**	**642**	**71**	**18,992**

Table 12 All day trip generation and mode share

AM peak	Passenger Kiss 'n' fly	Passenger Park 'n' fly	Passenger Taxi	Passenger Shuttle	Staff car driver	Staff car passenger	Bus	Train
Mode share	29%	11%	12%	3%	10%	3%	13%	19%
No. of trips	103,683	39,560	42,245	10,561	36,223	10,953	46,728	68,043

Table 13 AM peak trip generation and mode share

AM peak	Passenger Kiss 'n' fly	Passenger Park 'n' fly	Passenger Taxi	Passenger Shuttle	Staff car driver	Staff car passenger	Bus	Train
Mode	31%	13%	13%	3%	13%	6%	9%	13%

share								
No. of trips	5,798	2,371	2,526	632	2,499	1,083	1,642	2,371

Table 14 PM peak trip generation and mode share

PM	Passenger Kiss 'n' fly	Passenger Park 'n' fly	Passenger Taxi	Passenger Shuttle	Staff car driver	Staff car passenger	Bus	Train
Mode share	22%	8%	9%	2%	9%	4%	19%	28%
No trips	6,269	2,296	2,446	611	2,499	1,083	5,421	7,960

Table 15 Airport traffic generation to airport

Hr comm.	Car	Taxis	Mini bus	Bus	Road vehicles	Trains
00:00	301	152	7	-	460	-
01:00	564	276	13	2	855	0
02:00	545	220	10	12	786	1
03:00	936	348	15	26	1,324	1
04:00	2,204	674	29	42	2,949	2
05:00	4,986	919	38	35	5,978	2
06:00	6,084	1,132	48	394	7,657	22
07:00	5,519	1,000	41	360	6,920	20
08:00	4,631	946	39	280	5,895	15
09:00	4,842	946	39	301	6,127	16
10:00	2,979	946	39	111	4,075	12
11:00	2,947	946	39	108	4,039	11
12:00	3,946	946	39	210	5,141	16
13:00	3,946	946	39	210	5,141	16
14:00	3,826	957	39	195	5,018	11
15:00	4,172	1,132	48	195	5,547	19
16:00	3,053	1,000	41	108	4,202	14
17:00	2,966	934	38	112	4,050	15
18:00	2,756	720	28	133	3,638	21
19:00	1,907	389	15	111	2,422	16
20:00	2,324	198	8	95	2,625	5
21:00	1,669	97	4	51	1,821	3
22:00	384	66	3	24	477	1
23:00	321	91	4	14	430	1
Total	**67,806**	**15,981**	**662**	**3,126**	**87,575**	**242**

Table 16 Airport traffic generation from airport

Hr comm.	Car	Taxis	Mini bus	Bus	Road vehicles	Trains
00:00	122	-	-	10	132	1
01:00	138	17	1	18	173	2
02:00	462	91	4	13	570	1
03:00	966	209	9	21	1,205	2
04:00	2,306	341	15	40	2,702	4
05:00	2,676	311	13	53	3,053	6
06:00	2,563	584	23	230	3,401	25
07:00	3,629	920	38	185	4,772	20
08:00	4,180	978	40	138	5,337	15
09:00	4,393	1,140	48	138	5,719	15
10:00	5,148	971	40	105	6,264	11
11:00	4,901	946	39	105	5,990	11
12:00	4,749	946	39	149	5,883	16
13:00	4,749	946	39	149	5,883	16
14:00	3,892	946	39	98	4,975	11
15:00	5,392	946	39	186	6,563	20
16:00	5,407	946	39	134	6,525	15
17:00	5,831	978	40	137	6,986	15
18:00	6,876	1,140	48	167	8,232	18
19:00	5,655	971	40	109	6,774	12
20:00	6,370	821	34	11	7,236	1
21:00	2,256	437	18	5	2,717	1
22:00	887	211	9	4	1,111	0
23:00	455	117	5	6	582	1
Total	**84,004**	**15,913**	**659**	**2,209**	**102,785**	**242**

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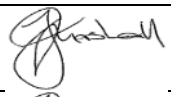
A	S Payne K McNatty G McCabe	G McCabe		G Marshall		20.07.2015
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VOLUME 4

Appendix K1
Biodiversity



Department of Infrastructure and Regional Development

Western Sydney Airport EIS

Biodiversity Assessment

October 2015

Limitations

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Table of contents

1. Introduction 1
   - 1.1 Background 1
   - 1.2 EIS requirements 2
   - 1.3 The proposal 9
   - 1.4 Purpose of this report 11
   - 1.5 Assumptions 11
2. Legislative context 13
   - 2.1 EPBC Act 13
   - 2.2 New South Wales Legislation 14
3. Methodology 17
   - 3.1 Literature and desktop assessment 17
   - 3.2 Field surveys: Terrestrial Biodiversity 18
   - 3.3 Field Surveys: Aquatic Biodiversity 26
   - 3.4 Survey effort, timing, limitations and staff 33
   - 3.5 Assessment of likelihood of occurrence 39
4. Existing environment 45
   - 4.1 Physical environment 45
   - 4.2 Plant species and vegetation zones 46
   - 4.3 Terrestrial fauna species and habitats 79
   - 4.4 Aquatic species and habitats 89
   - 4.5 Conservation significance 113
5. Construction impacts 135
   - 5.1 Stage 1 development 135
   - 5.2 Longer term development 148
6. Operation impacts 151
   - 6.1 Stage 1 development 151
   - 6.2 Longer term development 157
7. Cumulative impacts 159
8. Assessment of Significance 163
   - 8.1 Key threatening processes and threat abatement plans 163
   - 8.2 Impacts on MNES 169
   - 8.3 Impacts on Commonwealth land 183
   - 8.4 Impacts on NSW-listed biota 189
9. Recommended management measures 201
   - 9.1 Avoidance of impacts 201
   - 9.2 Recommended mitigation of impacts 202
   - 9.3 Offsetting of impacts 214

10. Conclusion 231
11. References 235

Table index

Table 1 EIS requirements for biodiversity assessment 2
Table 2 Confidence ratings applied to bat calls 23
Table 3 Weather conditions during targeted frog surveys 24
Table 4 Aquatic survey site locations 27
Table 5 Summary of the habitat sampled for macroinvertebrates at each aquatic survey site 28
Table 6 AUSRIVAS Band widths and interpretations for the NSW autumn edge and riffle models 29
Table 7 Fish survey method used at each site 31
Table 8 Key fish habitat and associated sensitivity scheme (DPI 2013) 32
Table 9 Classification of waterways for fish passage (DPI 2013). 32
Table 10 Survey effort and timing 33
Table 11 Site stratification and survey effort 35
Table 12 Weather conditions during terrestrial surveys 37
Table 13 Weather conditions during aquatic surveys 37
Table 14 Qualifications of staff 39
Table 15 Vegetation zones within the airport site 49
Table 16 Good condition Grey Box - Forest Red Gum grassy woodland on flats 54
Table 17 Poor condition Grey Box - Forest Red Gum grassy woodland on flats 56
Table 18 Good condition Grey Box - Forest Red Gum grassy woodland on hills 58
Table 19 Poor condition Grey Box - Forest Red Gum grassy woodland on hills 60
Table 20 Good condition Forest Red Gum - Rough-barked Apple grassy woodland 62
Table 21 Poor condition Forest Red Gum - Rough-barked Apple grassy woodland 64
Table 22 Good condition Broad-leaved Ironbark – *Melaleuca decora* grassy open forest 66
Table 23 Poor condition Broad-leaved Ironbark – *Melaleuca decora* grassy open forest on clay/gravel 68
Table 24 Good condition artificial freshwater wetland on floodplain 70
Table 25 Exotic grassland 72
Table 26 Cleared land and cropland 74
Table 27 Noxious weeds and WoNS recorded at the airport site 76
Table 28 Fauna habitats of grassland and cropped areas 80
Table 29 Fauna habitats of native woodland 82

Table 30 Fauna habitats of riparian forest 84
Table 31 Fauna habitats of dams....86
Table 32 Fauna habitats of buildings and other structures....88
Table 33 BCUS – Badgerys Creek upstream 90
Table 34 BCMC – Badgerys Creek mid-catchment 91
Table 35 BCDS – Badgerys Creek downstream....92
Table 36 SCUS – South Creek upstream 93
Table 37 SCDS – South Creek downstream....94
Table 38 SCREC – South Creek recovery....95
Table 39 DCUS – Duncans Creek Upstream....96
Table 40 DCDS – Duncans Creek Downstream....98
Table 41 OCUS – Oaky Creek upstream....99
Table 42 OCDS – Oaky Creek downstream 100
Table 43 CCUS – Cosgrove Creek upstream....101
Table 44 CCDS – Cosgrove Creek downstream 102
Table 45 TCUS – Thompson Creek upstream....103
Table 46 OCDAM – Oaky Creek Dam 104
Table 47 OSDAM – On Site Dam....105
Table 48 Fish habitat survey results 106
Table 49 In-situ water quality measurements 107
Table 50 Macrophyte species recorded in the study area 109
Table 51 Fish species caught at each survey site 110
Table 52 Relative abundance of the major taxonomic groups of macroinvertebrates collected from the March 2015 survey....111
Table 53 Univariate index summary for all survey sites....111
Table 54 AUSRIVAS scores for the macroinvertebrate survey 112
Table 55 Threatened flora recorded or that may occur at the airport site....115
Table 56 Assessment of Koala habitat in the airport site....125
Table 57 Threatened fauna recorded or that may occur at the airport site....126
Table 58 Estimated area of vegetation removal in the Stage 1 construction impact zone 137
Table 59 Estimated area of fauna habitat in the Stage 1 construction impact zone, environmental conservation zone and locality....139
Table 60 Estimated area of vegetation removal for longer term development 149
Table 61 Key Threatening Processes and Threat Abatement Plans of relevance to the proposed airport 164
Table 62 Threatened ecological communities listed under the EPBC Act within the Stage 1 area....170

Table 63 Threatened species listed under the EPBC Act with a moderate to high risk of impact in the Stage 1 area....171
Table 64 Threatened fauna species listed under the EPBC Act with a moderate to high risk of impact in the Stage 1 area....175
Table 65 Likely significance of impacts on plants....184
Table 66 Likely significance of impacts on animals....186
Table 67 Extent of impacts of Stage 1 on TECs listed under the TSC Act....189
Table 68 Extent of impacts of Stage 1 on threatened flora species and endangered populations listed under the TSC Act....191
Table 69 Extent of impacts of Stage 1 on threatened fauna species listed under the TSC Act....193
Table 70 Recommended mitigation measures....203
Table 71 Species credits required to offset impacts of the proposed airport....216
Table 72 Ecosystem credits required to offset impacts of the proposed airport....217
Table 73 Potential offset sites....219
Table 74 Threatened species recorded at the potential offset sites....220
Table 75 Proposed offset areas....222
Table 76 Species credits potentially available at offset sites....227
Table 77 Ecosystem credits for impacts on the natural environment....229

Figure index

Figure 1 Site location....8
Figure 2 Site layout....10
Figure 3 Survey effort....40
Figure 4 Vegetation....50
Figure 5 Threatened flora and ecological communities....116
Figure 6 Threatened fauna and habitat features....127
Figure 7 Regional vegetation and habitat....134

Appendices

Appendix A – Assessment of likelihood of occurrence of threatened and migratory species at the airport site
Appendix B – Survey guidelines and methodology
Appendix C – Field survey results
Appendix D – Assessments of significance for MNES

Glossary of terms

Term	Definition
Airport site	The land declared under the *Airports Act Regulation 1997* as the airport site for the proposed Western Sydney Airport.
BBAM	The NSW *BioBanking Assessment Methodology* (OEH, 2014)
Biodiversity credit	A unit of biodiversity value to measure specific development impacts or conservation gains in accordance with the FBA or the BBAM. Includes ecosystem credits or species credits.
Biodiversity values	The composition, structure and function of ecosystems, including native species, populations and ecological communities, and their habitats.
CEEC	Critically endangered ecological community
Construction impact zone (CIZ)	Includes the area of bulk earthworks in the northern half of the site (particularly for the establishment of the runway, terminal and aviation support facilities) together with areas of disturbance for ancillary infrastructure in the southern half of the site, including additional permissible activities prior to the construction of the second runway as well as minor activities during Stage 1 (e.g. drainage channels) (see Figure 2). The construction impact zone does not include the long term development such as the second runway or ancillary development outside the site boundary which will be subject to separate approvals. A full description is provided in Chapter 6 of the EIS.
Department of Infrastructure and Regional Development	The Commonwealth department responsible for proposing Stage 1 of the Western Sydney Airport.
DotE	The Commonwealth Department of the Environment
DPI	The NSW Department of Primary Industries
DSEWPaC	The former Department of Sustainability, Environment, Water, Population and Communities, now the Commonwealth Department of the Environment
EEC	Endangered ecological community
Ecosystem credit	The class of biodiversity credits created or required for the impact on EECs, CEECs and threatened species habitat for species that can be reliably predicted to occur within a vegetation type according to the BBAM.
Environmental conservation zone	The area at the airport site that would be provided as an environmental conservation zone, as outlined in the land use plan in the draft Airport Plan (see Chapter 4 of the EIS).
EPBC Act	The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FM Act	The NSW *Fisheries Management Act 1994*
Food tree	A tree species that is recognised as being of value as a foraging resource for a given fauna species.
Habitat tree	A tree that is recognised as being of value as a shelter, roosting and/or nesting resource for fauna species. Includes hollow-bearing trees, stags (standing dead trees) and trees with nests or other signs of fauna occupancy.
Longer term development	The longer term development potential of the airport includes dual runways and landside and airside facilities for approximately 82 million annual passenger movements. This patronage level may be reached around 2063.
Migratory species	Species that are listed as migratory under the EPBC Act.

Term	Definition
MNES	'Matters of national environmental significance' listed under the EPBC Act, including threatened biota, migratory species, World Heritage/National Heritage sites and Ramsar wetland sites.
NPW Act	The NSW *National Parks and Wildlife Act 1974*
NPWS	The NSW National Parks and Wildlife Service
NSW-listed biota	Threatened biota listed as threatened under the TSC Act and FM Act.
NW Act	The NSW *Noxious Weeds Act 1993*
OEH	The NSW Office of Environment and Heritage
PMST	Protected Matters Search Tool. A database administered by the Department of the Environment that contains known and predicted records of matters of national environmental significance listed under the EPBC Act.
Species credit	The class of biodiversity credits created or required for the impact on threatened species that cannot be reliably predicted to use an area of land based on habitat surrogates according to the BBAM.
Stage 1 development	Stage 1 of the airport would comprise one runway and cater for up to approximately 10 million annual passengers. This patronage level may be reached around 2030.
Stage 1 construction impact zone	The disturbance footprint for construction of the Stage 1 development, including the anticipated extent of vegetation clearing and grubbing, earthworks, drainage works and the permanent infrastructure that would be constructed for Stage 1 of the airport.
TEC	Threatened ecological community
The locality	Land within a 10 km radius of the airport site.
The Offset assessment guide	The spreadsheet offset calculator that accompanies the *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* (DSEWPaC, 2012).
The EPBC Act Offsets Policy	The *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* (DSEWPaC, 2012)
The region	A bioregion defined in a national system of bio-regionalisation. For this study this is the Sydney Basin Bioregion as defined in the Interim Biogeographic Regionalisation for Australia (Thackway and Cresswell, 1995).
Threatened biota	Threatened species, populations or communities listed under the EPBC Act and/or the TSC Act.
TSC Act	The NSW *Threatened Species Conservation Act 1995*
Western Sydney Airport (the airport)	The proposed airport that would be constructed on Commonwealth-owned land at Badgerys Creek, NSW. The proposed action that is the subject of this biodiversity assessment report.

1. Introduction

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies – including two previous environmental impact statements for a site at Badgerys Creek – having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The proposed airport would be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the proposed airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, a delegate of the Australian Government Minister for the Environment determined that the construction and operation of the proposed airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development (DIRD) is undertaking detailed planning and investigations for the proposed airport, including the development of a draft Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the proposed airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined

in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

If an Airport Plan is determined, it will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the proposed airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 EIS requirements

EIS assessment guidelines for the proposed airport were issued on 21 January 2015. Requirements of the assessment are presented in Table 1 along with a reference to where each matter is addressed in this report (where relevant to biodiversity). Some requirements are not relevant to this biodiversity report, and reference is made to where these are addressed elsewhere in the EIS.

Table 1 EIS requirements for biodiversity assessment

No.	EIS requirement	Where addressed in this report
4	**Description of the environment**	
	The EIS must include a description of the environment, land uses and character of the airport site and the surrounding areas that may be affected by the action. It is recommended that this include the following information:	A description of the existing environment is provided in Section 4. Further detail is provided in the EIS for the proposed airport.
	(a) Listed threatened species (including suitable habitat) and ecological communities that are or are likely to be present in all areas of potential impact. To satisfy this requirement details must be presented on the scope, timing/effort (survey season/s) and methodology for studies and surveys used to provide information on the relevant listed threatened species/ecological community/habitat (as identified in Attachment 3). This includes details of: • how best practice survey guidelines have been applied • how surveys are consistent with (or a justification for divergence from) published Australian Government guidelines and policy statements.	An assessment of the likelihood of occurrence of threatened and migratory biota is provided in Appendix A. Additional detail is provided in Section 4.4. A description of survey methodology, timing and effort is provided in Section 3.1. Details of specific survey requirements and how these have been applied or varied is provided in Appendix B.
	(b) A description of the World Heritage/National Heritage values of the Greater Blue Mountains Area World Heritage property/National Heritage Place, as described in the Statement of Outstanding Universal Value and including reference to the World Heritage criteria the area is listed for as well as the integrity of. the property.	See Sections 4.5.5 and 8.2.5.
	(c) A description of the environment in all areas of potential impact, including all components of the environment as defined in Section 528 of the EPBC Act: • ecosystems and their constituent parts, including people and communities • natural and physical resources • the qualities and characteristics of locations, places and areas • Heritage values of places • the social, economic and cultural aspects of a thing mentioned in preceding dot points.	A description of vegetation and habitat resources present in the proposed airport site is provided in Section 4. This includes a description of qualities and characteristics of these values. A description of the Greater Blue Mountains World Heritage Area is provided in Section 4.5.5. Social, economic and cultural aspects are addressed in relevant sections of the EIS.

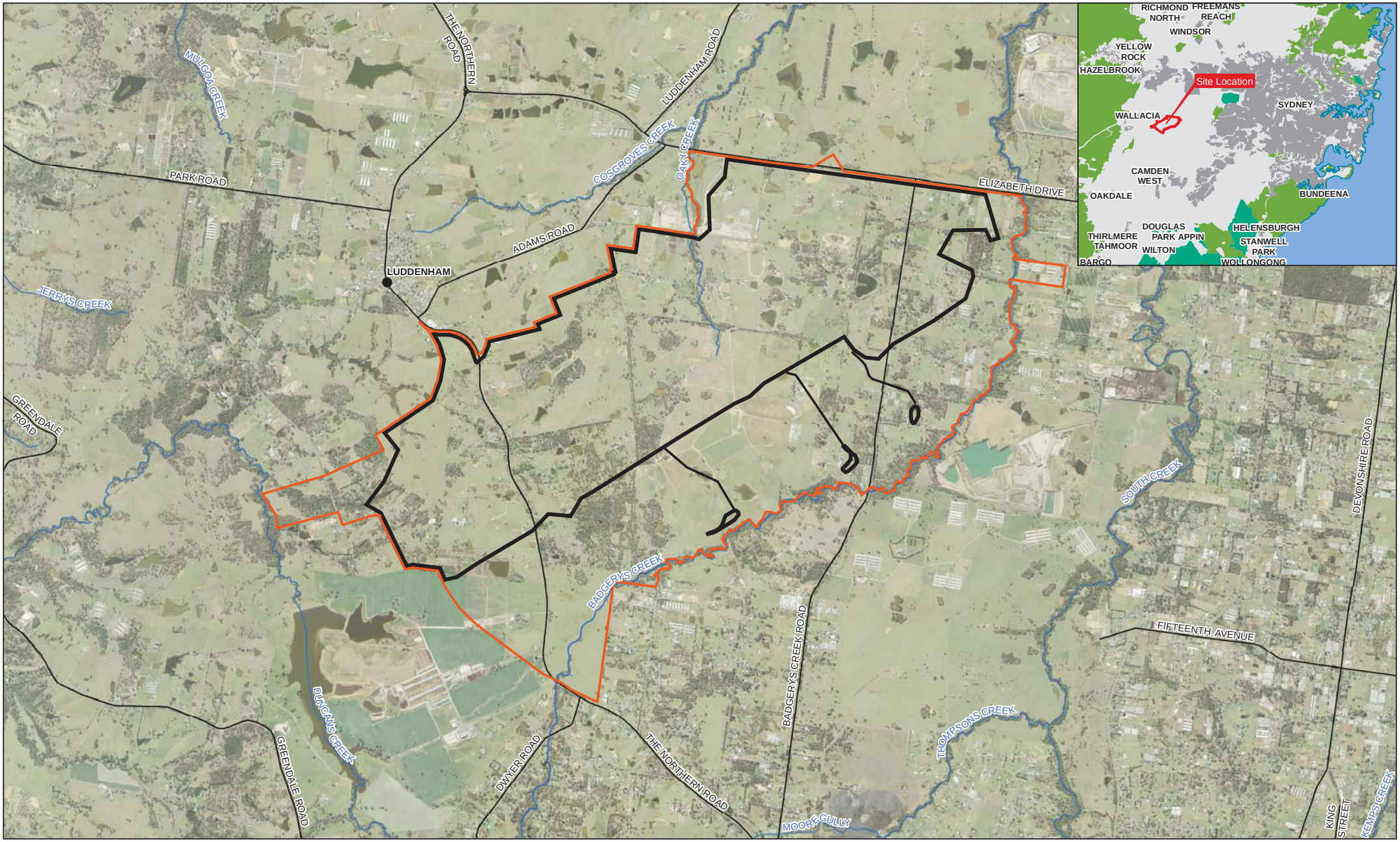
No.	EIS requirement	Where addressed in this report
5	**Relevant impacts**	
	(d) The EIS must include a description of all of the relevant impacts of the action. Relevant impacts are impacts that the action will have or is likely to have on a matter protected by a controlling provision (as listed in the preamble of this document). Impacts during both the construction, operational and (if relevant) the decommissioning phases of the project should be addressed, and the following information provided: • a detailed assessment of the nature and extent of the likely short-term and long-term relevant impacts (detailing direct and indirect impacts); • a statement whether any relevant impacts are likely to be unknown, unpredictable or irreversible; • analysis of the significance of the relevant impacts; and • any technical data and other information used or needed to make a detailed assessment of the relevant impacts.	A description of direct and indirect construction and operation impacts (short and long-term) is provided in Sections 5 and 6. A discussion of impacts on matters of national environmental significance (MNES) listed under the EPBC Act and other threatened biota is provided in Section 8.
	(e) The EIS should identify and address cumulative impacts, where potential project impacts are in addition to existing impacts of other activities (including known potential future expansions or developments by the proponent and other proponents in the region and vicinity). The EIS should address the potential cumulative impact of the proposal on ecosystem resilience. The cumulative effects of climate change impacts on the environment must also be considered in the assessment of ecosystem resilience. Where relevant to the potential impact, a risk assessment should be conducted and documented.	Potential cumulative impacts are assessed in Section 7. A discussion of ecosystem resilience is provided in Section 7.
	(f) The EIS should address the potential for facilitated impacts upon MNES at the local, regional, state, national and international scale.	Potential facilitated impacts are assessed in Section 7.
	(g) If the conclusion is made that any relevant controlling provision or element of a relevant controlling provision will not be impacted by the proposed action, then justification must be provided for how this conclusion has been reached. This includes any threatened species or ecological communities that are likely to be present on site, heritage items/places likely to be on site and other relevant elements of the environment that may be impacted by the proposed action.	Potential impacts on threatened biota and other controlling provisions are assessed in Section 8.3. Impacts on heritage items and places and other aspects of the environment are detailed in the EIS and relevant technical reports.
	(h) To support the assessment of local historic and indigenous heritage values, the EIS must include a full heritage impact assessment and the findings of the further program of archaeological survey that was foreshadowed in the referral for this project.	Not relevant to this report. Refer to the specialist reports included as Appendices to the EIS.
	(i) Further details of threatened species and ecological communities protected by the controlling provisions of Part 3 of the EPBC Act are provided at Attachment 3.	Details of threatened species indicated in Attachment 3 are discussed in Section 4.4. Impacts on MNES are discussed in Sections 5, 6 and 8.

No.	EIS requirement	Where addressed in this report
	(g) Impacts to the environment (as defined in section 528) should include but not be limited to the following: • changes to water quality on site and downstream of the site • changes to siltation • hydrological changes • removal and degradation of heritage items/places (historic, natural and indigenous) • native flora and fauna habitat removal and degradation (on site and in surrounding areas that may be affected by the action) • aircraft noise and vibration impacts on everyday activities and on sensitive environmental receptors (all sensitive receptors within the community and natural environment). Discussion and quantification/modelling of aircraft noise impacts should include consideration of all potential flight paths, height of flights, noise exposure patterns, noise contours, the range of frequencies of the noise, cumulative exposure, peak noise, frequency of overflights and temporal variability of this (including long term trends), varying aircraft types, varying aircraft operating procedures, and variations in noise patterns due to seasonal and meteorological factors • noise and vibration from construction activities and machinery • changes to air quality during construction and operation (including consideration of seasonal and meteorological variations that influence local air quality) • potential fuel jettisoning impacts • changes in traffic movements during construction and operation (associated with both passenger movements and workers) • bird or bat airstrike • lighting impacts on everyday activities and on sensitive environmental receptors (all sensitive receptors within the community and natural environment) • changes in recreational use and amenity of natural areas • change in qualities and characteristics of the surrounding areas and associated impacts to local communities (including land values and other economic impacts) • creation of any risks or hazards to people or property that may be associated with any component of the action.	A description of direct and indirect construction and operation impacts on biodiversity (short and long-term) is provided in Sections 5 and 6. A discussion of impacts on MNES and other threatened biota is provided in Section 8. Further detail on impacts of noise, vibration, air quality, water, hydrology, traffic, recreational use and amenity, economic impacts, and risks and hazards etc. are addressed in relevant sections of the EIS and associated technical reports.

No.	EIS requirement	Where addressed in this report
	Quantification and assessment of impacts should: • be against appropriate background/baseline levels • be prepared according to best practice guidelines and compared to best practice standards • consider seasonal and temporal variations where appropriate (including temporal changes in the sensitivity of the receptor) • be supported by maps, graphs and diagrams as appropriate to ensure information is readily understandable Guidelines and standards used to quantify baselines and impacts should be explained and justified.	The impact assessment provided in Sections 5 and 6: • is against a baseline description of the existing environment of the airport site informed by detailed desktop assessment and field survey. • was prepared in accordance with the 'Matters of National Environmental Significance Significant Impact Guidelines 1.1 and 1.2 (DotE 2013a, 2013b) and other specific survey and assessment guidelines for threatened biota (see Appendix B). • is supported by GIS maps of the biodiversity values at the airport site and quantitative calculations based on design drawings. Where appropriate impact calculations have been tabulated.
6	**Avoidance and mitigation measures**	
	(j) The EIS must provide information on proposed avoidance and mitigation measures to manage the relevant impact of the action on a matter protected by a controlling provision (as listed in the preamble of this document).	Avoidance and mitigation of impacts on biodiversity values is detailed in Section 0.
	(k) The EIS must take into account relevant agreements and plans that cover impacts or known threats to a matter protected by a controlling provision (including but not necessarily limited to): (a) any recovery plan and/or conservation advice for the affected species or ecological community (b) any threat abatement plan for a process that threatens an affected species or ecological community (c) any wildlife conservation plan for the affected species (d) any relevant strategic assessment undertaken in accordance with an agreement under Part 10 of the EPBC Act. (e) For the *Greater Blue Mountains Area World Heritage property,* the World Heritage Convention; the Australian World Heritage Management Principles; the *Greater Blue Mountains Area World Heritage Area Strategic Plan*, and relevant NSW National Parks and Wildlife Service/Office of Environment and Heritage Plans of Management.	This report has been prepared with reference to recovery plans, threat abatement plans, strategic plans and other relevant documents. A list of references is provided in section 11.

No.	EIS requirement	Where addressed in this report
	(l) The EIS must include specific and detailed descriptions of the proposed avoidance and mitigation measures based on best available practices. This must include the following elements : I. A consolidated list of mitigation measures proposed to be undertaken to prevent, minimise or compensate for the relevant impacts of the action, including: • a detailed description of proposed measures; • assessment of the expected or predicted effectiveness of the mitigation measures; • any statutory or policy basis for the mitigation measures; and • the likely cost of the mitigation measures. II. A detailed outline of a plan for the continuing management, mitigation and monitoring of relevant matters protected by a controlling provision, including a description of the outcomes that will be achieved and any provisions for independent environmental auditing. III. Where appropriate, each project phase (construction and operation) must be addressed separately. It must state the environmental outcomes, performance criteria, monitoring, reporting, corrective action, contingencies, responsibility and timing for each environmental issue. IV. The name of the agency responsible for endorsing or approving each mitigation measure or monitoring program.	Avoidance and mitigation of impacts on biodiversity values is detailed in Section 0. Further detail on avoidance and mitigation measures is provided in the EIS and other associated technical reports.
7	**Residual impacts and offsets**	
	<u>Residual impacts</u> a) The EIS must provide details of the likely residual impacts upon a matter protected by a controlling provision after the proposed avoidance and mitigation measures have been taken into account. This includes: 1. the reasons why avoidance or mitigation of impacts may not be reasonably achieved 2. quantification of the extent and scope of significant residual impacts.	An assessment of measures to avoid or mitigate impacts is included in Sections 9.1 and 9.2. Significant residual impacts are described in Section 9.3.2.
	<u>Offset Package</u> a) The EIS must include details of an offset package to be implemented to compensate for residual significant impacts associated with the project, as well as an analysis of how the offset meets the requirements of the Department's *Environment Protection and Biodiversity Conservation Act 1999* Environmental Offsets Policy October 2012 (EPBC Act Offset Policy). b) The offset package can comprise a combination of direct offsets and other compensatory measures, as long as it meets the requirements of the EPBC Act Offset Policy. Offsets should align with conservation priorities for the impacted protected matter and be tailored specifically to the attribute of the protected matter that is impacted in order to deliver a conservation gain. c) Offsets should compensate for an impact for the full duration of the impact.	A Biodiversity Offset Package for Western Sydney Airport has been prepared in accordance with the EPBC Act Offset Policy (GHD 2015a). An estimate of the quantum of biodiversity offsets required for affected threatened biota listed under the EPBC Act has been calculated in accordance with the offset assessment guide. An estimate of the quantum of biodiversity offsets required for impacts on the environment, including threatened biota listed under NSW legislation, has been calculated using the BioBanking assessment methodology for a

No.	EIS requirement	Where addressed in this report
	d) Offsets must directly contribute to the ongoing viability of the protected matter impacted by the project and deliver an overall conservation outcome that maintains or improves the viability of the protected matter, compared to what is likely to have occurred under the 'status quo' (i.e. if the action and associated offset had not taken place). e) Note: offsets do not make an unacceptable impact acceptable and do not reduce the likely impacts of a proposed action. Instead, offsets compensate for any residual significant impact. f) The EIS must provide: I. details of the offset package to compensate for significant residual impacts on a protected matter; and II. an analysis of how the offset package meets the requirements of the EPBC Act Offsets Policy. Further details of information requirements for EPBC Act offset proposals are provided at Attachment 4.	major project in NSW.
8	**Environmental record of person(s) proposing to take the action**	Refer to the EIS.
9	**Other approvals and conditions**	Refer to the EIS.
10	**Economic and social matters**	Refer to the EIS.
11	**Information sources provided in the EIS**	
	For information given in the EIS, the EIS must state: a) the source of the information b) how recent the information is c) how the reliability of the information was tested d) what uncertainties (if any) are in the information e) what guidelines, plans and/or policies have been considered during preparation of the EIS.	A list of reference material with year of publication is provided in Section 11. This includes relevant guidelines, plans and policies. Reliability of existing data at regarding flora biodiversity at the airport site was tested by conducting additional detailed surveys. Limitations of survey methods are discussed in Section 3.3.
12	**Conclusion**	
	An overall conclusion as to the environmental acceptability of the proposal on protected matters must be provided, which includes: a) a discussion on how consideration has been given to the objects of the EPBC Act, the principles of ecologically sustainable development, and the precautionary principle (as detailed at Attachment 1) b) justification for undertaking the proposal in the manner proposed, including the acceptability of the avoidance and mitigation measures c) if relevant, a discussion of residual impacts and any offsets and compensatory measures proposed or required for significant residual impacts on protected matters, and the relative degree of compensation and acceptability.	A conclusion with respect to biodiversity matters is provided in Section 10. A biodiversity offset package has been prepared in accordance with the EPBC Act Offset Policy (GHD 2015a). Consideration of the objects of the EPBC Act, the principles of ecologically sustainable development, the precautionary principle, and justification for the proposal is provided in the EIS.



Paper Size A3

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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

- Airport site
- Stage one construction impact zone
- Watercourses
- Roads

Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Assessment

Job Number	21-24265
Revision	A
Date	06 Oct 2015

Site location

Figure 1

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1.3 The proposal

1.3.1 Stage 1

Stage 1 of the proposed airport would include a 3,700 metre runway on an approximate north-east/south-west orientation. The Stage 1 development would also include a single full length parallel taxiway and a range of aviation support facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million domestic and international passengers per year which is consistent with approximately 63,000 air traffic movements per year. The proposed airport is proposed to operate on a 24-hour, curfew free basis.

The Stage 1 development area will be concentrated in the northern portion of the site, although some parts of the southern portion are also included in Stage 1. The existing terrain at the airport site is undulating and substantial earthworks are required to create a level surface to allow construction of the runway, taxiways and support services. The Stage 1 construction impact zone is predominantly located within the northern portion of the site following the alignment of the proposed runway. There will also be limited earthworks in the southern portion of the site during Stage 1 for the establishment of drainage swales and detention ponds as part of the water management system developed for the airport site. The airport site layout, including the approximate locations of airport infrastructure and the Stage 1 earthworks footprint are shown on Figure 2.

The southern portion of the airport site would predominantly remain uncleared during the initial stage of airport development. This area is designated for future aviation use, business development or environment protection in accordance with the draft Airport Plan.

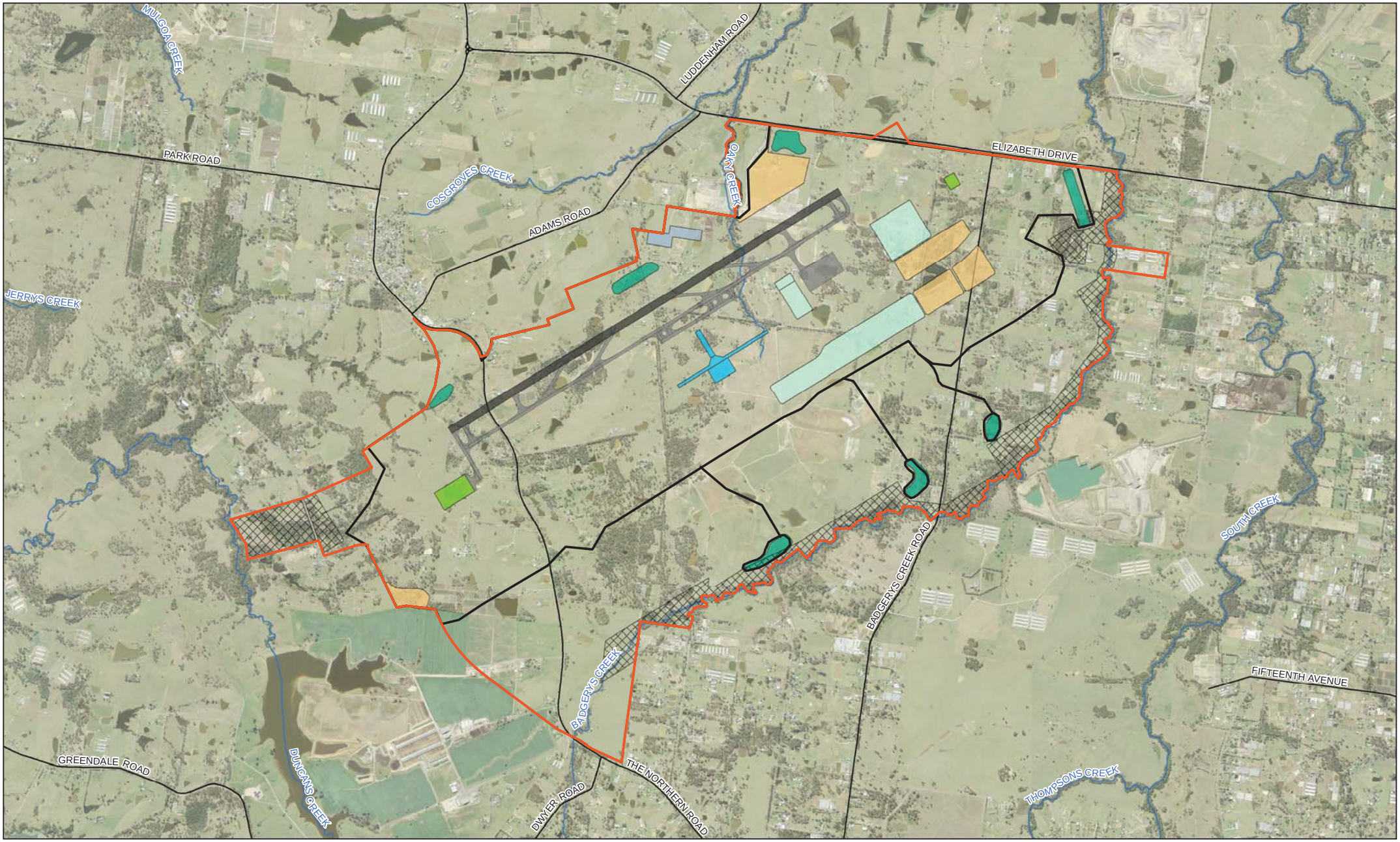
Portions of the airport site would be likely to remain undeveloped in the longer term to conserve riparian corridors and other features of higher environmental value. These areas have been included in the proposed ‘Environmental conservation zone’ in the draft Airport Plan and would be managed for biodiversity conservation (see Figure 2).

1.3.2 Longer term development

The proposed airport would be progressively developed as demand increases beyond 10 million annual passengers. Additional aviation infrastructure and support services such as taxiways, aprons, terminals and support facilities would be required to service the growing demand.

The need for a second runway is expected to be triggered when the operational capacity approaches 37 million annual passengers which is equivalent to approximately 164,000 air traffic movements per year. This is forecast to occur by around 2050. The second runway is expected to be located in the southern portion of the airport site, parallel to the first runway with a centre line separation distance of approximately 1,900 metres.

The long term capacity of the proposed airport is forecast to service approximately 82 million annual passengers which is equivalent to approximately 370,000 air traffic movements per year. The final layout of the indicative longer term development of the proposed airport would be confirmed as part of the development of future airport master plans and would be subject to further approval and regulation under the *Airports Act 1996*.



Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Business development
- Detention ponds
- Fuel farm
- Maintenance areas
- Runway
- Taxi area
- Terminal building
- Terminal support

Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Assessment

Job Number	21-24265
Revision	A
Date	06 Oct 2015

Site layout

Figure 2

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1.4 Purpose of this report

This assessment has been undertaken in accordance with the EIS guidelines issued by the Minister for the Environment under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and specifically considers matters relevant to biodiversity. The purpose of this report is to describe the native biota and habitats at the airport site and to assess the potential impacts of the construction and operation of the proposed airport on biodiversity values.

The scope of this biodiversity assessment is to:

- complete a desktop assessment, field survey, research and consultation to describe the biodiversity values of the airport site, including native vegetation types, flora and fauna species and their habitats;
- assess the value and conservation significance of native vegetation and habitats at the airport site and the potential for threatened or migratory biota listed under the EPBC Act and threatened biota listed under the NSW *Threatened Species Conservation* Act 1995 (TSC Act) to occur at the site and/or to be affected by the proposed airport;
- describe the proposed construction and operation of the proposed airport and identify potential impacts on biodiversity values, especially matters of national environmental significance (MNES);
- identify measures to avoid or mitigate impacts on biodiversity values;
- complete impact assessments pursuant to:
  - the *Matters of National Environmental Significance Significant Impact Guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999* (DotE 2013a) for impacts on threatened biota and other MNES;
  - the *Significant Impact Guidelines 1.2 - Actions on, or impacting upon, Commonwealth land and Actions by Commonwealth Agencies* (DotE 2013b) for impacts on the natural environment; and
- identify appropriate biodiversity offsets to compensate for residual significant impacts on protected matters arising from the proposed airport in accordance with the *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* (DSEWPaC 2012) including:
  - offsets for residual significant impacts on threatened biota listed under the EPBC Act calculated using the offset assessment guide; and
  - offsets for residual significant impacts on the environment calculated with the BioBanking assessment methodology for a major project.

1.5 Assumptions

This report is based on the following general assumptions:

- no vegetation clearing or other direct impacts would occur outside the airport site to meet the requirements of the proposed airport's Obstacle Limitation Surface (OLS) or for other significant infrastructure;
- the environmental conservation zones shown on Figure 2 would be managed as open space. Native vegetation would be retained and would be available as refuge habitat for displaced fauna and translocated snails, frogs, habitat resources etc. as required;

- assessments of significance have been prepared in accordance with the *'Matters of National Environmental Significance Significant Impact Guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999'* (DotE 2013a) for impacts on threatened biota and other MNES and the '*Significant Impact Guidelines 1.2 - Actions on, or impacting upon, Commonwealth land and Actions by Commonwealth Agencies'* (DotE 2013b) for impacts on flora and fauna. Impacts on other aspects of the environment are discussed in the EIS and relevant technical reports;
- the biodiversity offset package is for Stage 1 only and includes the preferred approach to offsetting along with the specific detail that was available at the time of publication;
- offsets on threatened biota listed under the EPBC Act have been calculated with reference to the EPBC Act Offset Policy; and
- the suite of biodiversity credits that would be presented to offset impacts on threatened biota listed under the EPBC Act and TSC Act have been calculated using BioBanking.

2. Legislative context

2.1 EPBC Act

2.1.1 Project background

The Australian Government announced on 15 April 2014 that Commonwealth-owned land at Badgerys Creek will be the site of a new airport for the proposed Western Sydney Airport (proposed airport). A brief survey of the site was carried out by SMEC in September 2014 and a biodiversity report was prepared which identified the biodiversity values present at the airport site and made recommendations for further surveys and assessment (SMEC 2014). A referral for the proposed airport proposal was submitted to the Australian Government Minister for the Environment under the EPBC Act in November 2014 (DIRD 2014), the SMEC (2014) report was included as an attachment to the referral. Based on the referral and attached information, the delegate of the Minister determined on 23 December 2014 that assessment is required as the action is a "controlled action", as it is likely to have a significant impact on the following matters of national environmental significance (MNES) and other matters that are protected under Part 3 of the EPBC Act:

- Listed threatened species and ecological communities (section 18 & section 18A)
- The heritage values of a National Heritage place (section 15B & section 15C)
- The world heritage values of a declared World Heritage property (section 12 & section 15A); and
- The environment because the proposal is a Commonwealth action (section 28).

Guidelines for the content of an environmental impact statement (EIS) for the proposed airport were issued in January 2015. An EIS has been prepared and this biodiversity impact assessment has been prepared to support the EIS and address the EIS requirements (refer to Table 1).

2.1.2 Objects of the EPBC Act

The objects of the EPBC Act include to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance (MNES) and to promote the conservation of biodiversity. Under the EPBC Act, an action includes a proposal, undertaking or activity.

The EPBC Act identifies MNES as:

- world heritage properties;
- national heritage places;
- wetlands of international importance (Ramsar wetlands);
- threatened species and ecological communities;
- migratory species;
- Commonwealth marine areas;
- Great Barrier Reef Marine Park;
- nuclear actions (including uranium mining); and
- a water resource, in relation to coal seam gas development and large coal mining development.

The EPBC Act also is concerned with actions that have a significant impact on the environment where the actions affect, or are taken on, Commonwealth land, or are carried out by a Commonwealth agency.

The EPBC Act has been addressed in this assessment through:

- desktop review to determine the threatened or migratory species or threatened ecological communities that have been previously recorded within the locality and hence could occur at the airport site, subject to the habitats present;
- desktop assessment and field surveys to describe the environment of the airport site, including biodiversity values and threatened biota listed under the Act or under NSW legislation (see below);
- targeted field surveys for threatened ecological communities and threatened and migratory species; and
- assessment of potential impacts on the environment and on specific MNES that could arise from the construction and operation of the proposed airport and measures to avoid or mitigate potential impacts.

2.2 New South Wales Legislation

The airport site is Commonwealth land. Consequently, the airport proposal does not require environmental assessment or approvals under various NSW environmental planning and assessment legislation. However, the EPBC Act requires protection of the environment from actions by the Commonwealth, and it is therefore appropriate to consider threatened biota that are listed under NSW legislation and other aspects of the airport site's biodiversity as part of this assessment.

The New South Wales (NSW) TSC Act and *Fisheries Management Act 1994* (FM Act) provide for the listing of threatened biota that are at risk of becoming extinct or endangered in NSW. The TSC Act also provides for the assessment of impacts on biodiversity values, the offsetting of impacts and the conservation of offset sites through BioBanking (see below).

2.2.1 Threatened Species Conservation Act 1995

The TSC Act provides legal status for biota of conservation significance in NSW. The TSC Act aims to, inter alia, 'conserve biological diversity and promote ecologically sustainable development'. The TSC Act contains schedules that list endangered, critically endangered and vulnerable species, populations, ecological communities, and key threatening processes in NSW.

Threatened biota listed under the TSC Act has been considered in this assessment through:

- desktop assessment and field survey to identify threatened biota that may be present at the airport site or affected by the proposed airport; and
- consideration of impacts on threatened biota and measures to avoid or mitigate potential impacts.

Part 7A of the TSC Act establishes the NSW Biodiversity Banking and Offsets Scheme (BioBanking), which was enabled by the *Threatened Species Conservation Amendment (Biodiversity Banking) Act 2006*. BioBanking includes a methodology for assessing biodiversity values, establishing rules for calculating biodiversity offsets and provides a framework for managing biodiversity offset sites.

The offset package for the proposed airport has been prepared with reference to the BioBanking methodology. Accordingly, this Biodiversity Assessment has also been prepared

with reference to the BioBanking methodology and operational manual (DECC 2009a), including description and sampling of plant community types in accordance with the methodology (see Section 3.2.2).

2.2.2 Fisheries Management Act 1994

The objects of the FM Act are to conserve, develop and share the fishery resources of the State for the benefit of present and future generations. It contains schedules that list endangered, critically endangered and vulnerable aquatic species, populations and ecological communities, key threatening processes in NSW, and noxious fish and marine vegetation.

One of the objectives of the FM Act is to 'conserve key fish habitats ' which includes aquatic habitats that are important to the maintenance of fish populations generally and the survival and recovery of threatened aquatic species.

The FM Act also includes provisions to ensure the maintenance and restoration of fish passage as part of the construction of new, or the modification of existing, in-stream structures.

Threatened biota listed under the FM Act has been considered in this assessment through:

- desktop assessment and field survey to identify threatened biota that may be present at the airport site or affected by the proposed airport;
- assessment of aquatic habitats, including key fish habitat, during field surveys;
- assessment of the potential for impacts on key fish habitat and threatened species, populations and ecological communities listed under the FM Act; and
- identification of suitable impact mitigation and environmental management measures to avoid or mitigate impacts on the aquatic environment.

2.2.3 Noxious Weeds Act 1993

The Noxious Weeds Act (NW Act) provides for the declaration of noxious weeds by the NSW Minister for Primary Industries. Under the NW Act, weeds may be considered noxious on a National, State, Regional or Local scale. The NW Act defines five classes of noxious weeds (Section 8 of the NW Act) and outlines particular controls applicable to each class. If present, noxious weeds should be assessed and controlled in order to help avoid economic or environmental impacts.

There are at least 12 noxious weed species present at the airport site (see Section 4.2.3). Mitigation measures are recommended in section 9.2 to minimise the impact and spread of weeds.

3. Methodology

3.1 Literature and desktop assessment

3.1.1 Literature review

A literature review was undertaken to identify MNES listed under the EPBC Act and threatened flora and fauna species, populations and ecological communities (biota) listed under the TSC Act and FM Act that have previously been identified at the airport site. The literature review assisted with identifying gaps in field surveys conducted previously, and with focusing field survey techniques and effort. Biodiversity resources pertaining to the airport site and locality (i.e. within a 10 km radius of the airport site) that were reviewed prior to conducting field investigations included:

- the previous EIS and specialist reports prepared for a proposed airport at Badgerys Creek between 1996 and 1999;
- the *Environmental field survey of Commonwealth land at Badgerys Creek Report* (SMEC 2014) and associated specialist reports;
- *Western Sydney Airport referral of proposal action (*DIRD 2014*);*
- *Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands* (Tozer et al. 2010);
- *Native Vegetation of the Cumberland Plain, Western Sydney* (NPWS 2006);
- aerial photographs and satellite imagery of the study area; and
- management plans, ecological assessments and research papers relating to the biodiversity values at the airport site and especially the threatened biota that is known or likely to occur in the locality.

Recent baseline surveys were carried out by SMEC at the airport site over three days in September 2014. The results of these surveys were documented in a biodiversity report (SMEC 2014) that was used to inform the EPBC Act referral for the proposed airport. Prior to these surveys, a number of flora and fauna surveys were conducted by Biosis Research for the 1999 EIS. Surveys for the 1999 EIS were conducted in December 1996, January 1997 (aquatic), September 1998 and January 1999. The results of these biodiversity assessments have been reviewed, checked against current site conditions and incorporated in this report where appropriate.

3.1.2 Database review

A database review was undertaken to identify threatened species and ecological communities listed under the EPBC Act that may be affected by the proposed airport, as well as threatened species, populations and communities listed under the TSC Act and FM Act. Database records pertaining to the airport site and locality since 1980 were reviewed prior to field investigations and included:

- the Commonwealth Department of the Environment (DotE) Protected Matters Search Tool (PMST) for all MNES that are known or are predicted to occur within a 10 km radius of the airport site (DotE 2015a) (database queried on 2 February 2015);
- DotE online species profiles and threats database (DotE 2015b);

- Office of Environment and Heritage (OEH) Wildlife Atlas database (licensed) for records of threatened species, populations and endangered ecological communities listed under the TSC Act that have been recorded within the locality (OEH 2015a), data supplied by OEH on 2 February 2015;
- OEH threatened biota profiles for descriptions of the distribution, habitat requirements and flowering season (where relevant) of threatened biota (OEH 2015b). This resource was used to identify the suite of threatened biota that could potentially be affected by the airport and to inform habitat assessments;
- the NSW VIS Classification 2.1- Community Identification (OEH 2015c) and NSW vegetation types database (OEH 2014) to identify matching plant community types (PCTs) at the airport site;
- mapping and descriptions of the NSW Mitchell landscapes (DECC 2008a, 2008b);
- Birdlife Australia Atlas Data for records of birds observed within a 3 km radius of the airport site (Birdlife Australia 2015), data supplied by Birdlife Australia on 8 May 2015;
- Birdline NSW (2015). Birdline NSW is a site for the reporting of rare or unusual birds outside their normal range, unusually high or low numbers, early or late arrivals or departures for migrant species and interesting behaviour or unusual habitat usage. This resource was checked to determine the arrival date and movements of Swift Parrots in NSW; and
- the DPI online protected species viewer for records of threatened aquatic species listed under the EPBC Act that have been recorded within the locality (DPI 2015a) (database queried on 2 February 2015).

Following collation of database records and species and community profiles, a 'likelihood of occurrence' assessment was prepared with reference to the broad habitats at the airport site. This was further refined following field surveys and assessment of habitat present (see section 4). The results of this assessment are presented in Appendix A.

3.2 Field surveys: Terrestrial Biodiversity

3.2.1 Overview

Staged surveys of the airport site were conducted between February and June 2015. Surveys were conducted by a team of suitably qualified ecologists and built on previous surveys carried out by SMEC (2014) and those undertaken by Biosis Research (1999) for the previous EIS.

Vegetation survey and assessment for both EPBC Act and TSC Act protected matters was carried out in accordance with the BioBanking Assessment Methodology (BBAM) (DECC 2009a) in order to assess vegetation type and condition and to calculate the quantum of offsets required for the proposed airport.

Survey methods and effort were also designed with reference to various threatened species survey guidelines. These included the Commonwealth survey guidelines for nationally threatened frogs (DEWHA 2010a) and birds (DEWHA 2010b), the survey guidelines for threatened species listed under the TSC Act (DEC 2004a), species-specific survey methods detailed by the NSW National Parks and Wildlife Service (NPWS 2000, 2002, 2003), survey methods detailed in recovery plans (e.g. for the Grey-headed Flying-fox - DECCW 2009) and referral guidelines (e.g. for the Koala - DotE 2014).

Survey methodology is discussed in section 3.2.2 and 3.2.3, survey effort, site stratification and timing is discussed in section 3.3, and an assessment of survey methods and effort against guidelines is provided in Appendix B. Limitations of surveys are discussed in section 3.4.3.

3.2.2 Flora survey

Flora surveys included vegetation mapping and targeted threatened flora searches. Vegetation within the airport site was surveyed with reference to the BBAM and appropriate threatened species survey guidelines (DEC 2004a)).

The flora survey involved the following techniques:

- Vegetation surveys and mapping;
- Plot-transect surveys;
- Wetland surveys; and
- Targeted threatened flora surveys.

Survey sites were selected using air photo interpretation and field habitat assessment. The locations of plot-transect surveys completed during the flora survey are displayed in Figure 4. A summary of survey effort is provided in Table 10 (Section 3.4.1) and the breakdown of survey effort between mapped vegetation zones is provided in (Section 4.2.2). A detailed description of the methodology is provided below.

Vegetation surveys and mapping

A high level vegetation assessment and map were prepared by SMEC (2014) based on the regional mapping included in *Native Vegetation of the Cumberland Plain, Western Sydney* (NPWS 2006). This vegetation mapping was ground-truthed in the field via driven and walked transects across the entire airport site and by walking the boundary of vegetation units where possible. Necessary adjustments were made with reference to a GPS tablet in the field. The site was divided into vegetation zones which represented a distinct vegetation type and broad condition class according to the BBAM. This approach ensured that the classification of vegetation was consistent with the methodology for BioBanking assessments and major projects in NSW.

Vegetation types were classified according to vegetation structure, species composition, soil type and landscape position. Plot/transect data was compared with Tozer *et al* (2010) diagnostic species lists for equivalent vegetation map units to help confirm the identity of matching vegetation types (OEH 2014). This approach is endorsed by the NSW OEH for confirming the identity of floristically similar vegetation types and is particularly relevant for identifying vegetation that may comprise a particular threatened ecological community (TEC) (Steenbeeke, G, OEH, pers. comm.).

Terrestrial vegetation types were further split into broad condition classes with reference to the BBAM to yield vegetation zones as follows:

- ‘High condition’, comprising Moderate/good - high or Moderate/good – medium condition vegetation which featured over storey and mid storey vegetation at benchmark levels for the equivalent vegetation type (i.e. woodland or forest structure);
- ‘Poor condition’, comprising Moderate/good – poor condition vegetation which featured over storey and mid storey vegetation cover substantially below benchmark levels for the equivalent vegetation type but greater than 50% of the groundcover present was native species (i.e. derived native grassland, shrubland or scrub structure);
- exotic grassland, comprising Low or Cleared condition vegetation which was dominated by perennial plant species and featured over storey and mid storey vegetation cover substantially below benchmark levels for the expected native vegetation type and less than 50% of the groundcover present was native species (i.e. exotic grassland, shrubland or scrub structure); and

- cleared land and cropland, comprising Low or Cleared condition vegetation which was dominated by annual plant species, bare earth or infrastructure and featured over storey and mid storey vegetation cover substantially below benchmark levels for the expected native vegetation type and less than 50% of the groundcover present was native species or greater than 90% of the ground surface was bare earth or infrastructure.

Wetlands were mapped as a native vegetation zone if they featured greater than 10% cover of native plant species and/or habitat features such as standing dead trees, shallow marginal water or mudflats. Waterbodies that were free of native plants or habitat features such as steep sided clay lined dams, concrete lined dams or flooded quarry pits were included in the mapped area of 'Cleared land and cropland'. Some smaller wetlands were also included in the mapped area of woodland, forest or grassland if they could not be accurately separated and defined on an aerial photo.

Plot/transect surveys

Plot/transect surveys were conducted on site in accordance with the BBAM to confirm vegetation types and assess site condition. The site value was determined by assessing ten biometric habitat attributes against benchmark values. Benchmarks are quantitative measures of the range of variability in condition in vegetation with relatively little evidence of alteration, disturbance or modification by humans since European settlement. Cover abundance data was also collected for each species within the 20 metre x 20 metre portion of each plot/transect.

Plots were used to sample potential vegetation zones (i.e. vegetation types and broad condition classes) based on the initial site stratification. Forty-three plots were sampled within the airport site as shown on Figure 3.

Species richness and biometric plot/transect data was recorded on pro forma data sheets along with a description of the landscape position, soil type, geology and disturbance history for each vegetation zone.

Wetland surveys

Wetlands were not sampled using plot/transects because of the inherent safety risk. Wetland vegetation was sampled by walking the margins of waterbodies and noting dominant plant species and percentage cover in each vegetation strata present (i.e. trees, shrubs, emergent, aquatic and fringing plants). Wetlands were defined based on observed vegetation structure, species composition and whether they were natural or artificial as inferred from geomorphic positon and presence of features such as dam walls. No natural freshwater wetlands were observed at the airport site. Artificial wetlands were matched to the closest equivalent native vegetation type.

These data were recorded on pro forma data sheets along with a description of the landscape position, soil type, geology, habitat resources present and disturbance history for each wetland sampled.

Targeted threatened flora surveys

Threatened plant surveys were conducted throughout the airport site during all time spent on site. The suite of threatened plants potentially present was identified based on the desktop assessment results (see Appendix A). Habitat for these species was identified based on OEH threatened species profiles and the experience and judgement of GHD ecologists. Much of the airport site contains highly modified landforms that are dominated by exotic species. These areas feature very little native plant cover, do not contain natural soil profiles or soil seed banks and could be readily discounted as containing any threatened plant species. Areas of potential

threatened plant habitat (i.e. near-intact native vegetation and areas with natural topsoil) were systematically traversed on foot and inspected for threatened plants.

3.2.3 Fauna survey

Fauna surveys conducted at the airport site included detailed habitat assessments and targeted fauna searches. Survey locations are shown on Figure 3.

Surveys included:

- four days and four nights of targeted frog surveys in March 2015;
- eleven days and six nights of targeted fauna surveys (diurnal and nocturnal) in March-May 2015; and
- two days of targeted winter bird surveys in May-June 2015.

Fauna surveys focussed on identifying threatened and migratory fauna species likely to be impacted by the proposed airport, and providing a quantitative assessment of habitat features that would be removed. Surveys were designed with reference to various survey guidelines (see section 3.2.1). Targeted surveys included diurnal bird surveys, searches for the Cumberland Plain Land Snail (*Meridolum corneovirens*), spotlighting, call playback, infra-red camera surveys and Anabat surveys. Opportunistic observations were also recorded throughout the surveys.

Fauna habitat assessment

Habitat assessments were conducted to help describe the suite of native fauna likely to occur at the airport site. Particular attention was paid to habitat features and resources considered important for threatened species.

Habitat assessments included identification and assessment of:

- vegetation patch size, connectivity, age, disturbance and floristic and structural diversity (important for determining habitat suitability for many threatened birds and mammals);
- quality of substrate to provide foraging habitat and shelter for Cumberland Plain Land Snails, frogs, reptiles and ground-foraging birds, including rocks, logs, peeling bark, leaf litter and native grassland;
- presence of winter-flowering eucalypts (important for the Swift Parrot (*Lathamus discolor*) and Grey-headed Flying-fox (*Pteropus poliocephalus*) and food trees of the Koala (*Phascolarctos cinereus*) and Glossy Black-cockatoo (*Calyptorhynchus lathami*);
- hollow-bearing trees and logs which provide refuge, nest and den sites for a range of threatened fauna species;
- stags and other roost sites for raptors and owls; and
- wetlands, water courses and moist grassland and other foraging or breeding habitat for waterbirds (including migratory birds), frogs, reptiles and mammals.

Evidence of animal presence was noted during all time spent on site, including specific searches for:

- mammal scats at the base of trees or along tracks and runways;
- tracks in soft substrate;
- nest/den sites within logs, tree bases or tree trunks;
- guano or moth remains at the base of hollow-bearing trees (diagnostic of the presence of tree-roosting bats);

- scratches on tree trunks (potential evidence of Koalas, gliders or goannas) and worn bark around tree hollows (diagnostic of active use of hollows); and
- owl pellets, whitewash or animal remains beneath trees (diagnostic of owl or raptor roosts).

Locations of important habitat features were captured with a handheld global positioning system (GPS) unit or a tablet.

Mapping of hollow-bearing trees was undertaken to provide an indication of the distribution and number of hollow-bearing trees as well as sizes of hollows that would be removed for the proposed airport. Given the large area of the airport site and access constraints at the time of surveys, detailed mapping was not undertaken throughout the entire site. Data collected included tree species, height, diameter at breast height, and number, size and location of hollows.

Bird surveys

Bird surveys comprised the following methods:

- Diurnal bird surveys
  - Diurnal bird surveys were performed in the early morning within the airport site on ten mornings in March and April 2015. Surveys were conducted in two locations by either one or two ecologists each morning. A total of 13 sites were surveyed in early morning surveys. Most sites were visited once only, however a number of sites were surveyed on two occasions. Surveys comprised area searches of at least one hour duration targeting larger woodland patches and wetland areas. Grassland areas were also surveyed while moving between woodland patches or dams. Species were identified by sight and call. Incidental observations of all birds were also recorded throughout the day during general surveys.
  - Area searches were carried out in many woodland patches in the mornings and afternoons of 21 May and 9 June 2015 targeting the Swift Parrot (*Lathamus discolor*) and Gang-gang Cockatoo (*Callocephalon fimbriatum*), with other birds also noted. The Swift Parrot occurs in western Sydney in winter months, foraging on winter-flowing eucalypts and lerps. Surveys were conducted with regard to the survey guidelines for the Swift Parrot included in DEWHA (2010b) and the bird survey guidelines contained in DEC (2004a). In addition, opportunistic surveys were carried out from 5 to 8 May 2015 for these species. Information on timing of the arrival of Swift Parrots in NSW was gained from Birdline NSW (2015). The first record of the species in NSW via this resource was on 28 April 2015 near Corowa. Sightings of the species in western Sydney were reported on various occasions from 14 May 2015 (Birdline NSW 2015).
- Wetland bird surveys
  - Dams were targeted during early morning bird surveys as well as general fauna surveys throughout the day. Surveys included scanning the water body, muddy edges and emergent vegetation with binoculars.
- Driven transects
  - Slow driven transects were conducted on 21 May and 9 June 2015 to target Swift Parrots and Gang-gang Cockatoos, with other birds also noted. This method combined with targeted area searches ensured as much of the airport site was covered as possible over these dates when these species were likely to be in the locality.

Microchiropteran bat surveys

Microbat ultrasonic echolocation call recordings (Anabat surveys) were undertaken using two Anabat units over ten nights and one unit on one additional night (totalling 21 Anabat unit nights). Of these, seven nights (14 Anabat unit nights) were in March (within the preferred survey season for Anabat surveys) and the remainder were in April and May. Anabats were placed at a total of twelve locations in the airport site. In most locations, Anabat units were left for two nights. In some instances, access or timing constraints meant that Anabat units were left at a location for only one night. Fixed recordings were undertaken from dusk until the following morning. Locations of survey sites are provided on Figure 3. A total of 206.5 hours from 19 nights of recording (all sites combined) was completed.

Calls were identified using zero-crossing analysis and AnalookW software (version 4.1t, Chris Corben 2015) by visually comparing the time-frequency graph and call characteristics (e.g. characteristic frequency and call shape) with reference calls and/or species call descriptions from published guidelines. *The Bat calls of NSW: Region based guide to the echolocation calls of microchiropteran bats* (Pennay et al. 2004) was used to assist call analysis. Call identification was also assisted by consulting distribution information for possible species (Pennay et al 2011; Churchill 2008; van Dyck and Strahan 2008) and records from the Atlas of NSW Wildlife (OEH 2015a). No reference calls were collected during the survey.

A call (pass) was defined as a sequence of four or more consecutive pulses of similar frequency. Calls with less than four defined pulses were excluded from the analysis. Due to variability in the quality of calls and the difficulty in distinguishing some species, the identification of each call was assigned a confidence rating (see Mills et al. 1996 and Duffy et al. 2000) as summarised in Table 2. Due to the absence of reference calls from the airport site, high level of variability within a bat call and overlap in call characteristics between some species, a conservative approach was taken when analysing calls.

Table 2 Confidence ratings applied to bat calls

Species Identification	Description
D - Definite	Species identification not in doubt.
P - Probable	Call most likely to represent a particular species, but there exists a low probability of confusion with species of similar call type or call lacks sufficient detail.
Po – Possible (Species Group)	Call made by one of two or more species. Call characteristics overlap making it too difficult to distinguish between species e.g. *Chalinolobus gouldii / Mormopterus* spp. *Nyctophilus* spp. The calls of *Nyctophilus geoffroyi* and *N. gouldi* cannot be distinguished during the analysis process and are therefore lumped together. *Scotorepens orion/Scoteanax rueppellii/Falsistrellus tasmaniensis.*

Targeted frog surveys

Targeted surveys for the Green and Golden Bell Frog (*Litoria aurea)* were conducted over four nights in March. Surveys were carried out with regard to the significant impact guidelines for this species (DEWHA 2009a) and the Commonwealth survey guidelines for threatened frogs (DEWHA 2010a). The referral guidelines recommend an initial habitat assessment followed by at least four nights of surveys between September and March, during warm and windless weather conditions following rainfall. Surveys of about an hour are recommended for wetlands up to 50 metres in width. Where possible, surveys should include use of a nearby reference site (DEWHA 2009a). The survey guidelines for threatened frogs further recommend surveys be under taken within one week of heavy rainfall (i.e. greater than 50 mm in seven days) between October and February.

The Green and Golden Bell Frog population at Homebush was used as a reference population for the survey. This site was visited once each week prior to and during the survey at the airport site to determine the level of frog activity and confirm that conditions were likely to be suitable for the detection of the targeted species if present. Surveys at the airport site were conducted in early March, in warm and windless conditions. Surveys were not possible in February (when there were many days of heavy rain) due to property access constraints. Heavy rain fell on the afternoon of survey night 2, and for some survey dates, rainfall of about 28 mm was recorded over the previous week (see Table 3). Other frog species were calling and were active during surveys at the airport site, suggesting that if Green and Golden Bell Frogs were present, they would also be active. Green and Golden Bell Frogs were active (but not calling) at the reference site at these times.

A summary of weather conditions and observed frog activity during surveys is provided in Table 3.

Table 3 Weather conditions during targeted frog surveys

Survey	Date	Temperature		Rainfall in preceding 24 hours (mm)	Rainfall in preceding 7 days (mm)	Conditions during survey	Frog activity during survey
		(min.)	(max.)				
Reference site night 1	6/3/15	13.4	30.7	0.0	20.4	Warm and windless	Frogs calling and active
Airport site survey night 1	11/3/15	17.8	30.6	0.0	0.0	Warm and windless	Frogs calling and active
Reference site night 2	*11/3/15*	*20.1*	*30.1*	*0.0*	*0.0*	*Warm and windless*	*Green and Golden Bell Frogs active.*
Airport site survey night 2	12/3/15	17.4	28.4	28.6	28.6	Warm and windless	Frogs calling and active
Airport site survey night 3	18/3/15	15.2	30.3	0.0	28.6	Warm and windless	Frogs calling and active
Reference site night 3	*18/3/15*	*17.3*	*30.3*	*0.0*	*14.6*	*Warm and windless*	*Green and Golden Bell Frogs active.*
Airport site survey night 4	19/3/15	15.0	32.0	0.0	0.0	Warm and windless	Frogs calling and active

Note: Airport site weather data from Badgerys Creek weather station (067108) and reference site weather data from the Sydney Olympic Park weather station (66212) (BOM 2015a).

Frog surveys targeted farm dams, creeks and other water bodies which were identified during the initial one-day site inspection, by aerial photograph inspection, desktop review and during field surveys. Given the size of the airport site, targeted surveys of one hour were carried out at sites with better quality habitat, while rapid surveys were conducted at others. These are described further below. Targeted surveys were carried out each night at four of the sites, while other sites were visited once only during surveys to enable a greater coverage of the airport site.

Frog surveys were undertaken with reference to DECC (2008d) hygiene protocols. Measures adopted comprised sterilising boots between survey sites to prevent transfer or introduction of chytrid fungus, and avoiding the use of suncream and insect repellent on hands.

Frog surveys included the following methods:

- Targeted surveys
  - Diurnal inspections of selected dams were conducted in the afternoons prior to nocturnal surveys on the four nights. Searches for basking frogs and call playback were undertaken at these dams. Scans for basking frogs were also conducted at dams during general fauna surveys in late March and early April. Notes at each water body were taken, and included size, geomorphology, presence of habitat features and structure, type and species composition of wetland and aquatic vegetation.
  - Active nocturnal searches for frogs were performed for a minimum of one hour at each survey site focussing on areas of suitable habitat. Creek banks and dam edges were systematically searched and aquatic vegetation was visually scanned using spotlights. Call playback and vocalisations imitating the call of the Green and Golden Bell Frog were broadcast at each targeted survey site, comprising a minimum of five minutes calling followed by a ten minute listening period. For larger dams, calls were broadcast at a number of locations around the dam edges. Frogs were identified by sight and call.
- Rapid surveys
  - Call playback and vocalisations imitating the call of the Green and Golden Bell Frog were broadcast at each rapid survey site, comprising a minimum of five minutes calling followed by a ten minute listening period. All frogs heard calling were recorded.

Nocturnal bird and mammal surveys

Nocturnal bird and mammal surveys comprised the following:

- Call playback

Call playback was undertaken on a total of nine nights at the airport site. Calls of the Barking Owl (*Ninox connivens*), Powerful Owl (*Ninox strenua*), and Masked Owl (*Tyto novaehollandiae*) were broadcast in woodland areas. Calls were broadcast through a 15 watt megaphone for a minute each with gaps of about a minute between the call of each species. Calls were then repeated. A quiet listening period of ten minutes was held prior to and following call playback. Potential roost sites were scanned with a spotlight.

- Spotlighting

Spotlighting targeting nocturnal birds and mammals was conducted over nine nights at the airport site. Spotlighting was undertaken by three ecologists using 210 lumens P14 Led Lenser torches. Each survey lasted between 1-2 hours. Surveys were carried out along road reserves and in larger woodland patches. Spotlighting for frogs was conducted separately as part of the targeted frog surveys described above, although any frogs heard or observed during other spotlighting surveys were recorded. Similarly, any nocturnal mammals and birds heard or observed during the targeted frog surveys were recorded.

Infra-red camera surveys

Two infra-red cameras were placed at four separate locations in woodland or near dams in the airport site to target cryptic species. Cameras were baited with a mixture of chicken wings and tinned sardines. Cameras were left set for a minimum of three weeks. Cameras were set to take three pictures over one minute when triggered by movement, with at least five minutes between each set of photographs.

Cumberland Plain Land Snail searches

Targeted searches for Cumberland Plain Land Snails were carried out in larger patches of vegetation (where possible with regard to access constraints) and along road reserves in the airport site. Active searches were conducted in leaf litter at the base of trees and under rubbish and logs. Searches were conducted for between half an hour to an hour in woodland patches, depending on the size of the patch. Live snails were photographed, and empty shells were collected and sent to the Australian Museum for identification and confirmation. GPS waypoints were collected for search areas, and for any snails recorded.

Koala scat searches

Targeted Koala scat searches were conducted in conjunction with the searches for the Cumberland Plain Land Snail, as both scats and snails occur in leaf litter at the base of trees. Scat searches focussed on Forest Red Gum (*Eucalyptus tereticornis*), a primary food tree in the Sydney area (DECC 2008c), and Grey Box (*Eucalyptus moluccana*), a secondary food tree in the Sydney area (DECC 2008c). Searches were conducted for between half an hour to an hour in woodland patches, depending on the size of the patch.

Opportunistic observations

Opportunistic and incidental observations of fauna species were recorded at all times during the field survey. Scats, burrows and diggings were noted and mature trees were scanned for roosting birds.

3.3 Field Surveys: Aquatic Biodiversity

3.3.1 Overview

An aquatic survey was carried out from 13 to 16 March 2015 (inclusive) covering 12 sites located at upstream and downstream locations on waterways that traverse the airport site. A second survey was carried out on 20 May 2015 and covered sites within the airport site as well as an upstream control site not able to be sampled in the first survey due to access constraints. Aquatic survey sites are indicated on Figure 3e. Survey site locations are provided in Table 4.

At each survey site a detailed habitat assessment was undertaken to determine the existing environment and to assess the potential presence of native aquatic flora and fauna, including species and or communities listed as threatened under the EPBC Act or FM Act.

Sampling included both stream habitat and two representative farm dams, as the latter are a dominant feature of the waterbodies in the study area. A general description of habitats, including macrophytes and riparian vegetation, was made using the NSW AUSRIVAS Habitat Assessment protocols. Water quality was assessed using *in situ* measurements and grab samples were tested for nutrients. Sampling targeted fish and macroinvertebrate fauna.

Table 4 Aquatic survey site locations

Site Code	Location	Latitude	Longitude	Date sampled
BCUS	Badgerys Creek upstream	-33.91463	150.70589	14/03/2015
BCMC	Badgerys Creek mid-catchment	-33.89892	150.73856	13/03/2015
BCDS	Badgerys Creek downstream	-33.87381	150.75488	13/03/2015
SCUS	South Creek upstream	-33.87575	150.76785	13/03/2015
SCDS	South Creek downstream	-33.83548	150.76577	
SCREC	South Creek Recovery	-33.80503	150.76668	15/03/2015
OCUS	Oaky Creek upstream	-33.88443	150.722935	28/05/2015
OCDS	Oaky Creek downstream	-33.86935	150.72107	15/03/2015
CCUS	Cosgrove Creek upstream	-33.86897	150.71779	15/03/2015
CCDS	Cosgrove Creek downstream	-33.83435	150.75961	
TCUS	Thompson Creek upstream	-33.93454	150.72919	13/03/2015
DCDS	Duncans Creek downstream	-33.90046	150.70448	16/03/2015
DCUS	Duncans Creek upstream	-33.89971	150.67655	28/05/2015
OCDAM	Oaky Creek Dam	-33.88338	150.72171	28/05/2015
OSDAM	On Site Dam	-33.88896	150.72912	28/05/2015

3.3.1 Aquatic habitat assessment

An assessment of the in-stream physical habitat was conducted at all survey sites based on the NSW AUSRIVAS habitat assessment sheet. This also included a reference site assessment. This entailed detailed assessments of the substrata and water channel and an on-site assessment of hydraulic habitat features and suitability for threatened taxa identified from the database and literature searches.

3.3.2 Water quality

Water quality sampling was conducted in accordance with the National Association of Testing Authorities (NATA) certification standards at all sites. A calibrated YSI 600 QS MSP water quality meter was used to record in-situ parameters, while alkalinity was obtained through the use of field titration kits. These in-situ parameters were compared to the ANZECC & ARMCANZ (2000) guidelines and the Airports (Environment Protection) Regulations 1997 (AEPR) trigger values to determine which sites were outside of the recommended ranges. Additional water quality grab samples were collected for confirmation of conductivity and to test for metals, nutrients, BTEX (benzene, toluene, ethylbenzene and xylenes), additional hydrocarbons and other constituents.

3.3.3 Macroinvertebrate sampling and analysis

Macroinvertebrates were sampled in accordance with the NSW AUSRIVAS sampling protocols (Turak et al. 2004). Representative macroinvertebrate samples were collected from edge, pool bed and riffle areas where adequate habitat was present to ensure the best chance of capturing the full range of taxa likely to be present at each site. Samples were predominantly collected in pool and edge habitats given an absence of riffle habitat at most sites (Table 5). Samples were not collected at two sites due to very low volumes of surface water and limited habitat (DCUS) and unsafe access (DCDS).

Table 5 Summary of the habitat sampled for macroinvertebrates at each aquatic survey site

Site	Edge	Pool	Riffle
BCUS	✓	-	-
BCMC	✓	-	-
BCDS	✓	✓	-
SCUS	✓	✓	-
SCDS	✓	-	-
SCREC	✓	✓	✓
OCUS	✓	-	-
OCDS	✓	-	-
CCUS	✓	-	-
CCDS	✓	-	-
TCUS	✓	✓	-
DCDS	-	-	-
DCUS	-	-	-
OCDAM	✓	✓	-
OSDAM	✓	✓	-

Samples were collected using a framed net (350 millimetres wide) with 250 micrometre mesh size. The nets and all other associated equipment were washed thoroughly between sampling sites to remove macroinvertebrates. Samples were collected by sweeping the collection net along the edge habitat at the sampling site. The operator worked systematically over three 10-metre sections covering overhanging vegetation, submerged snags, macrophyte beds, overhanging banks and areas with trailing vegetation.

Samples were then live picked, following the methodology of Turak et al. (2004). The collected material from each 10 metre section was placed into a sorting tray and the macroinvertebrates were picked for a minimum of 40 minutes. If new taxa were found between 30 and 40 minutes, sorting was continued for a further 10 minutes. If no new taxa were found, after an additional 10 minute period, then this process ceased. If new taxa were found, this process continued up to a maximum of one hour.

Following collection and sorting of macroinvertebrates, the results were entered into the NSW AUSRIVAS model. AUSRIVAS is a predictive model based on standardised sampling protocols that uses macroinvertebrate communities to assess the biological health of rivers and streams. Specifically, the model uses site-specific information to predict the macroinvertebrate fauna expected (E) to be present in the absence of environmental stressors. The expected fauna from sites with similar sets of predictor variables (physical and chemical characteristics which cannot be influenced due to human activities, e.g. altitude) are then compared to the observed fauna (O). A ratio between the expected and observed fauna values is derived to indicate the extent of any impact (referred to below as the 'O/E ratio'). The ratio derived from this analysis is compiled into bandwidths (i.e. X, A-D) which are used to indicate the overall health of a particular site using the classification shown in Table 6. Data are presented using the AUSRIVAS O/E 50 ratio (Observed/Expected score for taxa with a >50% probability of occurrence) and the previously mentioned rating Bands (Table 6).

Table 6 AUSRIVAS Band widths and interpretations for the NSW autumn edge and riffle models

Band	RIFFLE	EDGE	Explanation
	O/E Band width	O/E Band width	
X	>1.13	>1.17	More diverse than expected. Potential enrichment or naturally biologically rich.
A	0.84-1.13	0.81-1.17	Similar to reference. Water quality and / or habitat in good condition.
B	0.6-0.84	0.46-0.81	Significantly impaired. Water quality and/ or habitat potentially impacted resulting in loss of taxa.
C	0.34-0.6	0.11-0.46	Severely impaired. Water quality and/or habitat compromised significantly, resulting in a loss of biodiversity.
D	0-0.34	0-0.11	Extremely impaired. Highly degraded. Water and /or habitat quality is very low and very few of the expected taxa remain.

The Stream Invertebrate Grade Number – Average Level (SIGNAL 2) biotic index (Chessman, 2003) was also used to determine the ecological quality of sampling sites. This method assigns a score between 1 (most tolerant) and 10 (most sensitive) to each macroinvertebrate family. The SIGNAL index is then calculated as the average grade number for all families present in the sample. The resulting index score can then be interpreted using the following guidelines (source: Gooderham and Tsyrlin 2005):

- SIGNAL > 6 = Healthy habitat;
- SIGNAL 5-6 = Mild pollution;
- SIGNAL 4-5 = Moderate pollution; and
- SIGNAL < 4 = Severe pollution.

A useful and commonly used method to interpret SIGNAL 2 scores is to plot the SIGNAL 2 scores against the number of families collected at a given site. The plotting region is divided into four quadrants, which can be interpreted as:

- Quadrant 1 – indicates favourable habitat and chemically dilute water;
- Quadrant 2 – indicates high salinity or nutrient levels – these may be natural;
- Quadrant 3 – indicates toxic pollution, harsh physical conditions or inadequate sampling; and
- Quadrant 4 – indicates urban, industrial or agricultural pollution, or can indicate downstream effects of dams

Selecting the boundaries in the scatterplot requires consideration of the local geography, land use and sampling method. If reference sites are used in the study design, the boundaries can be set so that these sites all fall within Quadrant 1. However, in the current study design, reference sites were not included, so the taxa richness boundary was chosen as the median number of taxa collected during this sampling period (11) while the SIGNAL 2 boundary was chosen as the lower limit for the mild pollution category (SIGNAL 2 score of 5).

In addition to the AUSRIVAS and SIGNAL score assessments, simple biological metrics were also used as descriptors of each survey site. The metrics used in this assessment were:

- taxa richness;
- Ephemeroptera-Plecoptera-Trichoptera (EPT) richness; and
- a description of the community composition at each site.

Taxa Richness

The number of taxa (taxa richness) was counted for each site and other descriptive measures such as the number of pollution-sensitive taxa (Ephemeroptera, Plecoptera and Trichoptera – EPT) were examined at the family levels. Taxa richness refers to the number of different taxa contained in the sample. Unlike some biological indices a higher number does not always indicate better in-stream conditions. In some cases, higher values of this metric may indicate favourable conditions in terms of availability of food and/or the quality of habitat. However, high richness values can also occur when altered conditions provide habitats or additional resources that may not occur naturally (e.g. additional food supply due to increased nutrient levels).

Ephemeroptera-Plecoptera-Trichoptera (EPT) Richness

EPT is a widely used index based on the number of families within the Ephemeroptera, Plecoptera and Trichoptera orders to assess stream condition. These three orders have been identified as being intolerant to pollution and their use as indicators of disturbance has also been tested in NSW.

Community Composition

Total invertebrate abundance and the number of taxa and dominant taxa were calculated as percent composition of the overall total as well as on a site by site basis. Special consideration has been given to the Odonata because of the possible, albeit unlikely, occurrence of larvae of two dragonfly species listed as threatened under the FM Act:

- Adam's Emerald Dragonfly (*Archaeophya adamsi*); and
- Sydney Hawk Dragonfly (*Austrocordulia leonardi*).

Laboratory Identification

Macroinvertebrate specimens were identified to family level where possible using the latest taxonomic keys. A total of 15 macroinvertebrate samples were analysed with the resulting samples stored in site specific vials for retention by GHD for internal quality assurance procedures.

Given the particular interest in assessing whether Adam's Emerald Dragonfly or Sydney Hawk Dragonfly were present at the survey sites, all Odonates were identified to species level where possible.

Macroinvertebrate Quality Control

A number of quality control procedures were undertaken during the identification phase of this program, including:

- organisms that were heavily damaged were not selected during sorting. To overcome losses associated with damage to intact organisms during vial transfer; attempts were made to obtain significantly more than 200 organisms;
- identification was performed by qualified and experienced aquatic biologists with more than 100 hours of identification experience;

- reference collections were also used where necessary;
- NSW AUSRIVAS QA/QC protocols were followed;
- an additional 5% of samples were re-identified by another senior taxonomist and these QA/QC results are presented in Appendix B; and
- very small, immature, damaged animals or pupae that could not be positively identified were not included in the dataset.

3.3.4 Fish surveys

Electrofishing was to be undertaken at each site to identify and describe the composition of the fish communities residing within the waterways of the footprint area. This method was chosen initially because it is non-lethal, repeatable, is not size or species specific and does not require extended time at each site through waiting until soak times for nets and traps have been completed. However, this sampling method does not work in high electrical conductivity waters and these were encountered at all but one site surveyed in March and May 2015. Hence, alternative fish sampling (fyke netting and bait trapping) was carried out.

At each site where the waterway could be fully accessed, one dual wing fyke net (1.2m x 0.8m opening, 6mm mesh, 10m wings) and five bait traps were set for a period of between 3 and 4 hours per site. Both fyke nets and bait traps were able to be deployed at a majority of sites as shown in Table 7. Fish sampling was not undertaken at one site (DCUS) where there was no safe access to the water.

Table 7 Fish survey method used at each site

Site	Electrofishing	Fyke Net	Bait Traps
BCUS	-	-	✓
BCMC	-	-	-
BCDS	-	✓	✓
SCUS	-	✓	✓
SCDS	-	✓	✓
SCREC	-	✓	✓
OCUS	-	✓	✓
OCDS	-	-	✓
CCUS	-	-	✓
CCDS	-	-	✓
TCUS	-	-	✓
DCDS	-	-	✓
DCUS	-	-	-
OCDAM	-	✓	✓
OSDAM	-	✓	✓

Fish captured were identified to species level using appropriate keys (Allen et al. 2002). Native species were returned to the waterway unharmed, while non-native species were euthanized in accordance with ethics permit requirements.

The sensitivity of key fish habitat and the functionality of the waterways at the airport site was classified according to the *Policy and guidelines for fish habitat conservation and management* (DPI 2013) as indicated in Table 7 and Table 9. Aquatic habitat was also compared with known habitat requirements of threatened aquatic fauna known to occur in the region according to Department of Primary Industries threatened species profiles (DPI 2015a).

Table 8 Key fish habitat and associated sensitivity scheme (DPI 2013)

Key Fish Habitat Type	Description
Type 1 - highly sensitive fish habitat	Freshwater habitats that contain in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 metres in length, or native aquatic plants. Any known or expected protected or threatened species habitat or area of declared 'critical habitat' under the FM Act. SEPP 14 coastal wetlands, wetlands recognised under international agreements (e.g. Ramsar, JAMBA, CAMBA, ROKAMBA wetlands), wetlands listed in the Directory of Important Wetlands of Australia.
Type 2 - moderately sensitive key fish habitat	Freshwater habitats and brackish wetlands, lakes and lagoons other than those defined in TYPE 1. Weir pools and dams up to full supply level where the weir or dam is across a natural waterway.
Type 3 - minimally sensitive key fish habitat	Coastal and freshwater habitats not included in TYPES 1 or 2. Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation.
Not key fish habitat	First and second order streams on gaining streams (based on the Strahler method of stream ordering). Farm dams on first and second order streams or unmapped gullies.

Table 9 Classification of waterways for fish passage (DPI 2013).

Fish Habitat Classification	Characteristics of Waterway Type
Class 1 Major key fish habitat	Permanently flowing or flooded freshwater waterway (e.g. river or major creek), habitat of a threatened or protected fish species or 'critical habitat'.
Class 2 Moderate key fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks with semi - permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.
Class 3 Minimal key fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (e.g. fish, yabbies). Semi - permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.
Class 4 Unlikely key fish habitat	Named or unnamed waterway with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools after rain events (e.g. dry gullies or shallow floodplain depressions with no permanent aquatic flora present).

3.4 Survey effort, timing, limitations and staff

3.4.1 Survey stratification, effort and timing

Field survey methods and effort were designed with reference to the Commonwealth survey guidelines for threatened species listed under the EPBC Act (DEWHA 2010a, 2010b), the NSW draft Threatened Species Survey Guidelines (DEC 2004a), and any relevant survey and habitat information in recovery plans for relevant threatened species (see section 3.2.1 and the references provided in section 11). A summary of survey effort is provided in Table 10 and a detailed assessment of survey effort against the guidelines is provided in Appendix B.

Table 10 Survey effort and timing

Survey focus	Dates	Survey method	Effort
Initial survey	13/02/2015	Site familiarisation	1 day
Targeted frog surveys	11-12/03/2015 18-19/03/2015	Diurnal inspections of dams for basking frogs	4 afternoons
		Targeted surveys of dams for frogs, call playback	4 nights
		Rapid aural surveys, call playback	4 nights
Vegetation mapping and threatened flora surveys	Feb-May 2015	BioBanking plot/transect surveys	43 plot/transects
		Targeted flora searches	18 days
		Wetland assessments	7 sites
Fauna surveys	Feb-May 2015	Habitat assessment	18 days
		Diurnal bird surveys	16 days
		Early morning bird surveys	10 mornings (2-3 people for 1-2 hours on each morning) – 13 sites visited at least once
		Microchiropteran bat surveys (Anabat)	21 Anabat unit nights over 12 locations
		Targeted frog surveys	2 people for 4 afternoons and nights (80 person hours)
		Spotlighting (birds and mammals)	3 people on 5 nights (30 person hours) and a further 2 people on 4 nights (16 person hours)

Survey focus	Dates	Survey method	Effort
		Call playback (owls)	9 nights (0.25 hour per night, followed by spotlighting survey of 1 hour)
		Infra-red cameras	2 cameras for 8 weeks
		Active searches for the Cumberland Plain Land Snail, other ground fauna and scats	11 days (35 sites, about 25 person hours)
		Koala scat searches	11 days (35 sites, about 25 person hours)
		Opportunistic observations	18 days
	May and June, 2015	Winter bird surveys	2 people for 2 days
Aquatic surveys	March and May, 2015	Aquatic habitat assessment Macroinvertebrate sampling Fish surveys Water quality sampling	2 people for 5 days (sampling at 12 sites, of which 6 were in the airport site)

Targeted surveys at the airport site were stratified between vegetation and habitat types as required by the NSW draft Threatened Species Survey Guidelines (DEC 2004a). Stratification is necessary to ensure that the full range of potential habitats and vegetation types are systematically sampled. The survey area should be initially stratified on biophysical attributes (e.g. landform, geology, elevation, slope, soil type, aspect), followed by vegetation structure (e.g. forest, woodland, shrubland), and then floristics (e.g. species) (DEC 2004a).

The airport site has relatively uniform biophysical attributes, comprising either rolling low hills on shale substrate or riparian corridors on alluvium. These units were further split based on vegetation structure to yield four broad habitat types which comprised the stratification units for the field survey as follows:

- woodland, comprising grassy eucalypt woodlands on rolling hills and flats on shale or shale-gravel substrate;
- riparian forest, comprising grassy eucalypt forest or closed woodlands on flats on alluvial substrate;
- grassland, comprising native and exotic grassland in a variety of geomorphic positions; and
- wetland, comprising freshwater wetlands and farm dams in a variety of geomorphic positions.

Survey stratification units are mapped on Figure 3. Cleared land and cropland is also shown, which comprises extensively modified land with minimal native vegetation cover or habitat resources. Cleared land and cropland was not sampled with targeted survey techniques but was

sampled by broad survey techniques such as vegetation mapping and habitat assessments as well as opportunistic fauna observations.

Targeted fauna survey techniques were purposefully split between these stratification units based on the total area of each habitat type at the airport site and the likelihood of the targeted species occurring in each habitat type. The survey effort that was conducted in each stratification unit is summarised in Table 11.

Vegetation plot/transects were further stratified between individual vegetation zones based on floristics and condition. The split of plot/transects between vegetation zones is summarised in Table 11.

Aquatic survey sites were stratified to survey major streams that cross or rise within the airport site as well as South Creek and two dam sites. For each stream, survey sites included sites upstream and downstream of the airport site to provide control and impact sites.

Table 11 Site stratification and survey effort

	Woodland	Riparian forest	Grassland	Wetland
Total Area on airport site (hectares)	**158**	**92.3**	**1139.9**	**35.4**
Survey effort by technique (hectares)				
Active searches (sites)	28	7		
Anabat recording (sites, for at least one night)	4	2	1	5
Call playback (nights)	6	3		
Camera trap (cameras, set for four weeks)	3	1		
Diurnal bird surveys (sites, on a single morning)	8	4		4
Plot/transect	23	9	11	
Rapid frog survey (sites)		1		15
Targeted frog surveys (sites)				11
Spotlighting (sites, on a single night)	4	5		
Wetland assessments (sites)				7
Winter bird surveys (sites, on a single morning)	16	7		

The site stratification and survey effort should be considered along with the following considerations and qualifications:

- the point location for targeted fauna surveys shown on Figure 3 indicates the starting point for a survey that sampled a broader area, including:
  - active searches within the entire patch of treed vegetation surrounding the point over at least one hour;
  - diurnal bird surveys and winter bird surveys over around one hectare of treed vegetation, one kilometre of edge habitat or an entire wetland over at least one hour; and
  - targeted frog surveys around the margins of an entire wetland for at least one hour.
- call playback events were stratified between woodland and riparian forest in order to increase the variety of locations and habitat features sampled. However the airport site was considered a single 'site' for the purposes of calculating the total number of nights of survey effort. This is based on the fact that calls broadcast with a 100W megaphone may be heard at least a kilometre away (DEC 2004a) and that the home ranges of threatened forest owls typically range from 500 to over 1000 hectares (DEC 2006a). The nine nights of call playback performed at the airport site is sufficient to achieve a 90% chance of detection of each of the forest owl species that were targeted (DEC 2004a);
- anabat recording, bird surveys and spotlighting events that were mainly focussed on woodland or riparian forest also sampled adjoining areas of grassland and nearby dams. Similarly, sampling focussed on dams also sampled adjacent woodland and grassland areas;
- early morning bird surveys were conducted at the same location on different days on some occasions, thus the survey effort identified on Figure 3 and in Table 11 is an underestimate of the total number of times the different stratification units were visited; and
- habitat assessments, targeted searches for threatened plants and opportunistic fauna observations were performed in all native vegetation at the airport site during all time spent on site.

3.4.2 Weather conditions

Terrestrial field surveys

Weather conditions were generally conducive for field surveys and the detection of fauna and flora. Frog survey conditions have been discussed in section 3.2.3. Weather was generally sunny and mild to warm during the biodiversity surveys. Rain fell on seven days during the biodiversity surveys, but most days were dry. Rainfall was well above average across the Sydney region during summer and autumn. Badgerys Creek had a new rainfall record of 83.6 millimetres in one day in late April. Minimum temperatures were above average across the city during summer and autumn and nights were particularly warm in early May (BOM 2015b). These conditions were generally suitable for the detection of the species likely to occur at the airport site. Plants were generally healthy and not dormant and most species had above ground vegetation, flowers and/or fruit that permitted positive identification to the species level. Fauna species were active and calling.

Weather details for the Badgerys Creek weather station (BOM 2015a) during the survey period are summarised in Table 12.

Table 12 Weather conditions during terrestrial surveys

Survey	Date	Temperature (°C)		Rainfall (millimetres)
		(min.)	(max.)	
Initial survey	13/02/2015	18.9	26.7	7.6
Frog surveys	11/03/15	17.8	30.6	0
Frog surveys	12/03/15	17.4	28.4	28.6
Frog surveys	18/03/15	15.2	30.3	0
Frog surveys	19/03/15	15.0	32.0	0
Terrestrial biodiversity surveys	24/03/15	17.1	24.7	0
Terrestrial biodiversity surveys	25/03/15	11.8	24.4	10.8
Terrestrial biodiversity surveys	26/03/15	13.4	28.1	0
Terrestrial biodiversity surveys	27/03/15	8.2	26.7	0
Terrestrial biodiversity surveys	31/03/15	15.8	22.9	4.2
Terrestrial biodiversity surveys	1/04/15	15.5	26.1	3.6
Terrestrial biodiversity surveys	2/04/15	14.7	28.9	0
Terrestrial biodiversity surveys	5/05/2015	12.9	25.8	0.2
Terrestrial biodiversity surveys	6/05/2015	10.4	19.3	0
Terrestrial biodiversity surveys	7/05/2015	4.7	18.5	0
Terrestrial biodiversity surveys	8/05/2015	6.6	20.4	0
Winter bird surveys	20/05/2015	10.3	23.7	3.8
Winter bird surveys	10/06/2015	6.3	14.9	0

Aquatic field surveys

The weather conditions during the aquatic field surveys were fine although approximately 28 millimetres of rain fell in the region on 12 March 2015 prior to the initial surveys. Daily temperatures ranged from 10.1°C to 26.1°C during the initial March survey and ranged from 10.3°C to 21.0°C on the return visit in May (see Table 13).

Table 13 Weather conditions during aquatic surveys

Date	Minimum Temperature (°C)	Maximum Temperature (°C)	Rainfall (millimetres)
13th March 2015	14.2	26.1	0.0
14th March 2015	14.2	24.8	0.0
15th March 2015	13.2	24.1	0.0
16th March 2015	10.1	23.0	0.0
20th May 2015	10.3	21.0	0.8

3.4.3 Survey limitations

Flora and fauna field surveys conducted for the proposed airport would not be expected to detect all of the species present, however given the many days and various seasons over which surveys have been conducted, these would have recorded a large proportion of species that would occur. Flora and fauna surveys were conducted by GHD at the airport site between March and June 2015. Previously, surveys were conducted by SMEC at the airport site in September 2014 and these built upon surveys conducted for the previous EIS (Biosis 1999). The current field surveys were appropriately stratified to sample representative habitats on sites and conducted in accordance with survey effort and seasonal requirements of relevant survey guidelines (DEC 2004a; DEWHA 2010a, b) however were partially limited by property access

restrictions. The majority of the terrestrial survey effort was conducted in March, during the nominated survey period for most fauna groups (DEC 2004a; DEWHA 2010a, b) and in April when conditions were still warm and fauna were still active.

Some species that may occur in the locality or region on a seasonal basis, use habitats periodically (as part of a wider home range) or become active at different times of the year may not have been recorded. These species may include flora species that are difficult or impossible to locate or identify at certain times of year due to a lack of reproductive material and/or their seasonal nature (in particular, native orchids and forbs). Field surveys aimed to identify areas of suitable habitat for cryptic species and where necessary to assess the likelihood of occurrence at the airport site.

The targeted Green and Golden Bell Frog surveys were conducted towards the end of the nominated September-March survey period because of property access restrictions. On no occasion did a total of greater than 50 mm of rain fall in the week prior to a given survey as is specified in the EPBC Act significant impact guidelines for the species (DEWHA 2009a). However conditions were warm, humid and still and other frog species were calling and were active and easily detected during surveys at the airport site. Green and Golden Bell Frogs were active (but not calling) at the reference site and were readily observed. Given these considerations it is likely that the targeted Green and Golden Bell Frog surveys would have detected the species if a population was present at the airport site.

For the above reasons, the impact assessment and conclusions of this report draw upon information obtained from a variety of sources in addition to the field survey data. Where it is considered that the likelihood of observing a particular threatened species was diminished due to the extent of survey effort or seasonal or climatic factors, then this has been indicated. An assessment of the likelihood of occurrence of threatened species has been provided, on the basis of known distributional ranges, previous records in the locality, and habitat and resource availability at the airport site. The assessment of impacts includes those threatened species recorded at the airport site during the field surveys as well as those species not detected but considered likely to occur or to be impacted by the proposed airport.

Sampling for macroinvertebrates during autumn is ideal for analysing the data using the single season AUSRIVAS model. However, the completion of sampling during this season alone does not account for natural seasonal variation, which could result in some taxa not being collected as they are not present in the sampled habitats during this time of year. The sampling carried out has provided a sufficient indication of taxa and habitat conditions associated with areas potentially impacted by the proposal to enable a robust assessment of potential impacts on aquatic habitats.

3.4.4 Staff qualifications

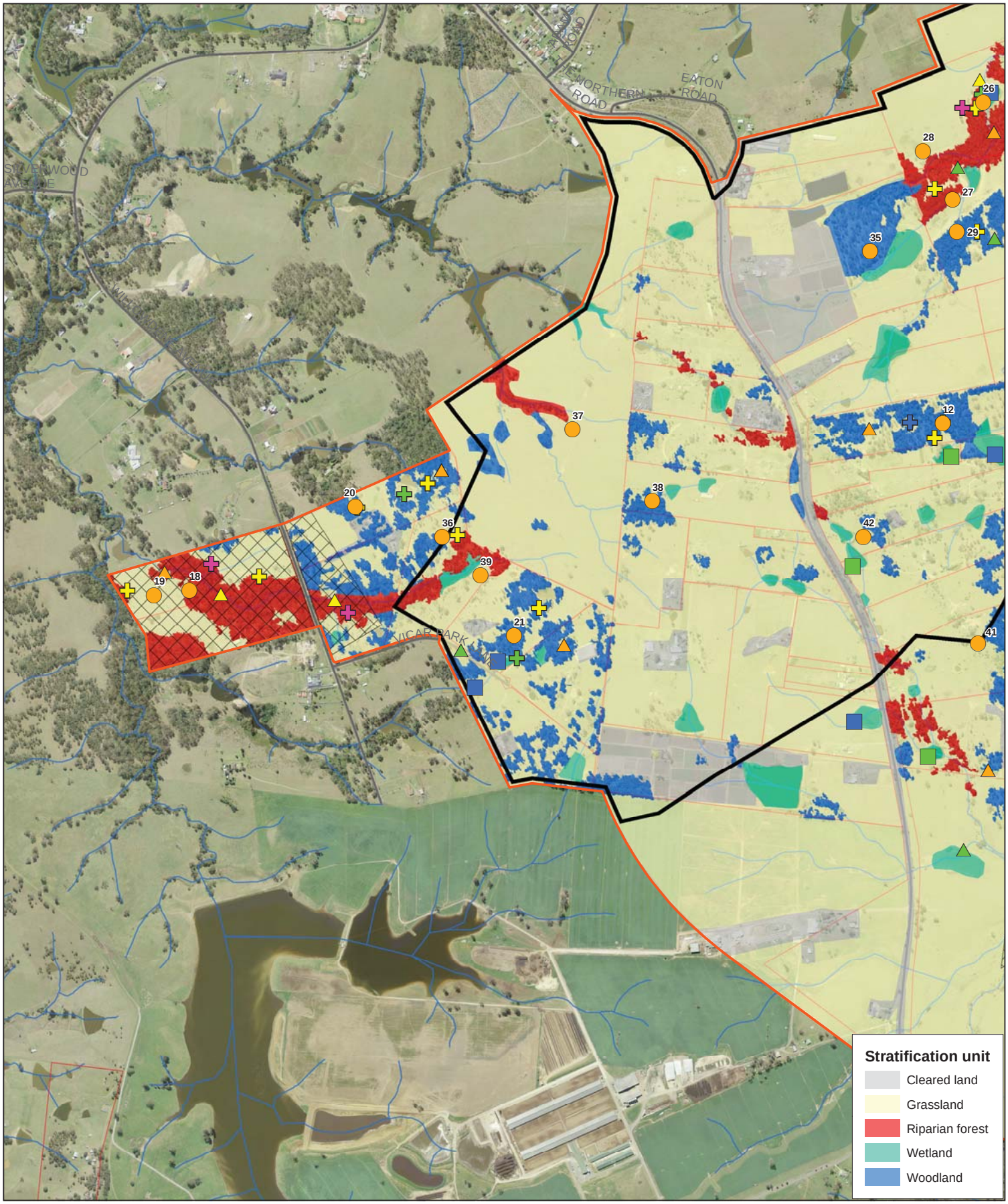
Qualifications of staff that undertook recent field surveys and prepared this report and the offset strategy are provided in Table 14. Flora and fauna surveys were conducted under a Section 132C scientific licence (SL100146) issued under the NSW *National Parks and Wildlife Act 1974* and complied with GHD's animal ethics permit requirements. All aquatic sampling was carried out with current scientific research permits under section 37 of the FM Act (permit number P01/0081(C)) and complied with GHD's ethics permit requirements.

Table 14 Qualifications of staff

Name	Position/Role	Qualifications	Years' Experience
Ben Harrington	Senior Ecologist / desktop assessment, site surveys, credit calculations and reporting	BSc, MSc (Physical Geography) NSW BioBanking Assessor Accreditation (number 0073)	10+ years
Kirsten Crosby	Senior Ecologist / desktop assessment, site surveys, reporting	BSc, PhD (Zoology) NSW BioBanking Assessor Accreditation (number 160)	10+ years
Malith Weerakoon	Graduate Ecologist / desktop assessment, data processing.	BSc, MPhil. (Zoology)	2+ years
Jayne Tipping	Principal Ecologist/technical review	BSc (Ecology), MEnvLaw	20+ years
Phil Taylor	Senior Aquatic Ecologist / reporting, analysis, impacts assessment	BSc, MSc (Ecology and Evolution)	10+ years
Tara Steele	Aquatic ecologist/ field surveys, macrophyte identifications	BA (Geographic Sciences), BSc (Ecology)	5 years
Josh Cox	Aquatic Ecologist/ field surveys, reporting	BSc (hons.)	5 years
Gavin Williams	Senior Aquatic Taxonomist / macroinvertebrate and fish identifications	Advanced Diploma Aquatic Resource Management	10+ years
Jamie Corfield	Principal Aquatic Ecologist / direction and technical review	Ph.D (Coastal management)	15 years

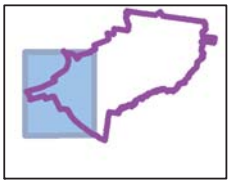
3.5 Assessment of likelihood of occurrence

Following the collation and review of database records and species and community profiles, a 'likelihood of occurrence' of threatened biota assessment was prepared with reference to the broad habitats contained within the airport site. Identification of potential habitat for threatened and migratory species was based on information provided in the species profiles (DotE 2015b, OEH 2015b), recovery plans, journal articles, and the field staffs' knowledge of species habitat requirements. The likelihood of occurrence assessment was further refined following field surveys. The likelihood of threatened and migratory biota occurring at the airport site was assessed based on presence of records from the locality since 1990, species distribution and habitat preferences, and the suitability of potential habitat present. The results of this assessment are provided in Appendix A.



Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Roads
- Watercourses
- Plot/transect
- Active searches for snails, ground fauna and scats
- Anabat recording
- Spotlighting
- Camera trap
- Call playback for owls
- Diurnal bird survey
- Winter bird survey
- Rapid frog survey
- Targeted frog survey



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Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Assessment

Job Number 21-24265
Revision A
Date 28 Aug 2015

Survey effort

Figure 3A

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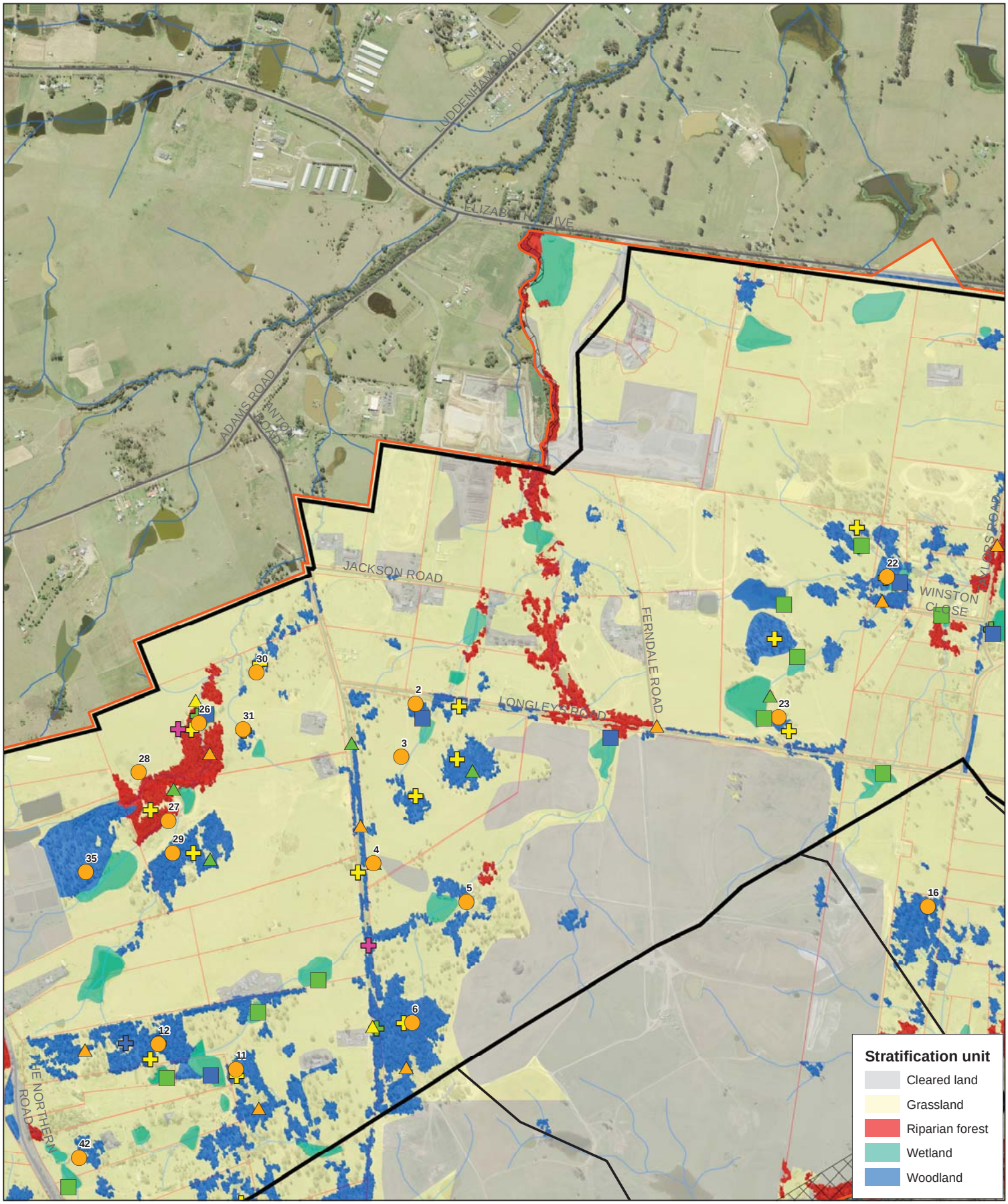

Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Roads
- Watercourses
- Plot/transect
- Active searches for snails, ground fauna and scats
- Anabat recording
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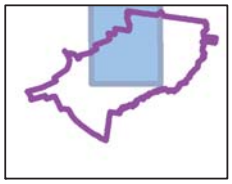
- Diurnal bird survey
- Winter bird survey
- Rapid frog survey
- Targeted frog survey



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Western Sydney Airport
Biodiversity Assessment

Job Number	21-24265
Revision	A
Date	28 Aug 2015

Survey effort

Figure 3B

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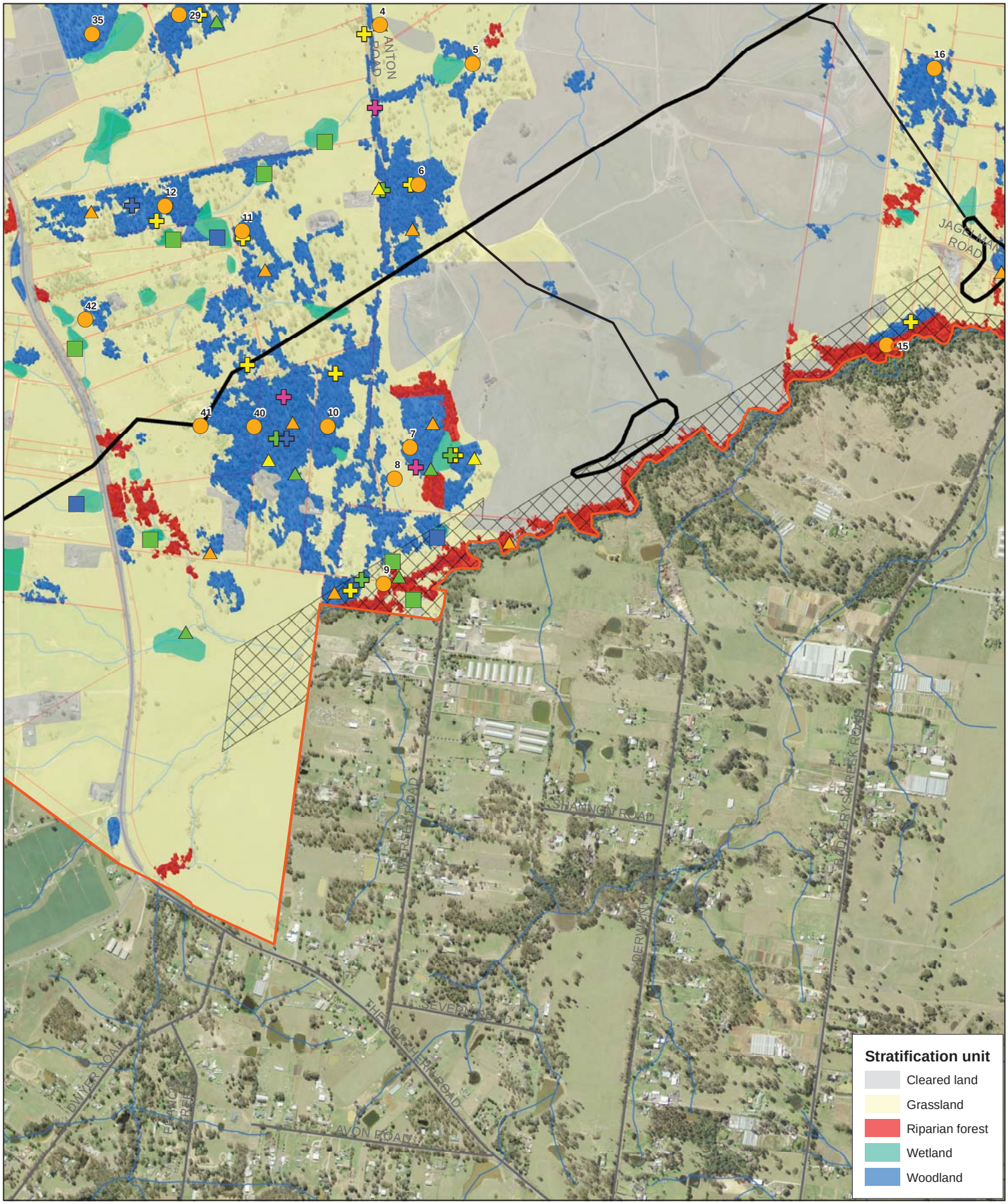

Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Roads
- Watercourses
- Plot/transect
- Active searches for snails, ground fauna and scats
- Anabat recording
- Spotlighting
- Camera trap
- Call playback for owls
- Diurnal bird survey
- Winter bird survey
- Rapid frog survey
- Targeted frog survey



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Western Sydney Airport
Biodiversity Assessment

Job Number	21-24265
Revision	A
Date	28 Aug 2015

Survey effort

Figure 3C

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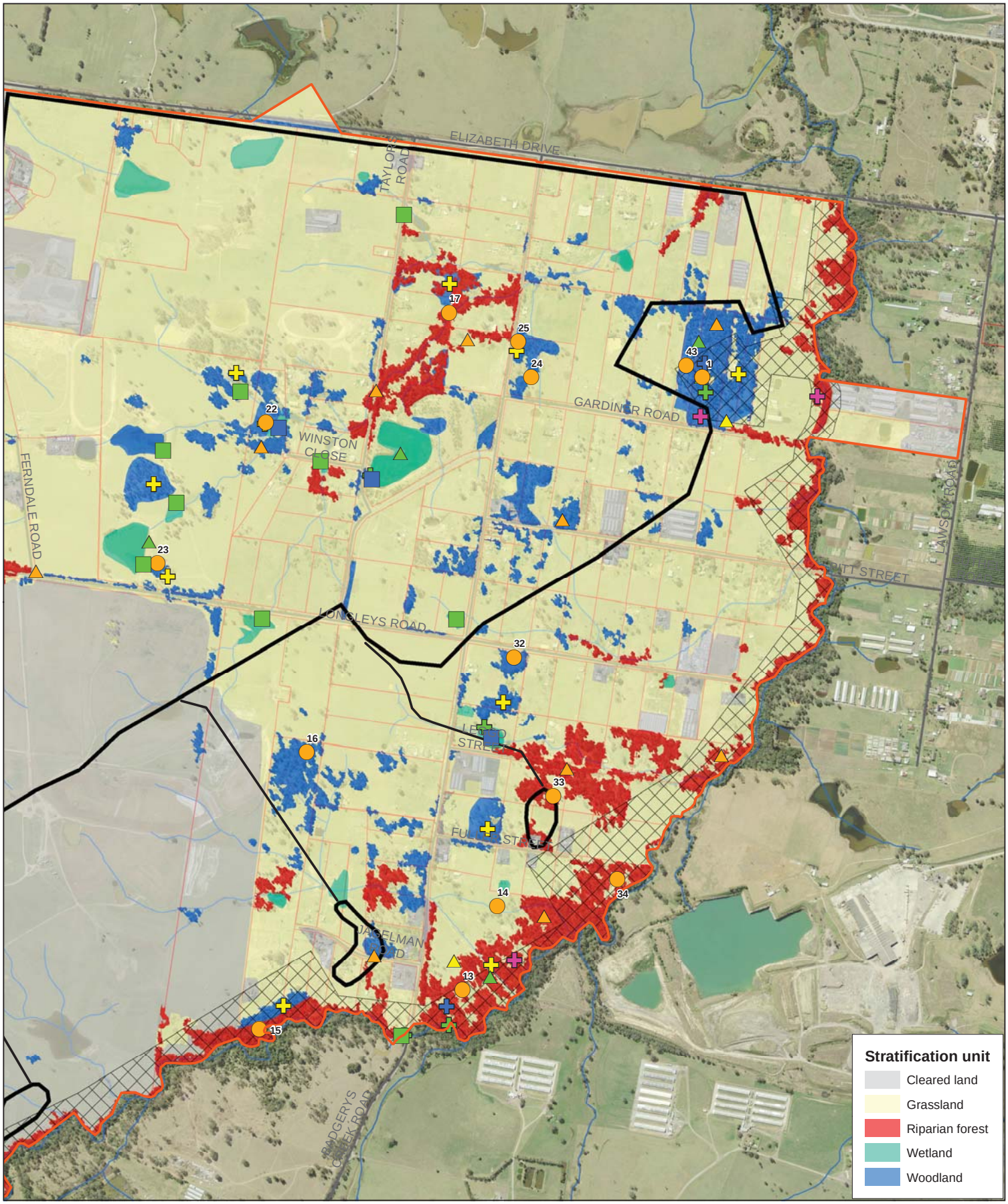

Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Roads
- Watercourses
- Plot/transect
- Active searches for snails, ground fauna and scats
- Anabat recording
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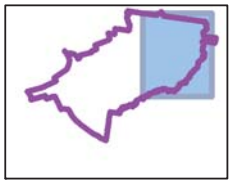

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Western Sydney Airport
Biodiversity Assessment

Job Number	21-24265
Revision	A
Date	28 Aug 2015

Survey effort

Figure 3D

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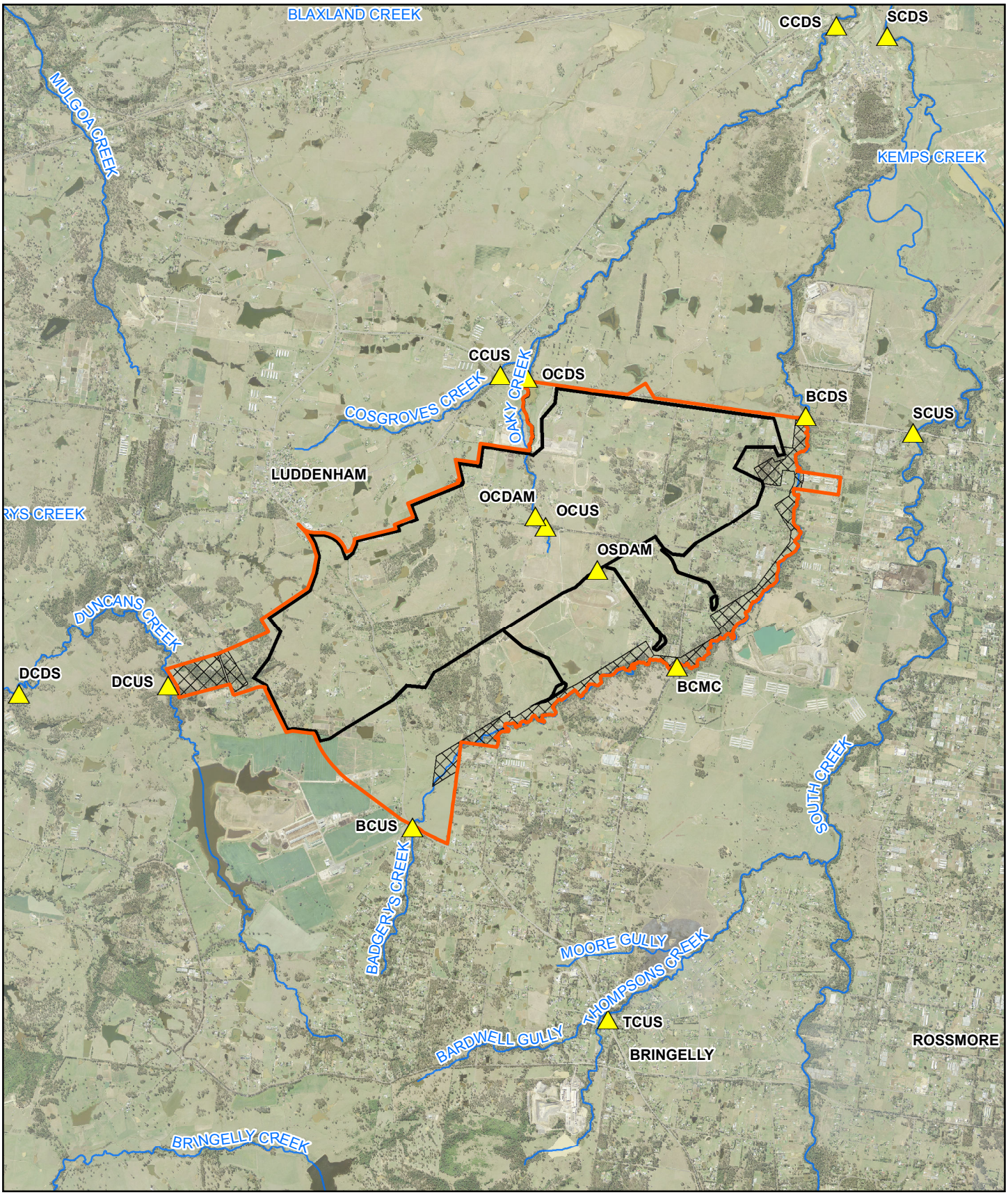

LEGEND

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Aquatic survey sites

Paper Size A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Biodiversity Assessment

Job Number 21-24265
Revision A
Date 28 Aug 2015

Aquatic survey sites

Figure 3E

Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

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4. Existing environment

4.1 Physical environment

4.1.1 Topography and landscape

The airport site is part of an elevated ridge system dividing the Nepean River and South Creek catchments on the Cumberland Plain. The site is characterised by rolling landscapes typical of the Bringelly Shale (see Section 4.1.2) with a prominent ridge in the west of the site, reaching an elevation of about 120 metres AHD, and smaller ridge lines in the vicinity with elevations of about 100 metres AHD. The topography of the airport site generally slopes away from the ridges in the west, with elevations between 40 metres and 90 metres AHD.

The airport site features remnant patches of grassy woodland and narrow corridors of riparian forest within extensive areas of derived grassland, cropland and cleared, developed land. The main land uses are agriculture and low density rural residential development.

The airport site is contained within the 'Cumberland Plain' Mitchell Landscape (DECC, 2008a). This landscape comprises low rolling hills and valleys in a rain shadow area between the Blue Mountains and the coast, with vegetation characterised by grassy woodlands and open forest dominated by Grey Box (*Eucalyptus moluccana*) and Forest Red Gum (*E. tereticornis*) and poorly drained valley floors with forests of Cabbage Gum (*E. amplifolia)* and Swamp Oak (*Casuarina glauca*) (DECC 2008b).

4.1.2 Geology and soils

The dominant geological formations beneath the airport site are Bringelly Shale, the Luddenham Dyke and Alluvium (Bannerman & Hazelton 1990). Bringelly Shale is a Triassic age geological unit mainly comprising claystone and siltstone and some areas of sandstone underlying parts of the airport site. The dyke outcrops toward the peak of the ridge in the west of the airport site. Alluvium at the airport site comprises Quaternary age sedimentary deposits along Cosgrove Creek and Badgerys Creek (refer to Chapter 17 of the EIS).

Geotechnical investigations at the airport site generally indicated surficial silt and/or clay topsoils overlying firm residual clays from the weathering of Bringelly Shale, with areas of alluvial gravels, sands, silts and clays associated with Badgerys Creek. The airport site is categorised as the Blacktown, Luddenham and South Creek soil landscapes. Kurosols (soils with strong texture contrast between the topsoil horizon and strongly acid subsoils horizon) occur over the majority of the airport site. Hydrosols (soils that are saturated for prolonged periods) occur in the vicinity of Badgerys Creek (refer to Chapter 17 of the EIS).

4.1.3 Hydrology

Within the broader catchment, the airport site lies in the Badgerys Creek, Cosgroves Creek and Duncans Creek sub-catchments. Badgerys Creek and Cosgroves Creek are tributaries of South Creek.

Badgerys Creek starts about two kilometres south-west of the airport site and flows north-easterly along its southern boundary before joining South Creek about four kilometres downstream. South Creek ultimately drains to the Hawkesbury River.

Oaky Creek starts at the airport site and flows north to Cosgroves Creek, before its confluence South Creek about seven kilometres downstream. Cosgroves Creek starts about one kilometre north of the airport site and flows north-easterly before joining South Creek about six kilometres north-west.

Duncans Creek starts about three kilometres south-west of the airport site and flows north-westerly before joining the Nepean River about nine kilometres downstream from the airport site. This creek is located just outside the airport site at the western end. Duncans Creek receives flows from a number of unnamed tributaries at the airport site.

There are a large number of small first and second order drainage lines across the airport site, many of which have been dammed and heavily modified resulting in isolated freshwater wetlands.

All drainage lines and water bodies contained water at the time of the airport site visits, and supported varying degrees of in stream and riparian vegetation. Drainage lines at the airport site are shown on Figure 1 and discussed in more detail in section 4.4.

The NSW Office of Water Risk assessment guidelines for groundwater dependent ecosystems indicate that several vegetation communities that occur within the airport site are 'high probability groundwater dependent ecosystems' (SMEC 2014). These are discussed further in Section 4.2.4.

4.1.4 Climate

The airport site is located in Western Sydney, which has a humid subtropical climate, and is generally a few degrees warmer than the Sydney central business district, although nights are cooler. The mean maximum temperature occurs in January, and is about 30 degrees Celsius on average. July is the coolest month, with the mean maximum being about 17 degrees Celsius. Rainfall occurs throughout the year, with summer being the wettest season. Annual rainfall is about 700 millimetres on average.

4.1.5 Land uses

The local Badgerys Creek environment has remained largely unchanged since the late 1990s with land use characterised by large and small rural holdings and residential allotments (SMEC 2014). Existing activities at the site include residential, agriculture, light commercial and demolition works. Associated disturbance at the site includes use of pesticides and fertilisers, chemical storage tanks and drums, rubbish dumping, stockpiled demolition waste, and stockpiled fill material of unknown origin.

The airport site is surrounded by low density rural residential, light industrial and mixed agricultural land uses. The South West Growth Centres structure plan shows that the area to the east and south east of the airport site will be set aside for industrial / employment lands (DoP 2010).

4.2 Plant species and vegetation zones

4.2.1 Plant species

A total of 280 species from 72 families were recorded at the airport site, comprising 202 native species and 78 exotic species. The Poaceae (grasses, 48 species, including 15 exotics), Asteraceae (31 species, including 16 native species), Fabaceae (25 species, including 22 native species) and Cyperaceae (16 species, of which only one was exotic) were the most diverse families recorded. The list of plant species recorded at the airport site is provided in Appendix C.

A total of 43 plot/transects was sampled across the site along with additional wetland assessments and opportunistic observations of native plant species. This survey is likely to have revealed the majority of the native plant species present at the site. There is a chance that some cryptic and/or seasonally flowering species were not detected, potentially including threatened species as discussed in Section 4.5.2. The airport site contains a considerable

greater diversity of exotic plant species than are listed in Appendix C, mainly associated with residential gardens or cropland. These areas were not a focus of this biodiversity assessment, beyond visual inspection to confirm that they did not contain native vegetation communities. No formal sampling of the plant species present in these areas was undertaken.

Based on the results of the field surveys, the airport site contains only moderate native plant species richness. Biometric plot/transect data revealed that 21 out of the 43 plots sampled in native vegetation featured native plant species richness that was below benchmark values for an undisturbed example of the equivalent plant community type. The majority of the native vegetation at the airport site has been previously cleared, grazed or otherwise modified and is in moderate or poor condition.

The suite of plant species at the airport site is representative of shale-derived soils, transitional shale-gravel soils, alluvial soils and wetlands. The airport site does not contain any sandstone outcrops or sandstone-derived soils, shale-sandstone transition soils, or deep Tertiary alluvial deposits and does not contain any plant species that have habitat requirements specific to these soil types. Many of the threatened plant species known or predicted to occur in the locality have these specific habitat requirements and would not occur at the airport site (see Appendix A).

4.2.2 Vegetation zones

Field surveys confirmed the presence and distribution of five NSW plant community types at the airport site. Stands of these plant community types include near-intact vegetation in 'moderate/good – high' condition, partially cleared or regrowth vegetation in 'moderate/good – poor' condition and extensively modified areas in 'cleared' condition (according to the BBAM, DECC 2009a). Accordingly nine vegetation zones (plant community types and broad condition classes) were identified and mapped at the airport site as shown on Figure 4. Attributes of these vegetation zones are summarised in and described in Table 16 to Table 24 below.

The most extensive vegetation zone at the airport site is exotic grassland. This vegetation contains no native over storey or mid storey and less than 50% of the ground cover vegetation is native. Grassland areas contain occasional isolated paddock trees that are remnants of adjoining native woodland and forest. There are also extensive areas of buildings, hard stand, bare earth, crop land and waterbodies that feature minimal vegetation cover that have been collectively mapped as 'cleared land and cropland'.

Grey Box - Forest Red Gum grassy woodland on flats is associated with mid and lower slopes, on shale derived soils across the airport site and is the most extensive native plant community type. It comprises an open forest or woodland of Forest Red Gum (*Eucalyptus tereticornis*) and Grey Box (*Eucalyptus moluccana*) with a grassy understorey and occasional dense patches of the shrub species Native Blackthorn (*Bursaria spinosa spinosa*).

There are small areas of tertiary gravel influenced soils in the east of the airport site that support Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest with a canopy of Forest Red Gum and Grey Box along with Broad-leaved Ironbark (*Eucalyptus fibrosa*), a characteristic mid storey of Honey Myrtle (*Melaleuca decora*) and a shrub and grass understorey.

There is a volcanic intrusion in the central western portion of the site which is associated with steeper terrain, rock fragments in soil profiles and some rock outcropping. In other parts of the Cumberland Plain this geology is often associated with Moist Shale Woodland and Western Sydney Dry Rainforest (NPWS 2002a; Tozer et al. 2010) however at the airport site it contains Grey Box - Forest Red Gum grassy woodland on hills with relatively few species representative of these other communities. Plot/transect data was compared with Tozer et al (2010) diagnostic species lists to confirm the identity of this vegetation type. The observed vegetation may be

because of frequent and/or recent fire and other disturbance at the airport site, which has prevented a succession towards rainforest species.

The above vegetation types grade into Forest Red Gum - Rough-barked Apple grassy woodland along the riparian corridors of Badgerys Creek and other drainage lines through the airport site. This community is a closed woodland or forest of Forest Red Gum, Grey Box and Cabbage Gum (E*ucalyptus amplifolia)* along with Swamp Oak (*Casuarina glauca*), Broad-leaved Apple (*Angophora subvelutina)* and paperbarks (*Melaleuca* spp.). Understorey vegetation is similar to Shale Plains Woodland along with additional moisture loving species such as rushes and sedges.

The condition of these plant community types varies across the airport site as a result of previous land uses and grazing intensity. Areas that have been historically cleared and/or heavily grazed now contain regrowth vegetation in poorer condition. There is moderate to severe weed infestation throughout, with linear remnants along roads and isolated patches in agricultural land the most severely affected. Notwithstanding the generally moderate to poor condition of vegetation at the airport site it has high conservation significance as a result of the presence of threatened biota and the generally limited extent and quality of similar vegetation in the Western Sydney region.

There are patches of derived native grassland at the airport site that comprise poor condition forms of the native vegetation communities described above. These areas contain at least 50% native groundcover, mainly comprising native grasses such as Kangaroo Grass (*Themeda australis*). There is a moderate species richness, but relative low cover and abundance of understorey herbs associated with the woodlands and forests described above. Exotic grasses and herbs are present throughout.

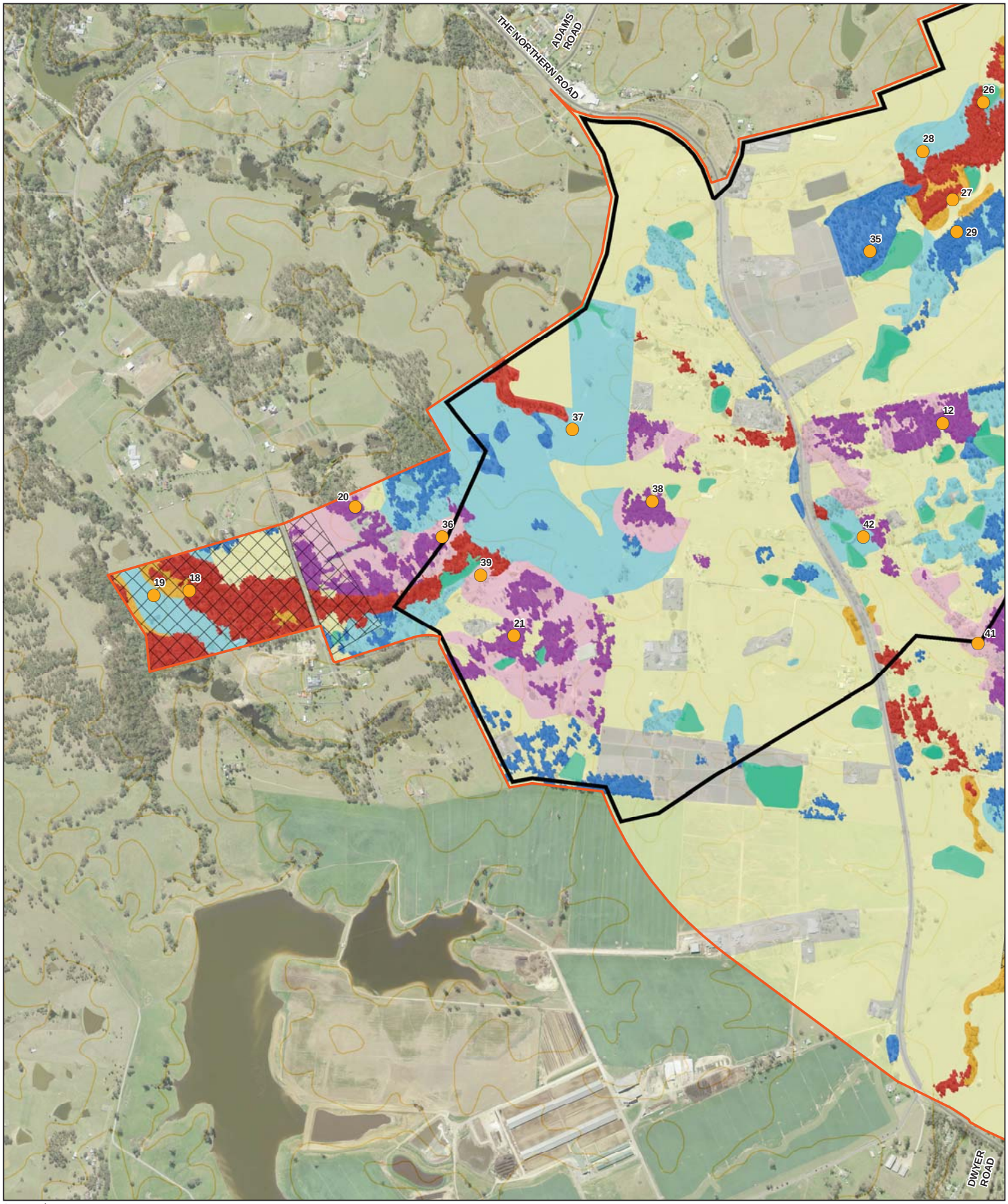
There are a large number of dams and flooded depressions throughout the airport site formed by the construction of barriers across small drainage lines. These water bodies contain a moderate diversity and abundance of native wetland plants.

There are local occurrences of one threatened ecological community (TEC) listed under the EPBC Act and three TECs listed under the TSC Act at the airport site as described in Section 4.5.1. The distribution of plant community types in the airport site is closely tied to soil type, underlying geology and drainage all of which are correlated with geomorphic position.

Table 15 Vegetation zones within the airport site

Vegetation Zone	Condition	EPBC Act Status	TSC Act Status	Area at the site (hectares)	Survey effort
Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	Moderate/good – medium or high	Cumberland Plain Woodland and Shale-gravel Transition Forest (CEEC)	Cumberland Plain Woodland (CEEC)	117.2	Plot/transects 2, 5, 6, 7, 10, 11, 12, 16, 22, 23, 25, 31, 32, 35
Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	Moderate/good - poor		Cumberland Plain Woodland (CEEC)	134.0	Plot/transects 8, 19, 24, 28, 30, 37, 42
Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	Moderate/good – medium or high	Cumberland Plain Woodland and Shale-gravel Transition Forest (CEEC)	Cumberland Plain Woodland (CEEC)	30.2	Plot/transects 20, 21, 36, 38, 40
Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	Moderate/good - poor		Cumberland Plain Woodland (CEEC)	31.0	Plot/transects 39, 41
Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	Moderate/good – medium or high		River Flat Eucalypt Forest (EEC)	92.3	Plot/transects 9, 13, 15, 17, 18, 26, 29, 33
Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	Moderate/good - poor		River Flat Eucalypt Forest (EEC)	18.4	Plot/transects 14, 27, 34
Good condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	Moderate/good – medium or high	Cumberland Plain Woodland and Shale-gravel Transition Forest (CEEC)	Shale-Gravel Transition Forest (EEC)	8.3	Plot/transect 1
Poor condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	Moderate/good - poor		Shale-Gravel Transition Forest (EEC)	2.3	Plot/transect 43
Good condition artificial freshwater wetland on floodplain (HN630)	Moderate/good			35.4	Wetland assessment at targeted frog survey sites 2, 4, 5, 8, 9, 10, 11
Total native vegetation				**469.2**	
Exotic grassland	Cleared			956.4	Plot/transect 3, 4
Cleared land or cropland	Cleared			348.7	General observations
Total				**1774.3**	

EEC – endangered ecological community. CEEC – critically endangered ecological community.



Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Contour
- Roads
- Plot/transect

- Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)
- Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)
- Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)
- Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)
- Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)
- Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)
- Good condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)
- Poor condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)
- Good condition artficial freshwater wetland (HN630)
- Exotic grassland
- Cleared land or cropland

Paper Size A3

0 55 110 220 330 440

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

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Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Assessment

Job Number 21-24265
Revision A
Date 06 Oct 2015

Vegetation zones

Figure 4A

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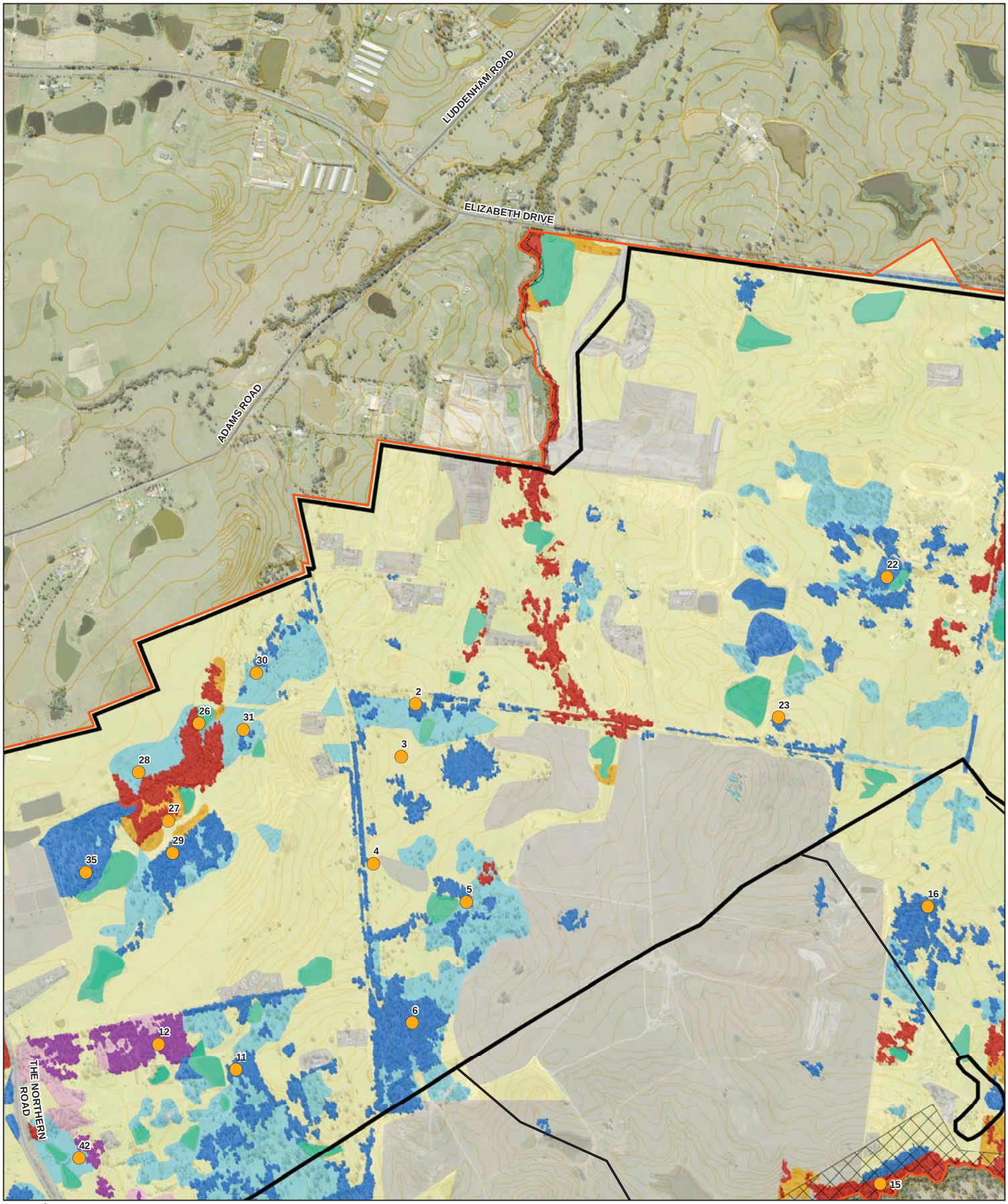

Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Contour
- Roads
- Plot/transect
- Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)
- Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)
- Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)
- Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)
- Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)
- Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)
- Good condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)
- Poor condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)
- Good condition artficial freshwater wetland (HN630)
- Exotic grassland
- Cleared land or cropland

Paper Size A3

0 55 110 220 330 440

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Job Number 21-24265
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Vegetation zones

Figure 4B

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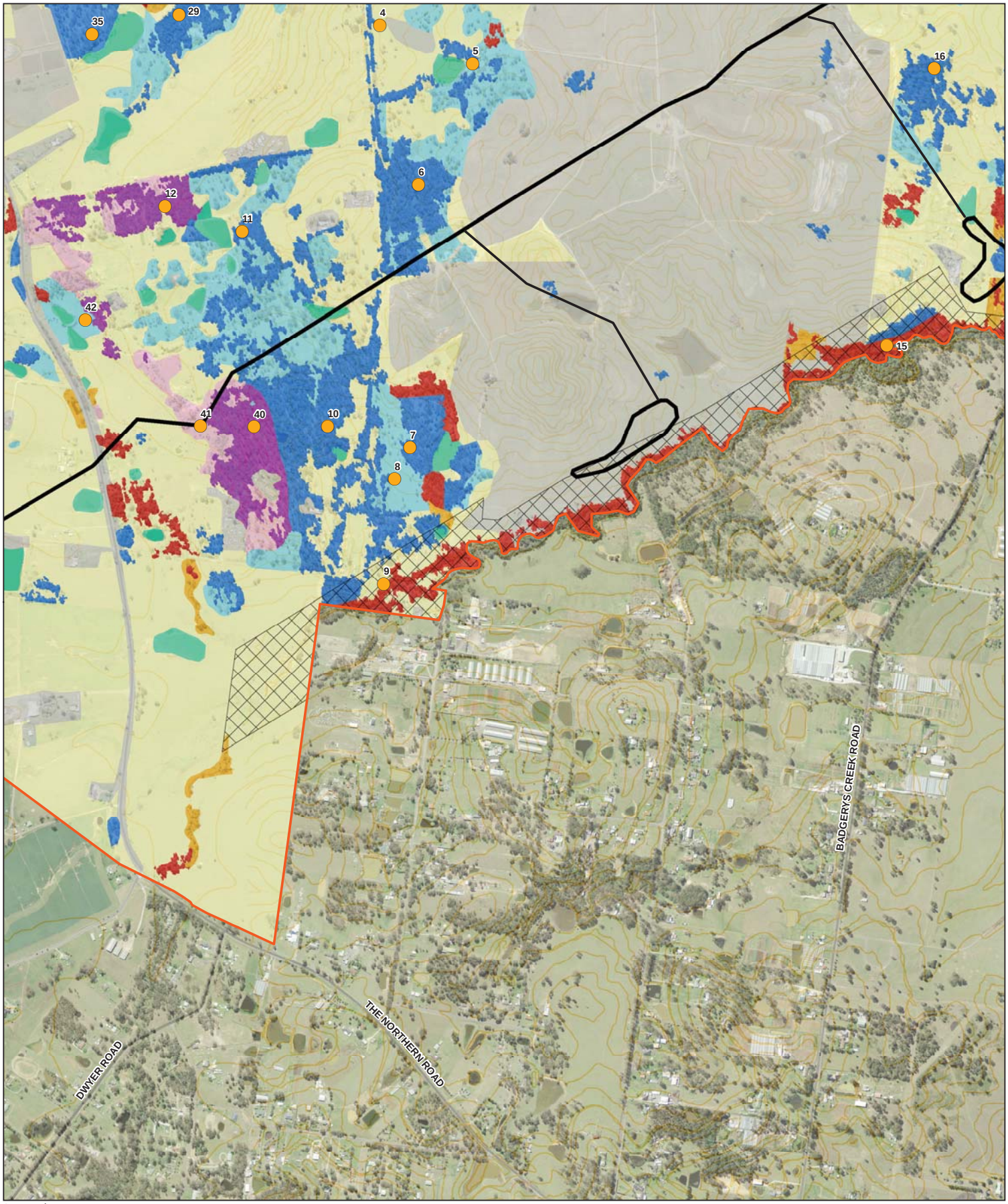

Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Contour
- Roads
- Plot/transect
- Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)
- Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)
- Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)
- Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)
- Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)
- Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)
- Good condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)
- Poor condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)
- Good condition artficial freshwater wetland (HN630)
- Exotic grassland
- Cleared land or cropland

Paper Size A3

0 55 110 220 330 440

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Vegetation zones

Figure 4C

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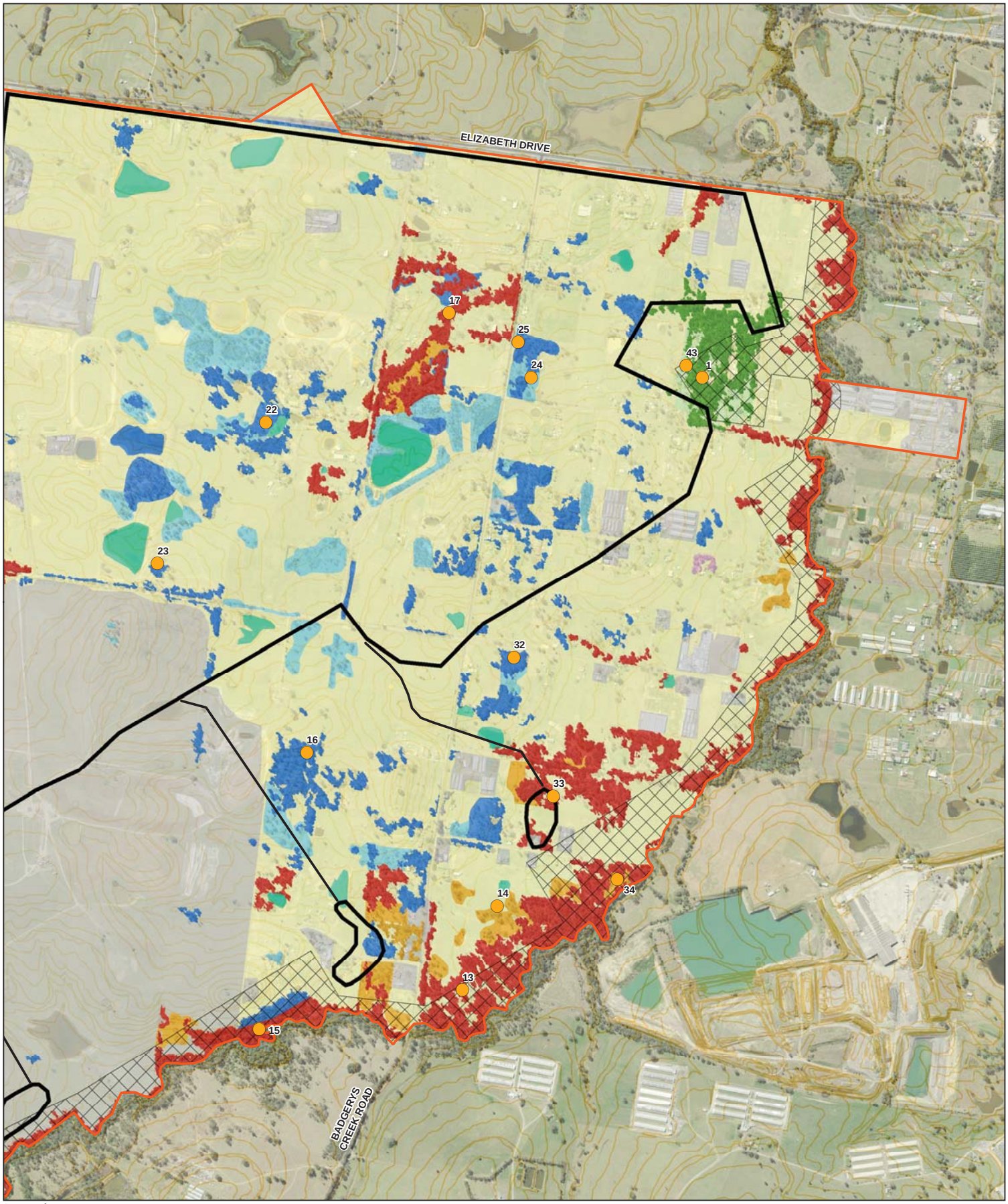

Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Contour
- Roads
- Plot/transect
- Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)
- Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)
- Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)
- Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)
- Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)
- Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)
- Good condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)
- Poor condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)
- Good condition artficial freshwater wetland (HN630)
- Exotic grassland
- Cleared land or cropland

Paper Size A3

0 55 110 220 330 440

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Assessment

Job Number 21-24265
Revision A
Date 06 Oct 2015

Vegetation zones

Figure 4D

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Table 16 Good condition Grey Box - Forest Red Gum grassy woodland on flats

Good condition Grey Box - Forest Red Gum grassy woodland on flats	
Plant community type (OEH, 2015c)	HN528- Grey Box - Forest Red Gum grassy woodland on flats, Sydney
Equivalent Map Units	Cumberland Shale Plains Woodland (GW p29) (Tozer et al. 2010); Shale Plains Woodland (NPWS 2002).
Survey effort	Plot/transects 2, 5, 6, 7, 10, 11, 12, 16, 22, 23, 25, 31, 32, 35.
Condition (DECC, 2008)	Moderate/good – medium or high. Remnant or regrowth native vegetation with near-intact over storey. Species richness was above benchmark in eight of the 14 plots and most native vegetation cover attributes were at benchmark values for this plant community type in the majority of plot/transects sampled. All canopy species were observed regenerating. Few hollow-bearing trees were recorded, including only one in the 14 plots sampled. There were generally low quantities of fallen woody debris, including none in five of the 14 plots sampled. There is frequently high exotic plant cover (10-84 per cent in plot/transects sampled) mainly consisting of grasses and herbs in the under storey.
Conservation significance	Comprises a local occurrence of 'Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest' (Cumberland Plain Woodland) which is listed as a CEEC under the EPBC Act. Also comprises a local occurrence of 'Cumberland Plain Woodland' which is listed as a CEEC under the TSC Act.
Landscape position	On shale derived soils on mid and lower slopes and flats in gently undulating terrain across the airport site.
Structure	Woodland or open forest with a sparse mid storey and a generally sparse shrub/grass understorey. Some patches have a very dense mid storey of Native Blackthorn (*Bursaria spinosa spinosa*).
Over storey	Continuous, around 15-25 metres tall and around 20 per cent cover. Features a mixed canopy of Grey Box (*Eucalyptus moluccana*) and Forest Red Gum (*E. tereticornis*) with occasional Thin-leaved Stringybark (*E. eugenioides*).
Mid storey	Patchy and variable (<1 per cent to 26.5 per cent cover). Generally sparse cover of tall shrubs such as *Dillwynia sieberi* or Gorse Bitter-pea (*Daviesia ulicifolia*) but with occasional very dense patches of Native Blackthorn, Black Wattle *(Acacia decurrens)* or Parramatta Wattle *(Acacia parramattensis)* to five metres tall and 50-80 per cent cover.
Groundcover	Dense and dominated by grasses and grass like plants such as Kangaroo Grass (*Themeda australis*), Weeping Grass (*Microlaena stipoides* var. *stipoides*), Threeawn Speargrass (*Aristida vagans*), Paddock Love Grass (*Eragrostis leptostachya*) and *Lomandra filiformis* subsp. *filiformis*. Other understorey species include: occasional shrubs such as Peach Heath (*Lissanthe strigosa*); moderate cover and species richness of herbs such as *Caesia parviflora var. vittata*, Kidney Weed (*Dichondra repens*), Native Wandering Jew (*Commelina cyanea*) and Blue Trumpet (*Brunoniella australis*); locally high cover of chenopods such as Climbing Saltbush (*Einadia nutans* subsp. *nutans*) and Berry Saltbush (*Einadia hastata*); and moderate cover and species richness of scramblers such as Amulla (*Eremophila debilis*) and *Glycine* species. There are occasional patches of leaf litter and bare earth.
Exotic species	A variety of exotic plants are present throughout this vegetation zone, including localised very dense infestations. Exotic plants present include small trees and tall shrubs such as African Boxthorn (*Lycium ferocissimum*) and African Olive (*Olea europaea* subsp. *cuspidata*); pasture grasses such as *Setaria parviflora,* Kikuyu (*Pennisetum clandestinum*) and Paspalum (*Paspalum dilatatum*); weedy grasses such as African Lovegrass (*Eragrostis curvula*) and Panic Veldtgrass (*Ehrharta erecta*); widespread wind borne herbs such as Fireweed (*Senecio madagascariensis*) and Dandelion (*Taraxacum officinale*); opportunistic herbs of disturbed areas such as Greater Beggar's Ticks (*Bidens subalternans*), Black-berry Nightshade (*Solanum nigrum*) and *Solanum sisymbriifolium*; and climbers such as Moth Vine (*Araujia sericifera*) and Bridal Creeper (*Asparagus asparagoides*).

Good condition Grey Box - Forest Red Gum grassy woodland on flats	
Good condition woodland with a grassy understorey.	
Good condition woodland with a shrub/grass understorey and dense patches of Native Blackthorn.	

Table 17 Poor condition Grey Box - Forest Red Gum grassy woodland on flats

Poor condition Grey Box - Forest Red Gum grassy woodland on flats	
Plant community type (OEH, 2015c	HN528- Grey Box - Forest Red Gum grassy woodland on flats.
Equivalent Map Units	Closest equivalents are Cumberland Shale Plains Woodland (GW p29) (Tozer et al. 2010) and Shale Plains Woodland (NPWS 2002A) though poor condition patches are generally not mapped.
Survey effort	Plot/transects 8, 19, 24, 28, 30, 37, 42.
Condition (DECC, 2008)	Moderate/good – poor, incorporating some areas of 'Low' that feature less than 50 per cent native groundcover. Highly modified remnant or regrowth native vegetation with minimal over storey cover (0 per cent in six of the seven plots sampled). Species richness, mid storey and native ground forb cover attributes were below benchmark values for this plant community type in the majority of plot/transects sampled. Native grass cover was consistently well above benchmark values The majority of the mapped area of this vegetation zone is a derived grassland. There are some patches of derived native Blackthorn shrub land or sub-mature over storey regeneration over exotic groundcover. All canopy species were observed regenerating somewhere within the full extent of this vegetation zone across the airport site but many patches did not feature any regeneration. There were no hollow-bearing trees and very little fallen woody debris (zero in six of the seven plots sampled). There is frequently high exotic plant cover (6-82 per cent in plot/transects sampled) mainly consisting of exotic grasses.
Conservation significance	Does not meet the condition criteria for a local occurrence of the CEEC Cumberland Plain Woodland as defined under the EPBC Act and associated guidelines (DEWHA 2010d). Comprises a local occurrence of 'Cumberland Plain Woodland' listed as a CEEC under the TSC Act and defined in relevant guidelines.
Landscape position	On shale derived soils on mid and lower slopes and flats in gently undulating terrain across the airport site.
Structure	Mainly a derived grassland with a sparse mid storey and very occasional, isolated trees. Some patches of derived shrubland or scrub with a very dense mid storey.
Over storey	Absent other than occasional isolated Grey Box or Forest Red Gum.
Mid storey	Patchy and variable. Generally sparse cover of tall shrubs such as *Dillwynia sieberi* but with occasional very dense patches of Native Blackthorn, Hickory wattle (*Acacia implexa),* Black Wattle or Parramatta Wattle to five metres tall and 25 per cent cover.
Groundcover	Dense and dominated by grasses and grass like plants especially Kangaroo Grass, along with Bladey Grass (*Imperata cylindrica*), Common Couch (*Cynodon dactylon)* Weeping Grass, Speargrasses (A*ristida* sp.) and *Lomandra filiformis* subsp. *filiformis*. Other understorey species include: very occasional shrubs such as Peach Heath; low cover and moderate species richness of herbs such as Kidney Weed, Native Wandering Jew and Blue Trumpet; and scramblers such as *Glycine* species. There are occasional patches of bare earth.
Exotic species	A variety of exotic plants are present throughout this vegetation zone, including localised very dense infestations. Exotic plants present include shrubs and woody vines such as African Boxthorn and Blackberry (*Rubus fruticosus* species aggregrate); pasture grasses such as *Setaria parviflora,* Kikuyu and Paspalum; weedy grasses such as African Lovegrass and Panic Veldtgrass; widespread wind borne herbs such as Fireweed and Dandelion; and opportunistic herbs of disturbed areas such as Cobbler's Pegs (*Bidens pilosa*), Spear Thistle (*Cyrsium vulgare)* and *Solanum sisymbriifolium*.

Poor condition Grey Box - Forest Red Gum grassy woodland on flats	
Derived native grassland with occasional shrubs and regenerating eucalypts.	
Kangaroo Grass dominated derived native grassland.	

Table 18 Good condition Grey Box - Forest Red Gum grassy woodland on hills

Good condition Grey Box - Forest Red Gum grassy woodland on hills	
Plant community type (OEH, 2015c	HN529- Grey Box - Forest Red Gum grassy woodland on shale, Sydney Basin (Grey Box - Forest Red Gum grassy woodland on hills).
Equivalent Map Units	Cumberland Shale Hills Woodland (GW p28) (Tozer et al. 2010); Shale Hills Woodland (NPWS 2002).
Survey effort	Plot/transects 20, 21, 36, 38, 40.
Condition (DECC, 2008)	Moderate/good – medium or high. Remnant or regrowth native vegetation with near-intact over storey that was at or slightly below benchmark values in all but one of the plot/transects sampled. Native mid storey cover was well below benchmark values in four out of the five plot/transects. Species richness, shrub, grass and forb cover attributes and woody debris were at or above benchmark values for this plant community type in the majority of plot/transects sampled. All canopy species were observed regenerating. There are few hollow-bearing trees, including only one in the five plots sampled. There is frequently high exotic plant cover (26-44 per cent in plot/transects sampled) mainly consisting of woody weeds in the mid storey.
Conservation significance	Comprises a local occurrence of 'Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest' (Cumberland Plain Woodland) which is listed as a CEEC under the EPBC Act. Also comprises a local occurrence of 'Cumberland Plain Woodland' which is listed as a CEEC under the TSC Act.
Landscape position	On shale derived soils on mid and upper slopes and ridges in undulating terrain, mainly in the west and south west of the airport site.
Structure	Woodland or open forest with a sparse mid storey and a generally sparse shrub/grass understorey. Some patches have a very dense mid storey of Native Blackthorn.
Over storey	Continuous, around 15-25 metres tall and around 18 per cent cover. Features a mixed canopy of Grey Box and Forest Red Gum with occasional Thin-leaved Stringybark.
Mid storey	Patchy and variable. Generally sparse but with occasional very dense patches of Native Blackthorn or Hickory Wattle (*Acacia implexa)* to five metres tall and up to 10 per cent cover.
Groundcover	Moderately dense, species rich and structurally variable. Groundcover species include: moderate cover of grasses and grass like plants such as, Weeping Grass, Two-colour Panic (*Panicum simile*), Red Grass (*Bothriochloa macra*), Threeawn Speargrass, Many-flowered Mat-rush (*Lomandra multiflora* subsp. *multiflora*) and *Lomandra filiformis* subsp. *filiformis*; occasional shrubs such as Wedge Guinea Flower (*Hibbertia diffusa*); moderate to high cover and species richness of herbs such as Indian Weed *(Sigesbeckia orientalis subsp. orientalis), Plectranthus parviflorus*, Native Wandering Jew, Forest Nightshade (*Solanum prinophyllum*) and Blue Trumpet; locally high cover of chenopods such as Climbing Saltbush and *Einadia trigonos* subsp*. trigonos*; and moderate cover and species richness of scramblers such as Amulla (*Eremophila debilis*) and *Glycine* species. There are occasional patches of leaf litter and bare earth.
Exotic species	A variety of exotic plants are present throughout this vegetation zone, including localised very dense infestations. Exotic plants include localised very dense stands of small trees and tall shrubs such as African Boxthorn, Lantana (*Lantana camara)* and especially African Olive; pasture grasses such as *Setaria parviflora,* Kikuyu and Paspalum; weedy grasses such as African Lovegrass and Panic Veldtgrass; widespread wind borne herbs such as Fireweed and Dandelion; opportunistic herbs of disturbed areas such as Greater Beggar's Ticks, *Solanum sisymbriifolium* and Paddy's Lucerne *(Sida rhombifolia),* including localised severe infestations; and climbers such as Moth Vine.

Good condition Grey Box - Forest Red Gum grassy woodland on hills		
Medium condition woodland with a grassy understorey and moderate weed infestation.		
Good condition woodland with a shrub/grass understorey and dense patches of Native Blackthorn.		

Table 19 Poor condition Grey Box - Forest Red Gum grassy woodland on hills

Poor condition Grey Box - Forest Red Gum grassy woodland on hills	
Plant community type (OEH, 2015c	HN529- Grey Box - Forest Red Gum grassy woodland on hills.
Equivalent Map Units	Closest equivalent is Cumberland Shale Hills Woodland (GW p28) (Tozer et al. 2010) and Shale Hills Woodland (NPWS 2002a) though poor condition patches are generally not mapped.
Survey effort	Plot/transects 39, 41.
Condition (DECC, 2008)	Moderate/good – poor, incorporating some areas of 'Low' that feature less than 50 per cent native groundcover. Highly modified remnant or regrowth native vegetation with no over storey cover (0 per cent in both plots sampled). Species richness was at or below benchmark values, with very low native midstorey cover in both of the plot/transects sampled. Native grass cover was consistently well above benchmark values. Species richness and forb cover were also at benchmark values in ungrazed paddocks or near refuges such as rock outcrops. The majority of the mapped area of this vegetation zone is a derived grassland. There are some patches of derived native Blackthorn shrub land or sub-mature over storey regeneration over exotic groundcover. All canopy species were observed regenerating somewhere within the full extent of this vegetation zone across the airport site but many patches did not feature any regeneration. There were no hollow-bearing trees or fallen woody debris. There is moderate exotic plant cover (34-40 per cent in plot/transects sampled) consisting of either exotic grasses and herbs in the groundcover or dense woody weeds in the mid storey.
Conservation significance	Does not meet the condition criteria for a local occurrence of the CEEC Cumberland Plain Woodland as defined under the EPBC Act and associated guidelines ((DEWHA 2010d). Comprises a local occurrence of 'Cumberland Plain Woodland' listed as a CEEC under the TSC Act and defined in relevant guidelines.
Landscape position	On shale derived soils on mid and upper slopes and ridges in undulating terrain, mainly in the west and south west of the airport site.
Structure	Mainly a derived grassland with a sparse mid storey and very occasional, isolated trees. Some patches of derived shrubland or scrub with a very dense mid storey.
Over storey	Absent other than occasional isolated Grey Box or Forest Red Gum.
Mid storey	Patchy. Very low cover of tall shrubs such as Native Blackthorn but with occasional patches of Native Blackthorn or Hickory wattle to five metres tall and 0.5 per cent cover.
Groundcover	Dense and dominated by grasses and sedges especially Kangaroo Grass, along with Weeping Grass, Two-colour Panic, Red Grass, Paddock Love Grass and Common Fringe-sedge (*Fimbristylis dichotoma*). Other understorey species include: very occasional shrubs such as Peach Heath; moderate cover of Rock Fern (*Cheilanthes sieberi* subsp. *sieberi*); moderate cover and species richness of herbs such as Kidney Weed, Common Woodruff (*Asperula conferta*), and Blue Trumpet; and scramblers such as *Glycine* species. There are occasional patches of bare earth and rock outcropping.
Exotic species	A variety of exotic plants are present throughout this vegetation zone, including localised very dense infestations. Exotic plants present include; dense patches of African Olive; shrubs and woody vines such as African Boxthorn and Blackberry (*Rubus fruticosus* species aggregrate); pasture grasses such as *Setaria parviflora,* Kikuyu and Paspalum; weedy grasses such as Rhodes Grass (*Chloris gayana*) and African Lovegrass; widespread wind borne herbs such as Fireweed and Dandelion; and opportunistic herbs of disturbed areas such as Cobbler's Pegs, Purpletop (*Verbena bonariensis*), Spear Thistle and *Solanum sisymbriifolium*.

Poor condition Grey Box - Forest Red Gum grassy woodland on hills	
	
Derived native grassland with occasional patches of Native Blackthorn.	

Table 20 Good condition Forest Red Gum - Rough-barked Apple grassy woodland

Good condition Forest Red Gum - Rough-barked Apple grassy woodland	
Plant community type (OEH, 2015c	HN526- Forest Red Gum - Rough-barked Apple grassy woodland on floodplains, Sydney Basin (Forest Red Gum - Rough-barked Apple grassy woodland).
Equivalent Map Units	Cumberland River Flat Forest (FoW p33) (Tozer et al. 2010); Alluvial Woodland and Riparian forest (NPWS 2002a).
Survey effort	Plot/transects 9, 13, 15, 17, 18, 26, 29, 33.
Condition (DECC, 2008)	Moderate/good – medium or high. Remnant or regrowth native vegetation with near-intact over storey that was at or slightly below benchmark values in all eight plot/transects sampled. Native mid storey cover was well below benchmark values in four out of eight plot/transects. Species richness and shrub cover was generally above benchmark values for this plant community type in the majority of plot/transects sampled, while grass and forb cover was highly variable. All canopy species were observed regenerating. Hollow-bearing trees a present, including seven in the eight plots sampled. There is frequently high exotic plant cover (16-78 per cent in plot/transects sampled) consisting of woody weeds in the mid storey, herbs in the groundcover and dense vine thickets.
Conservation significance	Comprises a local occurrence of 'River-flat eucalypt forest on coastal floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions' (River-flat eucalypt forest) which is listed as an EEC under the TSC Act.
Landscape position	On alluvial soils on banks and terraces of drainage lines throughout the site including Badgerys Creek, Oaky Creek and their tributaries.
Structure	Closed woodland or forest with a variable, locally dense mid storey and a patchy shrub/grass understorey. Some patches have a very dense mid storey of Native Blackthorn, Paperbarks (*Melaleuca* species), Swamp Oak (*Casuarina glauca)* or Acacia species.
Over storey	Continuous, around 15-25 metres tall and around 17 per cent cover. Features a mixed canopy of Forest Red Gum, Cabbage Gum (*Eucalyptus amplifolia* subsp. *amplifolia)* and Grey Box with occasional Thin-leaved Stringybark.
Mid storey	Patchy and variable (<1 per cent to 50 per cent cover in plot/transects sampled). Moderate in most pareas but with occasional very dense patches of Native Blackthorn, Prickly-leaved Tea Tree (*Melaleuca styphelioides*), Flax-leaved Paperbark (*Melaleuca linariifolia*), Swamp Oak (*Casuarina glauca)* or Acacia species to ten metres tall and up to 49 per cent cover.
Groundcover	Moderately dense, species rich and structurally variable. Groundcover species include: moderate cover of grasses especially Weeping Grass along with Threeawn Speargrass, Early Spring Grass (*Eriochloa pseudoacrotricha*), *Oplismenus aemulus;* and Slender Rat's Tail Grass (*Sporobolus creber*); locally dense patches of sedges such as Slender Flat-sedge (*Cyperus gracilis*), *Cyperus polystachyos and* occasional very dense patches of Native Blackthorn shrubs; moderate to high cover and species richness of herbs such as Indian Weed*, Plectranthus parviflorus*, Native Wandering Jew, Forest Nightshade, Indian Pennywort (*Centella asiatica*) and Blue Trumpet; locally high cover of chenopods such as Climbing Saltbush and *Einadia trigonos* subsp*. trigonos*; and moderate cover and species richness of scramblers such as Amulla, Slender Tick-trefoil (*Desmodium varians*) and *Glycine* species. Native vines such as Headache Vine (*Clematis glycinoides*) are locally abundant. There are occasional patches of leaf litter and bare earth. Drainage lines through this vegetation zone feature high species richness and cover/abundance of native aquatic herbs and ferns such as *Marsilea mutica, Alternanthera denticulate, Eleocharis cylindrostachys, Triglochin microtuberosa* and *Myriophyllum variifolium*,

Good condition Forest Red Gum - Rough-barked Apple grassy woodland	
Exotic species	A variety of exotic plants are present throughout this vegetation zone, including frequent severe infestations. Exotic plants present include localised very dense stands of small trees and tall shrubs such as African Boxthorn, Lantana, Green Cestrum (*Cestrum parqui*), Blackberry and especially African Olive; pasture grasses such as *Setaria parviflora,* Kikuyu and Paspalum; weedy grasses such as Panic Veldtgrass; widespread wind or bird spread herbs such as Fireweed, Madeira Winter Cherry (*Solanum pseudocapsicum*) and Dandelion; opportunistic herbs of disturbed areas such as Greater Beggar's Ticks, *Solanum sisymbriifolium* and Paddy's Lucerne; and localised very severe 'vine thickets' of scramblers such as Wandering Jew (*Tradescantia fluminensis*) and climbers such as Moth Vine, Madeira Vine (*Anredera cordifolia*) and Bridal Creeper *(Asparagus asparagoides)*.
Medium condition forest with intact mid and over storey but severe infestation with exotic vines and scramblers.	
Good condition forest with characteristic mid storey of *Melaleuca* species and Swamp Oak.	

Table 21 Poor condition Forest Red Gum - Rough-barked Apple grassy woodland

Good condition Forest Red Gum - Rough-barked Apple grassy woodland	
Plant community type (OEH, 2015c	HN526- Forest Red Gum - Rough-barked Apple grassy woodland on floodplains, Sydney Basin (Forest Red Gum - Rough-barked Apple grassy woodland).
Equivalent Map Units	Closest match is Cumberland River Flat Forest (FoW p33) (Tozer et al. 2010) and Alluvial Woodland and Riparian forest (NPWS 2002a) though poor condition patches are generally not mapped.
Survey effort	Plot/transects 14, 27, 34.
Condition (DECC, 2008)	Moderate/good – poor, incorporating some areas of 'Low' that feature less than 50 per cent native groundcover. Highly modified remnant or regrowth native vegetation with minimal over storey cover (0 per cent in two of three plots sampled). Species richness, mid storey and native ground forb and shrub cover attributes were at or below benchmark values for this plant community type in the majority of plot/transects sampled. Native grass cover was consistently at or well above benchmark values The majority of the mapped area of this vegetation zone is a derived grassland. There are some patches of derived Swamp Oak or Paperbark low closed woodland or native Blackthorn shrub land. All canopy species were observed regenerating somewhere within the full extent of this vegetation zone across the airport site but many patches did not feature any regeneration. There were no hollow-bearing trees and little fallen woody debris (zero in one plot and below benchmark in all plots sampled). There is frequently high exotic plant cover (6-80 per cent in plot/transects sampled) mainly consisting of grasses and herbs.
Conservation significance	Comprises a local occurrence of River-flat Eucalypt Forest which is listed as an EEC under the TSC Act.
Landscape position	On alluvial soils on banks and terraces of drainage lines throughout the site including Badgerys Creek, Oaky Creek and their tributaries.
Structure	The majority of the mapped area of this vegetation zone is a derived grassland. There are some patches of derived Swamp Oak or Paperbark low closed woodland or native Blackthorn shrub land.
Over storey	Generally absent. Occasional isolated Forest Red Gum, Cabbage Gum or Grey Box.
Mid storey	Patchy and variable. Low cover overall but with occasional very dense patches of Native Blackthorn, Prickly-leaved Tea Tree, Flax-leaved Paperbark and especially Swamp Oak to ten metres tall and up to 29 per cent cover.
Groundcover	Moderately dense, species rich and structurally variable. Groundcover species include: moderate cover of grasses especially Weeping Grass along with Threeawn Speargrass, *Oplismenus aemulus* and Slender Rat's Tail Grass; locally dense patches of sedges such as Slender Flat-sedge and *Cyperus polystachyos;* occasional very dense patches of Native Blackthorn shrubs; low to moderate cover and moderate species richness of herbs such as Kidney Weed, Native Wandering Jew, Indian Pennywort and Lesser Joyweed (*Alternanthera denticulata*); locally high cover of chenopods such as Climbing Saltbush and *Einadia trigonos* subsp*. trigonos*; and moderate cover and species richness of scramblers such as Amulla, Slender Tick-trefoil (*Desmodium varians*) and *Glycine* species. There are frequent patches of bare earth associated with livestock. Drainage lines and flooded depressions through this vegetation zone feature moderate species richness and cover/abundance of native aquatic herbs and ferns such as *Marsilea mutica, Alternanthera denticulate, Eleocharis cylindrostachys, Triglochin microtuberosa* and *Myriophyllum variifolium*,
Exotic species	A variety of exotic plants are present throughout this vegetation zone, including localised very dense infestations. Exotic plants include localised very dense stands of small trees and tall shrubs such as African Boxthorn, Lantana, Green Cestrum and Blackberry; localised dense patches of the exotic sedge Sharp Rush (*Juncus acutus* subsp. *acutus*); pasture grasses such as *Setaria parviflora,* Kikuyu and Paspalum; weedy grasses such as Panic Veldtgrass; widespread wind or bird spread herbs such as Common Sowthistle (*Sonchus oleraceus*), Fireweed, Madeira Winter Cherry and Dandelion; and opportunistic herbs of disturbed areas such as Greater Beggar's Ticks, *Solanum sisymbriifolium* and Paddy's Lucerne.

Good condition Forest Red Gum - Rough-barked Apple grassy woodland	
Derived Swamp Oak scrub.	
Derived native grassland with moisture-loving herbs and sedges adjacent to a good condition patch of this vegetation type.	

Table 22 Good condition Broad-leaved Ironbark – *Melaleuca decora* grassy open forest

Good condition Broad-leaved Ironbark –*Melaleuca decora* grassy open forest	
Plant community type (OEH, 2015c	HN512 - Broad-leaved Ironbark – Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin (Broad-leaved Ironbark - *Melaleuca decora* grassy open forest).
Equivalent map units	Castlereagh Shale-Gravel Transition Forest (DSF p502) (Tozer et al. 2010); Shale Gravel Transition Forest (NPWS 2002a).
Survey effort	Plot/transect 1.
Condition (DECC, 2008)	Moderate/good – high. Near-intact, remnant or regrowth native vegetation. Species richness and most native vegetation cover attributes were at benchmark values for this plant community type. All canopy species were observed regenerating. There were no hollow-bearing trees and there was small quantities of fallen woody debris. This vegetation zone contains very little exotic plant cover compared to most of the airport site and included 0 per cent along the transect sampled. Some exotic plants were observed at low cover/abundances in the surrounding plot.
Conservation significance	Comprises a local occurrence of Cumberland Plain Woodland which is listed as a CEEC under the EPBC Act. Also comprises a local occurrence of the related community Shale-Gravel Transition Forest which is listed as a separate EEC under the TSC Act.
Landscape position	Occurs on free draining, gravelly clay or sandy clay soils derived from alluvium on mid and upper slopes in the north east of the airport site.
Structure	Open forest with a variable, moderate to dense, structurally complex mid storey and a sparse shrub/grass understorey.
Over storey	Continuous, around 15-25 metres tall and around 25 per cent cover. Features a mixed canopy of Broad-leaved Ironbark (*Eucalyptus fibrosa*) and Forest Red Gum with occasional Thin-leaved Stringybark.
Mid storey	Variable and structurally complex, including mature *Melaleuca decora* to 10 metres tall and up to 40 per cent cover throughout; occasional very dense patches of Native Blackthorn, Black Wattle or Parramatta Wattle to five metres tall and 50 per cent cover and a range of other small trees such as Dwarf Cherry (*Exocarpos strictus*) and Wedge-leaf Hop-bush (*Dodonaea viscosa* subsp. *cuneata*).
Groundcover	Dense and dominated by grasses and grass like plants such as Threeawn Speargrass, Purple Wiregrass (*Aristida ramosa*), Wiry Panic (*Entolasia stricta*), Kangaroo Grass, Wallaby Grass (*Austrodanthonia racemosa*), Slender Chloris (*Chloris divaricata* var. *divaricata*), *Lomandra filiformis* subsp. *filiformis* and Many-flowered Mat-rush. Other understorey species include occasional: localised dense patches of *Melaleuca nodosa* and occasional other shrubs such as shrubs such as Rough Guinea Flower (*Hibbertia aspera*), Prickly Currant Bush (*Coprosma quadrifida*) and Sticky Cassinia (*Cassinia uncata*); herbs such as Pomax (*Pomax umbellata*), Variable Stinkweed (*Opercularia varia*), Slender Wire Lily (*Laxmannia gracilis*) and *Caesia parviflora* var. *vittata*; and scramblers such as *Glycine* species. There are occasional patches of leaf litter, gravel and bare earth.
Exotic species	There was no exotic species recorded along the transect sampled. This plant community type has generally very low exotic plant cover. Exotic plant species recorded include African Love Grass and wind-borne environmental weeds such as Dandelion and Fleabane.

Good condition Broad-leaved Ironbark –*Melaleuca decora* grassy open forest	
A patch of this vegetation zone in the northeast of the airport site, showing the characteristic dense mid storey of *Melaleuca decora* and gravelly soil.	

Table 23 Poor condition Broad-leaved Ironbark – *Melaleuca decora* grassy open forest on clay/gravel

Poor condition Broad-leaved Ironbark –*Melaleuca decora* grassy open forest on clay/gravel	
Plant community type (OEH, 2015c	HN512 - Broad-leaved Ironbark – Grey Box - *Melaleuca decora* grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin (Good condition Broad-leaved Ironbark - *Melaleuca decora* grassy open forest on clay/gravel).
Equivalent map units	Castlereagh Shale-Gravel Transition Forest (DSF p502) (Tozer et al. 2010) and Shale Gravel Transition Forest (NPWS 2002a) though poor condition patches are generally not mapped.
Survey effort	Plot/transect 43
Condition (DECC, 2008)	Moderate/good –poor. Sub-mature regrowth native vegetation. No overstorey other than isolated trees. Species richness and most other native vegetation cover attributes were close to benchmark values for this plant community type. All canopy species were observed regenerating. There were no hollow-bearing trees and very little fallen woody debris.
Conservation significance	Does not meet the condition criteria for a local occurrence of the CEEC Cumberland Plain Woodland as defined under the EPBC Act and associated guidelines (DEWHA, 2010d). Comprises a local occurrence of the related community Shale-Gravel Transition Forest which is listed as an EEC under the TSC Act.
Landscape position	Occurs on free draining, gravelly clay or sandy clay soils derived from alluvium on mid and upper slopes in the north east of the airport site.
Structure	Derived scrub, shrubland or grassland.
Over storey	Generally absent. Occasional isolated Broad-leaved Ironbark or Grey Box.
Mid storey	Patchy and variable. Moderate cover overall but with occasional very dense patches of *Melaleuca nodosa, Melaleuca decora* or Native Blackthorn to five metres tall.
Groundcover	Areas of derived grassland feature a dense cover of grasses and grass like plants such as Threeawn Speargrass, Wiry Panic, Kangaroo Grass, Weeping Grass, Two-colour Panic and *Lomandra filiformis* subsp. *filiformis*. Areas of derived scrub or shrubland feature a diverse patchy mix of sub mature mid storey species such as Wedge-leaf Hop-bush and *Melaleuca nodosa,* shrubs such as Rough Guinea Flower and Peach Heath, herbs such as Pomax and Hairy Stinkweed; and scramblers such as *Glycine* species. There are occasional substantial patches of leaf litter, gravel and bare earth.
Exotic species	There is moderate to high exotic plant cover throughout, including African Love Grass, Fleabane, Paddys Lucerne, Kikuyu and a diverse mix of assorted garden escapees.

Poor condition Broad-leaved Ironbark –*Melaleuca decora* grassy open forest on clay/gravel	
A patch of derived *Melaleuca* scrub.	

Table 24 Good condition artificial freshwater wetland on floodplain

Good condition artificial freshwater wetland on floodplain (HN630)	
Plant community type (OEH, 2015c	HN630 - *Phragmites australis* and *Typha orientalis* coastal freshwater wetlands of the Sydney Basin (Freshwater wetland).
Equivalent map unit	Closest match is Coastal Freshwater lagoon (FrW p313) though both natural and artificial examples have not been mapped because patches are too small to model (Tozer et al. 2010). NPWS (2002) does not map or describe freshwater wetlands.
Survey effort	Wetland assessment at targeted frog survey sites 2, 4, 5, 8, 9,10,11.
Condition (DECC, 2008)	Moderate/good. Near-intact, remnant native vegetation where this plant community type occurs throughout the majority of the airport site. Structure and species composition has probably been affected by changes to the drainage of the airport site, including creation of near-permanently inundated sedgelands upstream of culverts. These changes fall within the natural range of variation of the community.
Conservation significance	Not listed under the EPBC Act. Does not comprise an occurrence of the TEC 'Freshwater wetlands on coastal floodplains' listed under the TSC Act because artificial wetlands created on previously dry land are not regarded as part of this community (DECC, 2008).
Landscape position	Occurs on near-permanently inundated soils derived from alluvium on lower flats, depressions and drainage lines throughout the airport site. Vegetation structure appears to vary with inundation frequency and depth and also proximity to native woodland or forest.
Structure	Sedgeland or wet herbfield with a variable, moderate to dense understorey of shrubs, grasses, sedges , rushes and herbs. Artificial water bodies without native wetland vegetation have not been included in this vegetation zone. Large water bodies have been identified and included in 'Cleared land and cropland'. A number of smaller water bodies also fall within the mapped area of 'Exotic grassland'.
Over storey	Generally absent. Occasional isolated Cabbage Gum, *Melaleuca decora,* Flax-leaved Paperbark or Swamp Oak.
Mid storey	Generally absent. Occasional patches of *Melaleuca* species or Tantoon (*Leptospermum polygalifolium*) to two metres tall and up to 70 per cent cover.
Groundcover	Dense, structurally complex and variable. The most widespread form is a rushland, of species such as Common Reed (*Phragmites australis*), Cumbungi (*Typha orientalis*), Spike Rush and *Schoenoplectus validus*. Other wetland species include: moisture loving grasses such as Water Couch (*Zoysia macrantha* and Cooch; floating aquatic ferns such as Nardoo (*Marsilea mutica)* and *Azolla* species; emergent aquatic herbs such as Wooly Frogmouth (*Phylidrum lanuginosum), Persicaria* species and *Ludwigia peploides* subs. *montevidensis*; submerged aquatic herbs such as *Triglochin microtuberosum* and *Myriophyllum* species; and moisture loving herbs of wetland margins such as *Centella asiatica* and Swamp Goodenia (*Goodenia paniculata*).
Exotic species	There is generally low to moderate exotic plant cover. There is low to moderate cover of exotic moisture loving herbs such as *Ludwigia peruviana* throughout and occasional localised dense patches of the exotic sedge Sharp Rush. They are frequently fringed by African Love Grass or pasture grasses because the majority of these freshwater wetlands are surrounded by exotic grassland in cleared agricultural land. There is a localised severe infestation of Alligator Weed (*Alternanthera philoxeroides*) in the north western portion of the airport site associated with a dammed section of Oaky Creek.

Good condition artificial freshwater wetland on floodplain (HN630)	
An artificial freshwater wetland with native emergent rushes, fringing sedges and floating aquatic ferns surrounded by derived native grassland and exotic pasture grasses.	
An artificial freshwater wetland with native emergent rushes and sedges, water-loving grasses and herbs and floating aquatic ferns surrounded by native riparian forest.	

Table 25 Exotic grassland

Exotic grassland	
Plant community type (OEH, 2015c	No equivalent plant community type.
Survey effort	Plot/transects 3 and 4.
Condition (DECC, 2008)	Cleared. Very low native over storey and no mid storey cover. Less than 50 per cent of the ground cover present is native and native cover is frequently less than 10 per cent.
Conservation significance	Exotic vegetation.
Landscape position	Occurs on shale, alluvium and shale-gravel transition derived soils in a variety of topographic positions across the airport site. The most extensive areas are associated with lower slopes and alluvial flats adjoining Badgerys Creek in the east of the airport site and gently undulating terrain through the central portion of the airport site.
Structure	Closed tussock grassland or closed stoloniferous (i.e. running along the ground) grassland. Some areas of exotic garden vegetation, artificial water bodies, gravel tracks, houses and farm infrastructure have been included in the mapped extent of this vegetation zone.
Over storey	Absent apart from isolated paddock trees, which are frequently senescent (i.e. dead or dying).
Mid storey	Absent apart from occasional isolated Native Blackthorn, Swamp Oak, acacias or *Dilwinia sieberi.*
Groundcover	Dominated by exotic grasses as described below. A patchy and variable cover of native species is occasionally present, including shrubs such as Peach Heath, grasses such as Kangaroo Grass, Speargrass (*Aristida* species) and Common Couch, sedges such as Common Fringe-sedge; and scramblers such as *Glycine* species. There are occasional extensive areas of bare earth associated with grazing, top soil removal or dumped fill.
Exotic species	Moderate to very high exotic plant cover dominated by pasture grasses such as Kikuyu, *Setaria parviflora* and Carpet Grass (*Axonopus fissifolius).* There are also extensive areas dominated by noxious or environmental weeds such as African Love Grass, Khaki Weed (*Alternanthera pungens*), Blackberry (*Rubus fruticosus* species aggregate) or Noogoora Burr (*Xanthium occidentale)* and infestations of environmental weeds such as Dandelion, Rhodes Grass (*Chloris gayana*), *Solanum sysimbrifolium*, Stinkgrass (*Eragrostis cilianensis*) and Lamb's Tongues (*Plantago lanceolata*) throughout.
Heavily grazed exotic grassland.	

Exotic grassland	
Ungrazed exotic grassland.	

Table 26 Cleared land and cropland

Cleared land and cropland	
Plant community type (OEH, 2015c	No equivalent plant community type.
Survey effort	General observations.
Condition (DECC, 2008)	Cleared. No native over storey or mid storey. Less than 50 per cent of the ground cover present is native and/or >90 per cent of the ground cover is bare earth or hard stand.
Conservation significance	Cleared land or exotic vegetation.
Landscape position	Occurs on shale, alluvium and shale-gravel transition derived soils in a variety of topographic positions across the airport site. The most extensively cleared areas are associated with small rural residential lots in the suburb of Badgerys Creek in the east of the airport site, a quarry in the central north of the site and cropland on gently undulating terrain through the central portion of the airport site.
Structure	No natural structural equivalent. This vegetation zone includes planted or fallow cropland, exotic garden vegetation, artificial water bodies, bitumen roads and tracks, a quarry, houses and farm infrastructure.
Over storey	Absent apart from isolated paddock trees, which are frequently senescent (i.e. dead or dying).
Mid storey	Absent apart from occasional isolated Native Blackthorn, Swamp Oak, acacias or *Dilwinia sieberi.*
Groundcover	Dominated by exotic crops or weeds as described below. Patchy and variable cover of opportunistic native species is occasionally present, including shrubs such as Peach Heath, grasses such as Kangaroo Grass, Speargrass (*Aristida* species) and Common Couch, sedges such as *Juncus usitasis* and scramblers such as *Glycine* species. There are extensive areas of infrastructure or bare earth associated with quarrying, race tracks, fallow cropland, top soil removal or dumped fill.
Exotic species	There is patchy and variable exotic plant cover dominated by flower, grain or vegetable crops. There are also extensive areas dominated by noxious or environmental weeds such as African Olive, Blackberry or Inkweed (*Phytolacca octandra)* and minor infestations of environmental weeds such as African Love Grass, *Bidens* species, Rhodes Grass, *Solanum sysimbrifolium* and Lamb's Tongues throughout.
Extensive green houses comprising cleared land, distinct from the surrounding exotic grassland.	

Cleared land and cropland	
Ploughed cropland at the location of previous records of *Pultenaea parviflora* (Biosis 1999; SMEC 2014) (see Section 4.5.2). Part of an extensive commercial farm in the centre of the site.	

4.2.3 Noxious and environmental weeds

The Australian Weeds Strategy (AWS) provides a framework to establish consistent guidelines for all parties, identifying priorities for weed management across the nation with the aim of minimising the impact of weeds on Australia's environmental, economic and social assets (AWS 2015). The AWS includes the identification of 'weeds of national significance' (WoNS) which are recognised as Australia's worst invasive plants. These weeds cause negative impacts to many of Australia's natural and productive landscapes. A total of nine WoNs were observed at the airport site (Table 27).

Eight of the WoNS recorded at the airport site are also listed as noxious weeds under the NW Act in the Liverpool Local Government Area control area surrounding the airport site. A further seven listed noxious weed species were recorded at the airport site (DPI 2015b). The Noxious Weeds Act Control Category and control requirements for these species are included in Table 27. Noxious weeds are placed into one of five categories, with control requirements of Class 1 weeds the most onerous (is total eradication) and no control requirements for Class 5 weeds, although Class 5 weeds are notifiable and have restrictions on their sale and movement. These control requirements are not a legal requirement on Commonwealth land however have been included as a guide to the comparative seriousness of each weed species.

As stated in Section 4.2.1 the airport site is likely to contain additional exotic plant species to those revealed by the field surveys because survey effort was not focussed on domestic gardens and other areas that were dominated by exotic plants. The airport site may therefore contain additional WoNS and noxious weeds. Those species identified in Table 27 should be considered a guide to the most serious and widespread of the weeds at the airport site.

Table 27 Noxious weeds and WoNS recorded at the airport site

Scientific Name	Common Name	WoNS ? (AWS 2015)	NW Act Control Category (DPI 2015b)	Control Requirements (DPI 2015b)
Alternanthera philoxeroides	Alligator Weed	Yes	3	The plant must be fully and continuously suppressed and destroyed.
Anredeira cordifolia	Madeira Vine	Yes		
Asparagus asparagoides	Bridal Creeper	Yes	4	The plant must not be sold, propagated or knowingly distributed.
Bryophyllum species	Mother of Millions	No	4	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread and the plant must not be sold, propagated or knowingly distributed.
Cestrum parqui	Green Cestrum	No	3	The plant must be fully and continuously suppressed and destroyed.
Cortaderia selloana	Pampas Grass	No	3	The plant must be fully and continuously suppressed and destroyed and the plant must not be sold, propagated or knowingly distributed.
Lantana camara	Lantana	Yes	4	The growth of the plant must be managed in a manner that reduces its numbers spread and incidence and continuously inhibits its reproduction and the plant must not be sold propagated or knowingly distributed.
Ligustrum lucidum	Small-leaved Privet-	No	4	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread.
Ligustrum sinense	Broad-leaved Privet	No	4	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread.
Lycium feroccissimum	African Boxthorn	Yes	4	The plant must not be sold, propagated or knowingly distributed.

Scientific Name	Common Name	WoNS ? (AWS 2015)	NW Act Control Category (DPI 2015b)	Control Requirements (DPI 2015b)
Olea europa subsp. cuspidata	African Olive	No	4	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread and the plant must not be sold, propagated or knowingly distributed.
Opuntia stricta	Common Prickly Pear	Yes	4	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread and the plant must not be sold, propagated or knowingly distributed.
Ricinus communis	Castor Oil Plant	No	4	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread.
Rubus fruticosus species aggregate	Blackberry	Yes	4	The growth of the plant must be managed in a manner that continuously inhibits the ability of the plant to spread and the plant must not be sold, propagated or knowingly distributed. This is an All of NSW declaration.
Salvinia molesta	Salvinia	Yes	2	Regionally Prohibited Weed The plant must be eradicated from the land and that land must be kept free of the plant.
Senecio madagascariensis	Fireweed	Yes	4	The plant must not be sold, propagated or knowingly distributed.



Blackberry infestation in an area of exotic grassland.

Scientific Name	Common Name	WoNS ? (AWS 2015)	NW Act Control Category (DPI 2015b)	Control Requirements (DPI 2015b)



African Olive, African Boxthorn and exotic grasses and herbs in remnant woodland in a road corridor.

The distribution and abundance of WoNS and noxious weeds are linked to disturbance. Particularly severe or extensive infestations include:

- Madeira Vine, Bridal Creeper, Lantana, privet species and African Olive in the riparian corridor of Badgerys Creek.
- African Olive and privet species in the riparian corridors of small drainage lines in the west of the airport site.
- Alligator Weed in dammed sections of Oaky Creek and the adjoining floodplain in the north of the airport site.
- African Boxthorn, African Olive, Common Prickly Pear and Blackberry on the margins of commercial farms in the centre of the airport site and on rural residential lots in the suburb of Badgerys Creek.

There are patchy, generally minor infestations of wind and vehicle-spread environmental weeds throughout the airport site. These widespread weeds include African Love Grass and herbs such as Dandelion, Fleabane, Cobblers Pegs and the WoNs Fireweed.

4.2.4 Groundwater dependent ecosystems

The Atlas of Groundwater Dependent Ecosystems (GDEs) (BOM 2015c) maps the potential for creeks and vegetation to be either groundwater dependent or inflow dependent. No creeks in the airport site are mapped as being GDEs that are reliant on the surface expression of groundwater (rivers, springs, wetlands). South Creek to the east and the Nepean River to the west are both mapped as this type of GDE.

Most large patches of native vegetation (including riparian vegetation) at the airport site are mapped in BOM 2015c as having a high potential for groundwater interaction (i.e. they are likely to be GDEs that are reliant on subsurface groundwater). Some patches of native vegetation are mapped as having a low or moderate potential for groundwater interaction. Native vegetation along Badgerys Creek is mapped as being highly likely to be an inflow dependent ecosystem

(reliant on groundwater in addition to rainfall). Most other patches of native vegetation at the airport site are also mapped as being likely or highly likely to be inflow dependent (BOM 2015c).

As part of the NSW Office of Water's risk assessment guidelines for GDEs, the probability of vegetation types in coastal NSW being GDEs was assessed by Kuginis et al (2012). According to Kuginis et al (2012) all native vegetation communities present at the airport site are likely to be GDEs.

Given the above mapping by BOM (2015c) and identification of GDEs by Kuginis et al (2012), it is assumed that all native vegetation at the airport site is groundwater dependent, at least to some degree.

4.3 Terrestrial fauna species and habitats

4.3.1 Fauna species

A high diversity of fauna species was recorded at the airport site during the recent surveys and the surveys by Biosis Research (1997) and SMEC (2014). A total of 172 fauna species were recorded during the recent survey, including 126 bird species, 10 bat species, 10 terrestrial or arboreal mammal species, 10 frog species, 10 reptile species, four snail species, and two fish species. As many as 10 other microchiropteran bat species may also have been recorded, but poor data quality and/or interspecific call similarities precluded reliable identification of additional species. A further 20 fauna species, including 10 bird species, seven mammal species, two reptile species and one frog species were recorded by Biosis Research (1997) and/or SMEC (2014). The full list of species recorded is presented in Appendix C.

One threatened fauna species listed under the EPBC Act was recorded at the airport site. The Grey-headed Flying-fox (*Pteropus poliocephalus*) was recorded during the recent surveys and the surveys for the 1999 EIS (PPK 1999). A further 10 threatened fauna species listed under the TSC Act (but not under the EPBC Act) have been recorded at the airport site during current and previous surveys. These are discussed in more detail in section 4.5.3. Locations of threatened fauna recorded at the airport site are shown on Figure 6.

A number of introduced fauna species were recorded. These included seven bird species, six mammal species (including the Red Fox (*Vulpes vulpes*), Goat (*Capra hircus*) and Rabbit (*Oryctolagus cuniculus*), one fish species (Mosquitofish (*Gambusia holbrooki*)), and two snail species.

4.3.2 Fauna habitats

Five broad fauna habitat types were recorded within the airport site:

- grassland and cropped areas;
- native woodland;
- riparian forest;
- dams; and
- buildings and other structures.

These are described in Table 28 to Table 32 below.

Table 28 Fauna habitats of grassland and cropped areas

Grassland and cropped areas		
Description	The majority of the airport site contains grassland within fenced grazing land. These areas would have historically supported native woodland vegetation but have been extensively modified by previous clearing and agriculture. Exotic grassland and cleared land contain few habitat resources of relevance to most native species due to low structural and floristic diversity. Exotic grasses and herbs would provide foraging resources for relatively mobile and opportunistic native fauna species. Occasional paddock trees and shrubs (e.g Native Blackthorn or African Olive) also occur in these areas. Regrowth trees and shrubs would provide some foraging resources for native woodland birds. Most of the species recorded in grassland areas would use these areas as an adjunct to the higher quality, more extensive areas of suitable habitat at and adjoining the airport site. Some small fauna species such as lizards may rely on grassland habitat for their survival.	
Typical fauna species recorded	Bird species commonly recorded in this habitat type include the Magpie-lark (*Grallina cyanoleuca*), Australian Magpie (*Cracticus tibicen*), Australian Raven (*Corvus coronoides*), White-winged Chough (*Corcorax melanorhamphos*), Australian Pipit (*Anthus novaeseelandiae*) and Welcome Swallow (*Hirundo neoxema*). Use of fertiliser in some paddocks led to large number of birds such as the Straw-necked Ibis (*Threskiornis spinicollis*) foraging in fields. Where grass was long, cryptic species such as the Brown Quail (*Coturnix ypsilophora*) were sometimes observed. A range of raptors were recorded hunting over the grassland areas. These included the Black-shouldered Kite (*Elanus axillaris*), Brown Falcon (*Falco berigora*), Wedge-tailed Eagle (*Aquila audax*) and the Little Eagle (*Hieraaetus morphnoides*). Double-barred Finches (*Taeniopygia bichenovii*), Yellow-rumped Thornbills (*Acanthiza chrysorrhoa*) and Superb Fairy-wrens (*Malurus superbus*) were observed where shrubs and paddock trees were present. Grassland and cropped areas provide foraging habitat for larger herbivorous species, including the Eastern Grey Kangaroo (*Macropus giganteus*) and Swamp Wallaby (*Wallabia bicolor*). These mammals were recorded only in small numbers. Bats typical of open agricultural land such as the White-striped Freetail Bat (*Tadarida australis*) and Gould's Wattled Bat (*Chalinolobus gouldii*) were recorded. Grassland areas also provides habitat for a range of reptile species, including snakes and small lizards. Small grass skinks (*Lamproholis* spp.) were observed, as was a Red-bellied Black-snake (*Pseudechis porphyriacus*). Spotted Grass Frogs (*Limnodynastes tasmaniensis*) were heard calling from small soaks in grassland areas and an Eastern Dwarf Tree Frog (*Litoria fallax*) was recorded in thick grass.	
Threatened fauna species recorded	Little Eagle (*Hieraaetus morphnoides*) (TSC Act)	Forages for rabbits and other mammals in grassland.
Migratory fauna species recorded	Cattle Egret (*Ardea ibis*)	Foraging in fields in association with cattle. Roosting in paddock trees
	White-throated Needletail (*Hirundapus caudacudatus*)	Foraging for insects above grassland areas
Introduced species recorded	European Rabbit (*Oryctolagus cuniculus*) Brown Hare (*Lepus europaeus*) Red Fox (*Vulpes vulpes*) House Mouse (*Mus musculus*)	

Grassland and cropped areas



Cropped land.



Exotic grassland.

Table 29 Fauna habitats of native woodland

Native Woodland	
Description	Native woodland at the airport site provides moderate quality fauna habitats. Habitat resources include: mature canopy trees and associated nectar, fruits and leaves as well as foraging substrate; a range of fruiting and flowering small trees and shrubs; and connectivity with wetland and aquatic habitat. Woodland and forest at the airport site forms some more extensive patches particularly where it is connected by riparian corridors (see Figure 3) however the majority is fragmented and subject to edge effects. There are roads, residences, agriculture and industry throughout the airport site and associated noise and light disturbance and barriers to fauna movement. Grazing and the presence of exotic pest fauna would further reduce the value of habitats. The airport site and broader airport site contain only moderate quantities of pre-European occupation age trees and associated habitat resources such as tree-hollows and stags. These trees include hollows with a range of sizes, orientations and landscape positions and both living and dead trees. *Eucalyptus* species provide foraging and shelter resources for a range of birds and mammals. Foraging resources include seasonal nectar resources, seeds and insects. Winter-flowering acacias and Native Blackthorn would help provide year-round foraging resources for a range of native birds, bats and mammals. Much of the shrub and ground layer vegetation and habitat features of the woodland and forest in the airport site have been removed and 'cleaned up' for grazing. Woodland at the airport site generally contains low quantities of woody debris and leaf litter, although some patches have higher quantities of these resources. Fallen timber and leaf litter provides shelter habitat for small reptiles, snakes and small mammals. A number of termite mounds were observed within the airport site.
Typical fauna species recorded	Nectarivorous species including the Eastern Spinebill (*Acanthorhynchus tenuirostris*) and White-plumed Honeyeater (*Lichenostomus penicillatus*) were recorded foraging in woodland areas. Insectivorous species recorded included the Rufous Whistler (*Pachycephala rufiventris*), Golden Whistler (*Pachycephala pectoralis*), Black-faced Cuckoo-shrike (*Coracina novaehollandiae*), Eastern Yellow Robin (*Eopsaltria australis*) and Grey Shrike-thrush (*Colluricincla harmonica*). In some woodland patches Bell Miners (*Manorina melanophrys*) were dominant. Small and gregarious flocking bird species such as Silvereye (*Zosterops lateralis*), Red-browed Finches (*Neochmia temporalis*), Double-barred Finches (*Taeniopygia bichenovii*), White-browed Scrubwren (*Sericornis frontalis*) and Grey Fantail (*Rhipidura albiscapa*) were recorded foraging in the shrubby midstorey where this was present. Hollow-bearing trees provide nesting habitat for species such as the Galah (*Eolophus roseicapilla*), Eastern Rosella (*Platycercus eximius*) and Common Brush-tailed Possum (*Trichosurus vulpecula*). Microbat species recorded included species typical of open woodland and/or agricultural areas, and some species that require large tracts of continuous vegetation. The East Coast Freetail Bat (*Mormopterus (Micronomus) norfolkensis*) was the most common microchiropteran bat species recorded at the airport site. Other species included the Chocolate Wattled Bat (*Chalinolobus morio*) and Eastern Freetail Bat (*Mormopterus ridei*). The Eastern False Pipistrelle (*Falsistrellus tasmaniensis*), which does require larger tracts, was possibly recorded during recent surveys and recorded previously by Biosis Research (1999). This species may use the Badgerys Creek corridor and large adjacent woodland patches for foraging and breeding. Elegant Snake-eyed Skinks (*Cryptobepharus pulcher*) were regularly observed basking on logs and timber, and Dark-flecked Garden Sunskinks (*Lampropholis delicata*) were regularly observed in the leaf litter. The Cumberland Plain Land Snail (*Meridolum corneovirens*) and Common Southern Carnivorous Snail (*Austrorhytida capillacea*) were recorded where deep litter occurred at the base of trees. Termite mounds showed some evidence of disturbance, most likely from Short-beaked Echidnas (*Tachyglossus aculeatus*).

Native Woodland		
Threatened fauna species recorded	Grey-headed Flying-fox (*Pteropus poliocephalus*) EPBC Act/TSC Act	Would forage throughout woodland patches. No breeding habitat present.
	East Coast Freetail Bat (*Mormopterus norfolkensis*) - TSC Act	Would forage throughout woodland patches. May breed in hollow-bearing trees.
	Little Lorikeet (*Glossopsitta pusilla*) - TSC Act	Would forage throughout woodland patches. Unlikely to breed in the area.
	Scarlet Robin (*Petroica boodang*) - TSC Act	Would forage throughout woodland patches. Unlikely to breed in the area.
	Varied Sittella (*Daphoenositta chrysoptera*) - TSC Act	Would forage throughout woodland patches. May breed in the area.
	Cumberland Plain Land Snail (*Meridolum corneovirens*) - TSC Act	Occurs in leaf litter in woodland patches.
Migratory fauna species recorded	Rufous Fantail (*Rhipidura rufifrons*)	Would forage throughout woodland patches. Unlikely to breed in the area.
Introduced species recorded	Garden Snail (*Cantareus aspersa*) Asian Tramp Snail (*Bradybaena similaris*)	



Shale-Gravel Transition Forest.



Cumberland Plain Woodland.

Table 30 Fauna habitats of riparian forest

Riparian forest	
Description	There is a relatively extensive network of drainage lines and waterbodies across the airport site. Most drainage lines feature near-intact geomorphology and good instream and riparian vegetation but moderate to severe weed infestation and some evidence of degradation by cattle such as grazing, bank erosion, increased turbidity and probably also nutrient enrichment from waste. The main creek is Badgerys Creek which runs from the south-west along the southern and eastern boundaries of the airport site. Much of Badgerys Creek is vegetated. Creek banks are generally steep and are often dominated by weeds. Some patches of emergent aquatic vegetation (eg *Typha*) are present long the creek. Riparian forest is a closed woodland or forest of eucalypts with Swamp Oak (*Casuarina glauca*) present along the margins of the creeks. This species also occurs on the associated flats. A range of paperbarks (*Melaleuca* spp.) are also present. Understorey vegetation is similar to the adjacent native woodland along with additional moisture loving species such rushes and sedges. Large, hollow-bearing trees tend to occur in higher densities along the riparian corridor than in other woodland patches. *Eucalyptus* and other species provide foraging and shelter resources for a range of birds and mammals. Foraging resources include seasonal nectar resources, seeds and insects. Winter-flowering acacias and paperbarks would help provide year-round foraging resources for a range of native birds, bats and mammals. Much of the shrub and ground layer vegetation and habitat features of the riparian areas in the airport site have been removed and 'cleaned up' for grazing. Low quantities of woody debris and leaf litter are present, although some patches have higher quantities of these resources. Fallen timber and leaf litter provides shelter habitat for small reptiles, snakes and small mammals. Dense weed infestations are present along the creek banks which may also reduce habitat quality for some species. Drainage lines provide habitat for native fish and aquatic invertebrates and breeding habitat for a number of stream breeding frogs. These drainage lines are not suitable habitat for any of the threatened frogs with the potential to occur in the locality, which are generally associated with clear, rocky streams located on sandstone substrates higher in the catchment.
Typical fauna species recorded	A higher diversity of bird species tended to occur along the Badgerys Creek riparian corridor compared to woodland patches. Species recorded included the Scarlet Robin (*Petroica boodang*), Varied Sittella (*Daphoenositta chrysoptera*), and Black Bittern (*Ixobrychhus flavicollis*), listed as vulnerable species under the TSC Act. The migratory Rufous Whistler (*Rhipidura rufifrons*) was observed at a number of locations, including along Badgerys Creek. Other species included the Scarlet Honeyeater (*Myzomela sanguinolenta*), Weebill (*Smicrornis brevirostris*), Olive-backed Oriole (*Oriolus sagittatus*), Fan-tailed Cuckoo (*Cacomantis flabelliformis*), Eastern Shrike-tit (*Falcunculus frontatus*), Azure Kingfisher (*Ceyx azureus*) and Buff-rumped Thornbill (*Acanthiza reguloides*). Some of these species also occurred in woodland patches away from riparian corridors. The Swamp Wallaby (*Wallabia bicolor*) was recorded along the riparian corridor. A small colony of microbats was observed under the bridge over Badgerys Creek on Badgerys Creek Road. Microbats recorded included the East Coast Freetail Bat (*Mormopterus norfolkensis*) and the Large-footed Myotis (*Myotis macropus*) (probable record). This latter species would forage along the creek and nearby dams. Eastern Snake-necked Turtles (*Chelodinia longicolllis*) were observed on occasion in the creeks. Also recorded were Eastern Water Skinks (*Egernia quoyii*) and Australian Water Dragons (*Intellagama lesueurii*). The Striped Marsh Frog (*Limnodynastes peroni*) was the most common frog heard calling along the creeks. Native fish such as gudgeons were observed, as well as introduced species such as the Mosquitofish (*Gambusia holbrooki*).

Riparian forest		
Threatened fauna species recorded	Grey-headed Flying-fox (*Pteropus poliocephalus*) EPBC Act/TSC Act	Would forage throughout riparian forest. No breeding habitat present.
	East Coast Freetail Bat (*Mormopterus norfolkensis*) - TSC Act	Would forage throughout riparian forest. May breed in hollow-bearing trees.
	Large-footed Myotis (*Myotis macropus*) – TSC Act	Would forage along creeklines. May roost in hollow-bearing trees.
	Little Lorikeet (*Glossopsitta pusilla*) - TSC Act	Would forage throughout riparian forest. Unlikely to breed in the area.
	Scarlet Robin (*Petroica boodang*) - TSC Act	Would forage throughout riparian forest. Unlikely to breed in the area.
	Varied Sittella (*Daphoenositta chrysoptera*) - TSC Act	Would forage throughout riparian forest. May breed in the area.
	Black Bittern (*Ixobrychhus flavicollis*) – TSC Act	Would forage and may breed within the riparian forest.
	Cumberland Plain Land Snail (*Meridolum corneovirens*) - TSC Act	Occurs in leaf litter along the outer margins of the riparian forest, where it intergrades with Cumberland Plain Woodland.
Migratory fauna species recorded	Rufous Fantail (*Rhipidura rufifrons*)	Would forage throughout riparian forest. Unlikely to breed in the area.
Introduced species recorded	Garden Snail (*Cantareus aspersa*) Asian Tramp Snail (*Bradybaena similaris*)	



Riparian forest in poorer condition along Badgerys Creek.



Riparian forest in good condition adjacent to Badgerys Creek.

Table 31 Fauna habitats of dams

Dams		
Description	There are a number of dams and flooded depressions in the airport site with varying growth of native wetland and aquatic plants, including some water bodies with extensive reed beds. These range in habitat value for native fauna depending on their size, presence of emergent or aquatic vegetation, and level of use by cattle and associated disturbance. Many dams contained a variety of aquatic vegetation, including *Typha orientalis*, *Eleocharis cylindrostachys*, and *Eleocharis sphacelata* and have been mapped as a native freshwater wetland vegetation zone (see Table 24).	
Typical fauna species recorded	A moderate diversity and abundance of native waterfowl, waders and other wetland birds were observed in these water bodies. Three migratory waterbirds, the Cattle Egret (*Ardea ibis*), Eastern Great Egret (*Ardea modesta*) and Lathams Snipe (*Gallinago hardwickii*) were recorded. The White-bellied Sea-eagle (*Haliaeetus leucogaster*) was observed on a number of occasions roosting near or flying over a number of dams. A range of ducks and grebes was observed, including various common species and three threatened Blue-billed Ducks (*Oxyura australis*). Large flocks of ibis (*Threskiornis* spp.), herons (*Ardea* spp. and *Egretta* spp.), and cormorants (*Phaacrocorax* spp.) were observed. Coots, moorhens and swamphens were common. Occasional Black-winged Stilts (*Himantopus himantopus*), spoonbills (*Platalea* spp.) and Black-fronted Dotterels (*Elseyornis melanops*) were observed. Australian Reed Warblers (*Acrocephalus australis*) and Golden-headed Cisticolas (*Cisticola exilis*) were recorded at dams with dense stands of reeds. A range of frog species was recorded during targeted nocturnal surveys. These included Peron's Tree Frog (*Litoria peronii*), Verreaux's Tree Frog (*Litoria verreauxii*), Eastern Dwarf Tree Frog (*Litoria fallax*), Broad-palmed Frog (*Litoria latopalmata*), Striped Marsh Frog (*Lymnodynastes peronii*), Spotted Grass Frog (*Limnodynastes tasmaniensis*), and Common Eastern Froglet (*Crinia signifera*). Also heard calling nearby in damp grassy areas were the Smooth Toadlet (*Uperoleia laevigata*), Wrinkled Toadlet (*Uperoleia rugosa*) and Bibron's Toadlet (*Pseudophryne bibroni*). Potential habitat for the Green and Golden Bell Frog (*Litoria aurea*) is present at many dams however none were recorded during targeted surveys. Eastern Snake-necked Turtles (*Chelodinia longicolllis*) were observed in a number of dams and moving between dams. Red-bellied Black-Snakes (*Pseudechis porphyriacus*) were observed near dams and this species is likely to hunt for frogs in these areas. Long-finned Eels (*Anguilla rhinehardtii*) and Mosquitofish (*Gambusia holbrooki*) were also observed in a number of dams.	
Threatened fauna species recorded	Blue-billed Duck (*Oxyura australis*) – TSC Act	Would forage on dams. Unlikely to breed in the area.
Migratory fauna species recorded	White-bellied Sea-eagle (*Haliaeetus leucogaster*)	Would forage on dams. May use nearby tall trees for nesting.
	Latham's Snipe (*Gallinago hardwickii*)	Would forage and may breed around margins of dams.
	Cattle Egret (*Ardea ibis*)	Would forage around margins of dams.
	Eastern Great Egret (*Ardea alba*)	Would forage around margins of dams.
Introduced species recorded	Red Fox (*Vulpes vulpes*) Mosquitofish (*Gambusia holbrooki*)	

Dams



Typical farm dam in open paddock.



Larger farm dam adjacent to riparian forest.

Table 32 Fauna habitats of buildings and other structures

Buildings and other structures		
Description	A number of sheds and buildings are present at the airport site. These provide roosting habitat for birds and microbats. Sheds and buildings are also likely to provide shelter for rodents and snakes. Roosting microbats were observed under the bridge over Badgerys Creek on Badgerys Creek Road. Anabats were placed at this location and large numbers of calls probably attributed to the Large-footed Myotis were recorded.	
Typical fauna species recorded	Birds observed roosting in buildings and under bridges included Welcome Swallows (*Hirundo neoxena*) and Fairy Martins (*Petrochelidon ariel*). A Barn Owl (*Tyto javanica*) was heard one night, and may also roost in old buildings and sheds at the airport site. A number of bat species, small mammals and snakes may also utilise old buildings at the site. Note however that many houses and sheds are currently being demolished at the airport site, reducing the incidence of this habitat feature. The Large-footed Myotis (*Myotis macropus*) listed as vulnerable under the TSC Act was tentatively (Probable) identified from the call analysis at Badgerys Creek bridge.	
Threatened fauna species recorded	Large-footed Myotis (*Myotis macropus*) – TSC Act	Possible colony recorded under a bridge over Badgerys Creek. Likely to forage over open water and may also roost in tree hollows.
Introduced species recorded	House Mouse (*Mus musculus*)	



Roosting bats and swallow nests under Badgerys Creek Road bridge.

4.3.3 Connectivity

Wildlife corridors are vital for the maintenance of ecological processes, including the movement of animals and the continuation of viable populations. Corridors can consist of a sequence of stepping stones across the landscape (discontinuous areas of habitat such as paddock trees, wetlands and roadside vegetation), continuous lineal strips of vegetation and habitat (such as riparian strips, ridge lines etc.), or they may be parts of an extensive patch of vegetation (DEC 2004b).

Connectivity of vegetation at the airport site with vegetation outside the airport site is limited (see Figure 7). As is the case within the site, most vegetation in the locality occurs as small patches, with long linear patches of vegetation tending to occur along creek lines. The Badgerys Creek corridor remains generally vegetated to the north of the site, albeit with some gaps in vegetation cover. It then links to the South Creek and Cosgrove Creek vegetated corridors. The

Western Sydney Urban Bushland Biodiversity Survey (NPWS 1997) identified a number of riparian corridors as targets for conservation within the Liverpool LGA, such as South Creek and Kemps Creek, but did not specifically include the Badgerys Creek corridor. More recent work by EcoLogical Australia (2012) mapped corridors along riparian areas and linked core stands of vegetation that exceeded a minimum size threshold. In this study, most native vegetation in the airport site was mapped as 'regional core'. These lands were considered significant to achieving local conservation management goals and were recommended for protection. All regional core vegetation in the Liverpool LGA was mapped as providing regional connectivity. This includes the Badgerys Creek Corridor.

Most patches of native vegetation at the airport site were mapped by Ecological Australia (2012) as being linked, and thus having a patch size of greater than 100 hectares. There is only limited connectivity however with other patches of vegetation outside the airport site. Large expanses of cleared land occur along the northern edge of Elizabeth Drive and Adam's Road. Small patches of vegetation to the south and west provide 'stepping stones' to other patches of vegetation outside the airport site.

Connectivity for fauna species is thus mainly along the Badgerys Creek riparian corridor or between closely linked patches within the airport site. Species with only limited mobility, such as the Cumberland Plain Land Snail, have minimal opportunities for dispersal. The Cumberland Plain Land Snail would generally be restricted isolated patches of vegetation in which the local population occurs, with no opportunity for movement between patches that are separated by grassland or cleared land. Small woodland birds would tend to move along the riparian corridors or along roadside vegetation to access other areas of habitat. More mobile fauna, such as Grey-headed Flying-foxes and larger birds would move easily between patches of vegetation at the airport site and other areas of habitat in the locality.

Habitat connectivity through and outside the airport site would be further reduced by development in coming years. The South West Growth Centres structure plan shows that the area to the east and south east of the airport site will be set aside for industrial / employment lands (DoP 2010). The Northern Road upgrade and realignment would comprise a barrier to fauna movement along the western boundary of the airport site. Likely future road and rail links to the airport site would further fragment and isolate habitat (see Section 7). The Badgerys Creek riparian corridor is likely to continue to function as an important fauna movement corridor.

4.4 Aquatic species and habitats

4.4.1 Aquatic habitats

Approximately 70 per cent of the total length of the mapped watercourses on the airport site are first and second order watercourses. Badgerys Creek has the highest stream order on the site, being fourth order for most of its length along the eastern boundary of the airport site.

The following aquatic survey site descriptions are based on site visits that were undertaken in March and May 2015. All sites were accessed close to road crossings or other public access points except for the dam sites which required access to leased properties (Figure 3e). Site descriptions and habitat dimensions are based on the New South Wales AUSRIVAS habitat assessment sheets. Because of the high electrical conductivity readings, electrofishing was not carried out at any of the sites visited on either occasion.

Table 33 BCUS – Badgerys Creek upstream

BCUS – Badgerys Creek upstream	
Landscape position and stream type	Site BCUS is located in a broad valley dominated by agriculture on the flood plain. At this location Badgerys Creek is mapped as a third order stream (GHD 2015b).
Description	The symmetric channel form had vertical sides approximately 3m high and the channel was inundated with dense stands of the macrophyte *Typha orientalis*, which was restricting flow in this narrow (~4m wide) channel and covering all visible open channels. Flows are intermittent at this site and the dominant habitat at the time of sampling was soft substrate pools and substantial macrophyte habitat. Water extraction pumps were noted at the site. The average depth in the sampled habitat was 0.3m with a mean wetted width of 4m. Silt and clay dominated the pools (90 per cent) suggesting the reach is subject to extended periods of low / no surface flows.
Key fish habitat	Badgerys Creek is mapped as Key Fish Habitat by DPI (2007). Based on the lack of woody debris but presence of aquatic vegetation it is considered to be Type 2 (moderately sensitive) key fish habitat.
Survey effort	Macroinvertebrate sampling was restricted to edge habitat at each end of the bridge culverts, because this was the only open habitat available. There was no suitable habitat to permit the use of fyke nets. Bait traps were set around the ends of the bridge culverts.
Catchment landuse	Catchment land use is predominately agricultural so the site is subject to nutrient enrichment and has a moderate erosion potential through land clearing and a poor riparian buffer zone. The riparian zone is dominated by native and pastoral grasses with very little canopy cover. There were some individual stands of Eucalyptus spp. disconnected from the river channel on the right hand side otherwise trees were largely absent and therefore there was no natural shading in the channel.
Macrophytes in the channel at BCUS both upstream and downstream of the bridge	
	

Table 34 BCMC – Badgerys Creek mid-catchment

BCMC – Badgerys Creek mid-catchment	
Landscape position and stream type	Site BCMC represents the downstream condition on Badgerys Creek. At this location Badgerys Creek is mapped as a fourth order stream (GHD 2015b).
Description	The creek channel was asymmetrical with vegetated shallow point bars on either bank. The banks were compounded with some toe deposition, which were also vegetated throughout the reach. The average channel width was 2m with an average depth at the sampling point of 0.1m. The available habitat at BCMC included several isolated pools in the upper section of the site where the surface flows ceased and farther downstream there was a moderate amount of soft substrate runs present. The substrate in the edge / pools was 100 per cent silt and clay and was also covered entirely by a layer of detritus. Large woody debris was present in the reach, but not at abundant levels (~10 per cent) which would provide adequate fish habitat. Compositionally, the riparian zone was dominated by grasses and shrubs, while at the sampling point itself there was adequate canopy from *Casuarina* spp. which thinned out with distance downstream. Erosion potential was minimal at this site because of the extent of the grass cover, which may buffer the surrounding perimeter from fertilizer-based nutrient runoff from the intensive agricultural practices adjacent to the stream.
Key fish habitat	Badgerys Creek is mapped as Key Fish Habitat by DPI (2007). Based on the presence of aquatic vegetation it is considered to be Type 2 (moderately sensitive) key fish habitat.
Survey effort	One macroinvertebrate sample was collected from the edge (of a pool). The water depth was too shallow for both the fyke net and the bait traps (maximum depth approximately 15-20 cm). As a consequence, fish sampling was not completed at this site.
Catchment landuse	Agriculture. Native vegetation in the riparian corridor.
Isolated pools at BCMC, where macroinvertebrate sampling was completed.	
	

Table 35 BCDS – Badgerys Creek downstream

BCDS – Badgerys Creek downstream	
Landscape position and stream type	Site BCDS is the downstream location on Badgerys Creek. At this location Badgerys Creek is mapped in as a fourth order stream (GHD 2015b).
Description	Access was unimpeded to BCDS, which was accessed via a road bridge crossing. Existing habitat included a large pool immediately downstream of the bridge and no evidence of existing or semi-permanent riffle habitat. The pools and the edge habitat that characterised this site were lined with a canopy of mainly Casuarina spp. (approximately 50 per cent cover) and an extensive understory dominated by native and exotic shrubs. On the water's surface in the larger pools (Plate 4-3) there was an extensive blanket of duckweed (Wolffia sp.) suggesting low flows and some nutrient enrichment is a feature of this reach. The substrate throughout the reach was dominated by silts and clay in the edge and pool habitat (90 per cent and 50 per cent respectively) and the pools contained approximately 30 per cent cobble. The composition of the substrate further emphasises the low flow characteristics at this site. Furthermore, there was a thick detrital layer covering both habitat types which has the potential to lower dissolved oxygen concentrations substantially, which would lower the probability of this site providing adequate habitat for the fish species which were documented in the data base search. Because of the elevated electrical conductivity at this site, electrofishing was not undertaken at this site. There were no natural barriers to fish passage although during the summer months connectivity maybe compromised through periods of drying. There is a farm dam within 1km upstream of BCDS, which would alter the hydrology during runoff events.
Key fish habitat	Badgerys Creek is mapped as Key Fish Habitat by DPI (2007). Based on the presence of woody debris it is considered to be Type 2 (moderately sensitive) key fish habitat.
Survey effort	Macroinvertebrates, fish and water quality.
Catchment landuse	BCDS is located within a broad valley surrounded by agricultural and rural/residential land uses, suggesting that existing disturbances to the site are dominated by the influence of nutrient enrichment following rainfall / runoff events.
Fyke net location at BCDS.	

Table 36 SCUS – South Creek upstream

SCUS – South Creek upstream	
Landscape position and stream type	Site SCUS is the upstream location on South Creek. At this location South Creek is a sixth order stream.
Description	Access to SCUS was via the Elizabeth Drive Bridge. Four habitat types were documented at SCUS which were: macrophytes; soft-substrate pool; soft substrate run and large woody debris. The substrate in the edge and pool habitats were mainly comprised of silt and clay (75 per cent and 90 per cent respectively), although sand (15 per cent) and gravel (10 per cent) also formed significant components of the edge habitat. The channel shape was irregular but a broad description would be that it was asymmetrical with meander bends and some areas of erosional undercuts with the occasional dispositional point bar. The mean channel width was 8m and the mean edge and pool depths were 0.3m and 0.7m respectively. The bank morphology was also irregular and difficult to describe because of the extent of the vegetation cover on both sides; bank height was approximately 3m. Grasses and trees <10m dominated the riparian zone, but there were extensive thickets of *Bolboschoenus* spp. throughout the reach.
Key fish habitat	South Creek is mapped as Key Fish Habitat by DPI (2007). Based on the presence of woody debris and aquatic vegetation it is considered to be Type 1 (highly sensitive) key fish habitat.
Survey effort	Water quality, macroinvertebrates and fish sampling. Fyke netting was conducted downstream of the bridge and bait traps were also used. The pool directly upstream of the bridge was completely covered by a floating macrophyte (*Salvinia*), preventing macroinvertebrate sampling in that reach, however appropriate habitat for both an edge and a pool bed macroinvertebrate sample was present both under the bridge and downstream of it.
Catchment landuse	The potential risk of diffuse runoff from the surrounding area is reduced by the extent of coverage and width of the riparian zone despite the zone itself having some elevated areas of erosion. The bridge is causing an obvious change in the hydraulics by channelling flow through an unnatural chute resulting in some channelization. This however would not impose a permanent barrier to fish movement. Several small farm dams were present in the majority of all upstream water courses, which may not block fish passage directly, but do impact the natural hydrology of the catchment.
Floating macrophyte in pool upstream of SCUS (top) and fyke net set location (bottom).	
	

Table 37 SCDS – South Creek downstream

SCDS – South Creek downstream	
Landscape position and stream type	Site SCDS is the downstream location on South Creek. At this location South Creek is a fifth order stream.
Description	Large sections of macrophytes provided suitable habitat for a macroinvertebrate edge sample to be collected, however, the large channel at this site was too deep for a pool sample to be collected safely and no riffle habitat was present. Substrate at the site was 100 per cent silt with mode stream width 3m, the edge habitat depth was 1m with a bank height of 1.5m. Although only flowing slightly, water was turbid and an oil slick was observed in backwaters. The substrate was made up of clay and silt and some large woody debris was found along the banks of the site. Shading was restricted to the edges of the creek, and most of the riparian vegetation was made up of a mix of ground cover and introduced shrubs with some canopy cover from *Casuarina cunninghamiana*. The site was littered with car tyres, plastic sheeting and metal.
Key fish habitat	South Creek is mapped as Key Fish Habitat by DPI (2007). Based on the presence of woody debris and aquatic vegetation it is considered to be Type 1 (highly sensitive) key fish habitat.
Survey effort	Water quality, macroinvertebrates and fish sampling.
Catchment landuse	SCDS is located adjacent to the fairway of a golf course.
Looking downstream (top) and upstream (bottom) at SCDS.	
	

Table 38 SCREC – South Creek recovery

SCREC – South Creek recovery	
Landscape position and stream type	Site SCREC is the recovery location on South Creek. At this location South Creek is a fifth order stream.
Description	SCREC was the only site in the March 2015 program that had riffle habitat, which enabled all three macroinvertebrate sample types (edge, pool and riffle) to be collected. The site was polluted by rubbish. There were no visible impediments to fish passage at this site. The riparian zone was dominated by *Casuarina* spp., which provided shading upstream of the bridge. The width of the riparian zone narrowed with distance downstream and was gradually replaced with pastoral grasses as the agricultural land use intensified. There was also an increase in the dominance of weeds with this change in vegetation type. The Creek substrate was variable at this site with the riffle and pool habitats under the bridge dominated by cobbles. The edge habitat substrate was almost entirely composed of silt and clay (90 per cent). The mode stream width at SCREC was 3m with a bank height of 2m, while the habitat depths varied from 0.15m in the riffle habitat to 0.7 m in the pool habitat.
Key fish habitat	South Creek is mapped as Key Fish Habitat by DPI (2007). Based on the presence of woody debris and aquatic vegetation it is considered to be Type 1 (highly sensitive) key fish habitat.
Survey effort	The large pool underneath the bridge provided suitable habitat for fyke netting, while bait trapping was done farther upstream from the bridge.
Catchment landuse	Agriculture and housing.
Fyke location in pool below bridge (top), riffle habitat (bottom) at SCREC.	
	

Table 39 DCUS – Duncans Creek Upstream

DCUS – Duncans Creek Upstream	
Landscape position and stream type	DCUS is located in the upper reaches of Duncans Creek. At this location Duncans Creek is mapped in GHD 2015 as a fifth order stream.
	DCUS is located in the upper reaches of Duncans Creek in a section of the catchment that was not impounded. There were, however, dams upstream on the tributaries and intermittent drainage lines which likely influence the natural hydrology of the creek at this point. Potential habitat was largely overgrown at the time of the survey meaning that there had been little flow at this site for some time. Furthermore, the existing surface water appeared to be coming from the overflow of a dam upstream that had occurred recently (most likely during the April rain event).
Key fish habitat	Duncans Creek is mapped as Key Fish Habitat by DPI (2007). It is considered to be Type 3 (moderately sensitive) key fish habitat.
Survey effort	Water quality only. Surface water was sparse at the time of our site visit meaning that there were no macroinvertebrate or fish samples collected.
Catchment landuse	Low-density grazing and native vegetation.
Facing upstream	
Facing downstream showing grassy creek bed	

DCUS – Duncans Creek Upstream	
The farm directly upstream of site DCUS.	

Table 40 DCDS – Duncans Creek Downstream

DCDS – Duncans Creek Upstream	
Landscape position and stream type	DCUS is located where Duncans Creek crosses Greendale Road, about 1 km to the west of the airport site. At this location Duncan's Creek is mapped as a fifth order stream (GHD 2015b).
Description	The mode stream width was 3m with a bank height of 5m, while the depth of the pool was approximately 0.2m. Large sections of the creek bed both upstream and downstream of the bridge have been colonised by grasses (native and introduced pasture grasses) indicating low flows through this section of creek, which is likely to be an impact from the high number of small farm dams in the upstream catchment area which is also restricting fish passage.
Key fish habitat	Duncans Creek is mapped as Key Fish Habitat by DPI (2007). It is considered to be Type 3 (minimally sensitive) key fish habitat.
Survey effort	Water quality only. Surface water was sparse at the time of our site visit meaning that there were no macroinvertebrate or fish samples collected.
Catchment landuse	Low-density grazing and native vegetation.
Downstream view	
Upstream view	

Table 41 OCUS – Oaky Creek upstream

OCUS – Oaky Creek upstream	
Landscape position and stream type	OCUS is located upstream of a dam on Oaky Creek. At this location Oaky Creek is mapped as a third order stream (GHD 2015b).
Description	OCUS is located upstream of a dam on Oaky Creek, but was not influenced by the impoundment. This reach consisted of a long narrow pool downstream of a road culvert (Longley's Road) and a macrophyte filled pool upstream of the culvert. The riparian zone itself was occupied by three vegetation types: grasses, shrubs and small trees (70 per cent, 20 per cent and 10 per cent respectively). There was no flow at the time of sampling, but it was evident that the April rainfall event had generated flow through the creek. The site was characterised by vertical banks ~0.5 m in height that were well vegetated. The mode stream width was 1.5m while the depth in the edge habitat was 0.25m. Most of the reach was shaded by *Casuarina* spp. and *Callistemon* spp. with some intrusions of weedy shrubs (*Lantana camara*, *Rubus* spp.). *Typha* spp. was growing in a thick stand upstream of the culvert. The right bank of the narrow pool was lined with exposed roots whereas the right side was mainly made up of undercut banks and trailing vegetation. The reach was too narrow to collect a poolbed sample for macroinvertebrates, but an edge sample was taken with the substrate dominated by silt and clay (>65 per cent).
Key fish habitat	Oaky Creek is mapped as Key Fish Habitat by DPI (2007). Based on the presence of limited aquatic vegetation and woody debris it is considered to be Type 2 (moderately sensitive) key fish habitat.
Survey effort	Water quality, macroinvertebrate and fish sampling. A fyke net and bait traps were deployed at the site.
Catchment landuse	The surrounding land use was intensive agricultural practices which were widespread in the vicinity of the site. There were sections along the riparian zone which had moderate levels of unnatural erosion – likely imposed through the direct and indirect effects of historical land clearing.
Looking upstream in shaded pool downstream of culvert.	
Macrophytes pushed over by flow in culvert upstream of site.	

Table 42 OCDS – Oaky Creek downstream

OCDS – Oaky Creek downstream	
Landscape position and stream type	OCDS is located at a bridge along Elizabeth Drive consisting of two box culverts, which is located amongst agricultural land. At this location Oaky Creek is mapped as a third order stream (GHD 2015b).
Description	OCDS was characterised by a pool in the culvert underneath the bridge while a large pool downstream of the bridge, which appeared to have good habitat, was inaccessible due to the presence of a large fence; which imposes a barrier to larger species. It would be advisable that should this site be sampled again, access be obtained to the pool for a better representation of the creek conditions than the pool within the culvert. Apart from the possible impedance from the fence spanning the width of the stream, there were no additional barriers to fish passage at this site. Pools were connected by surface flows throughout the reach. Riparian vegetation was composed of large trees, *Casuarina* spp. and *Eucalyptus* spp., with dense shrubs and ground cover, while downstream of the bridge was dominated by pasture grasses and introduced shrubs and vines. The substrate under the bridge was concrete, while the largest wetted area with the remaining substrate was classified as silt and clay (100 per cent). The mode stream width was 3.5m with a bank height of 1.5m, while the edge habitat depth was 0.15m.
Key fish habitat	Oaky Creek is mapped as Key Fish Habitat by DPI (2007). Based on the lack of aquatic vegetation and woody debris it is considered to be Type 3 (minimally sensitive) key fish habitat.
Survey effort	Water quality, macroinvertebrate and fish sampling. An edge macroinvertebrate sample was collected at the end of the culverts but there was no suitable pool or riffle habitat for additional samples to be collected. There was no suitable site within the creek for the use of fyke nets, so only bait traps were used at this site.
Catchment landuse	Agriculture.
Culvert underneath bridge.	
Blocked access to large pool downstream of bridge at OCDS.	

Table 43 CCUS – Cosgrove Creek upstream

CCUS – Cosgrove Creek upstream	
Landscape position and stream type	The CCUS site is located alongside Adams Road, outside the airport site. At this location Cosgrove Creek is mapped as a fourth order stream (GHD 2015b).
Description	The upstream Cosgrove Creek site consisted of a large pool upstream of the bridge, which contained a mosaic of aquatic habitats, including extensive submerged macrophyte cover throughout. Smaller pools were also present underneath the bridge culverts. The riparian zone was good quality with tiered habitat with *Casuarina* spp. dominant, while at ground level rushes lined the creek banks overhanging the channel. The mode stream width at CCUS was 3m with a bank height of 0.5m, while the edge habitat depth was 0.4m. Fish passage was impeded at this site with some pools at the bridge being disconnected due to the low levels of flow at this time.
Key fish habitat	Cosgrove Creek is mapped as Key Fish Habitat by DPI (2007). Based on the presence of aquatic vegetation it is considered to be Type 2 (moderately sensitive) key fish habitat.
Survey effort	A macroinvertebrate edge sample was collected in the pool upstream of the bridge, but this pool was not deep enough to collect a pool sample and there was no riffle habitat at the site. There was no section of the creek channel large enough to set the fyke net and the high EC level precluded electrofishing, resulting in the sole use of bait traps for fish sampling at this site.
Catchment landuse	The site is located within a broad valley which is predominantly cleared for agricultural activities.
Pool upstream of bridge.	
Pool underneath the bridge.	

Table 44 CCDS – Cosgrove Creek downstream

CCDS – Cosgrove Creek downstream	
Landscape position and stream type	The CCDS site is located about 3 km north of the airport site. At this location Cosgrove Creek is mapped as a fourth order stream (GHD 2015b).
Description	Aquatic habitat at the downstream Cosgrove Creek site was restricted to isolated pools, with the largest of these immediately upstream of the road crossing. This discontinuity resulting from low flows is creating a barrier to fish passage. This is the only site sampled in March 2015 where rubbish was absent. Habitat resources included floating macrophytes and algae, overhanging grasses and shrubs. Habitat substrate was entirely silt while mode stream width was 1.5m with a bank height of 0.5m and an edge habitat depth of 0.5m. The riparian canopy was provided by *Casuarina* spp. with occasional tea trees also present. Ground cover was thick with low growing forbs and vines present.
Key fish habitat	Cosgrove Creek is mapped as Key Fish Habitat by DPI (2007). Based on the presence of aquatic vegetation it is considered to be Type 2 (moderately sensitive) key fish habitat.
Survey effort	Overhanging grasses and shrubs provided habitat for a macroinvertebrate edge sample. However, the pool was not deep enough for a pool sample to be collected and no riffle habitat was present. EC at this site was on the upper limit for electrofishing, but, as no other sites had been fished using this method, bait traps were used to standardise the methods across all sites. There was no section of creek with a large enough area to set the fyke net.
Catchment landuse	CCDS is located upstream of a concreted creek crossing amongst a small vegetated channel through the golf course.
Pool upstream of road crossing.	
Looking downstream past the road crossing.	

Table 45 TCUS – Thompson Creek upstream

TCUS – Thompson Creek upstream	
Landscape position and stream type	TCUS is located at The Northern Road, about 3 km south of the airport site. It is a third order stream.
Landscape position and stream type	TCUS was easily accessed from the side of The Northern Road Bridge. The site is dominated by pool habitat, with minimal flow between pools. Fish passage was restricted at this site due to some small drop offs downstream off the bridge which may restrict the upstream movement of some species. These appear to have been created by high flows through this reach which may have been exacerbated due to the construction of the bridge causing some minor channelization. The mode stream width was 2.5m with a bank height of 1m, while the habitat depth varied from 0.15m in the edge habitat to 0.7m in the pool habitat. The immediate riparian zone was dominated by grasses and weeds, with *Casuarina* spp. and *Eucalyptus* spp. providing shading throughout the reach. The riparian zone in the lower section of the reach was thick with shrubs, rushes and weeds. There was considerable area on the left bank which was un-vegetated with some slumping exposing tree roots present downstream of the bridge. The stream banks within the reach were composed of hard clays and the substrate also consisted of high proportions of a mixture of clay and silt suggesting significant erosion from the stream bank.
Key fish habitat	Thompsons Creek is mapped as Key Fish Habitat by DPI (2007). It is considered to be Type 2 (moderately sensitive) key fish habitat.
Survey effort	Edge and pool macroinvertebrate samples were collected, but no riffle habitat was present to sample. EC levels were too high for electrofishing, and the creek had too many snags to allow the fyke net to be set, resulting in the sole use of bait traps at this site.
Catchment landuse	The area is predominantly used as a rural residential zone and is one of the most heavily populated site areas.
Downstream of bridge.	
Upstream of bridge.	

Table 46 OCDAM – Oaky Creek Dam

OCDAM – Oaky Creek Dam	
Landscape position and stream type	The dam is approximately 12 m wide and 40 m long, with the majority of shallow areas covered in emergent macrophytes (*Juncus* spp. & *Typha orientalis*). The riparian zone consisted mainly of pasture in the paddocks on the downstream side, while on the upstream side of the dam, *Casuarina* spp. were present, providing some shade. There were discontinuous stands of un-identified shrubs the area. There was rubbish such as car and tractor parts submerged in the water, and a number of Wood Ducks were observed on the water's surface. This site is located downstream of OCUS. Some large wood debris was present within the dam, which provided habitat structure. Several horses were seen nearby and evidence that they had been accessing the dam recently was seen. The substrate within the dam was made up of silt (100 per cent) with a layer of detritus with mean depth approximately 1.1m.
Survey effort	A fyke net and bait traps were set at this site. An edge and a pool-bed sample were collected for macroinvertebrates.
Catchment landuse	Rural residential and agricultural land.
Upstream showing dense emergent macrophyte growth (*Triglochin sp.*) and a car tyre in the water.	
Open water in deep section of dam.	

Table 47 OSDAM – On Site Dam

OSDAM – On Site Dam	
Landscape position and stream type	This site is located mostly within the Stage 1 construction impact zone. The dam is not located on a creek line, but on a minor drainage line within a cattle paddock. There were no trees in the paddock, creating an environment with no shade. The dam bank was grassed along one side, while the grass on the opposite bank was discontinuous with patches of mud with evidence of stock access, likely the cause of the turbid nature of the water. Submerged habitat was uncommon in the dam, with only some small sections of submerged macrophytes present. The dam was approximately 20 m long, 15 m wide and 1m deep. The paddocks surrounding the dame did not have any cattle in them at the time of sampling. The substrate of the dam was made up of silt and clay (>90 per cent). The field on one side of the dam had recently been ploughed which may also be contributing sediment through runoff during periods of rain.
Survey effort	A pool bed and edge sample were taken, fyke nets and bait traps were set.
Catchment landuse	Rural residential and agricultural land.
Expanse of water at OSDAM.	
Bank with submerged grass.	

4.4.2 Fish habitat

The results of the fish habitat assessment indicate that 71 per cent of sites are classified as Class 3 (minimal fish habitat), 22 per cent as Class 2 (moderate habitat) and 7 per cent as Class 4 (unlikely habitat) (Table 48), as per the waterway class definitions in DPI (2013) (refer to Section 3.3.4). Those within the airport site are all Class 3 (minimal fish habitat). All survey sites at creeks are mapped as key fish habitat by DPI (2007). Those on site are Type 2 (moderately sensitive) key fish habitat (Table 48). Isolated farm dams are not key fish habitat. Farm dams located along creeks (such as OCDAM) may be considered Type 3 minimally sensitive key fish habitat.

The majority of sites are intermittent with some indication of semi-permanent pools existing throughout the reaches surveyed, which may provide refuge during periods of stress for some

fish species. The intermittent nature of these systems also suggests that they are unlikely to be suitable habitat for listed threatened species recorded in the data base search.

Table 48 Fish habitat survey results

Site	Location	Waterway Class (DPI 2013)	Key Fish Habitat type (DPI 2013)
BCUS	Badgerys Creek upstream	3 (minimal key fish habitat)	2 (moderately sensitive)
BCMC	Badgerys Creek mid-catchment	3 (minimal key fish habitat)	2 (moderately sensitive)
BCDS	Badgerys Creek downstream	3 (minimal key fish habitat)	2 (moderately sensitive)
SCUS	South Creek upstream	2 (moderate key fish habitat)	1 (highly sensitive)
SCDS	South Creek downstream	2 (moderate key fish habitat)	1 (highly sensitive)
SCREC	South Creek Recovery	2 (moderate key fish habitat)	1 (highly sensitive)
OCUS	Oaky Creek upstream	3 (minimal key fish habitat)	2 (moderately sensitive)
OCDS	Oaky Creek downstream	3 (minimal key fish habitat)	2 (moderately sensitive)
CCUS	Cosgrove Creek upstream	3 (minimal key fish habitat)	2 (moderately sensitive)
CCDS	Cosgrove Creek downstream	3 (minimal key fish habitat)	2 (moderately sensitive)
TCUS	Thompson Creek upstream	3 (minimal key fish habitat)	2 (moderately sensitive)
DCDS	Duncans Creek downstream	3 (minimal key fish habitat)	3 (minimally sensitive)
DCUS	Duncans Creek upstream	4 (unlikely key fish habitat)	3 (minimally sensitive)
OCDAM	Oaky Creek Dam	3 (minimal key fish habitat)	3 (minimally sensitive)
OSDAM	On Site Dam	3 (minimal key fish habitat)	Not key fish habitat

4.4.3 Water quality

The Airports (Environment Protection) Regulations 1997 (AEPR) regulate water pollution at airports and contain a schedule of acceptable limits. The requirements of these regulations are listed in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) which are considered in this assessment. Guideline levels for specific water quality parameters are shown in Table 44.

The ANZECC (2000) guidelines outline default trigger values for physical and chemical stressors and toxicants for several water system groups. These trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. For the sites monitored in this project, the trigger values for south-eastern Australian lowland river ecosystems are most applicable.

Comparison of the AEPR to the ANZECC (2000) guidelines shows that the contaminants selected and the trigger values are broadly comparable. However there are a number of parameters for which the AEPR is significantly more stringent. For these parameters the compliance with the AEPR will ensure that ANZECC guidelines will also be met, however pollution from past and present land uses may make it difficult to comply with the AEPR. In

particular the very stringent limit for ammonia in the AEPR (<0.02 mg/L) will be difficult to meet and it is possible that baseline water quality prior to development already exceeds this limit. The AEPR contain provisions which allow an airport lessee company to apply to the Minister for a local standard where the standard set out in the Schedule to the regulations is not appropriate. This may be required for the proposed airport.

In-situ water quality parameters

The results of the in-situ water quality parameters are shown in Table 49.

Electrical conductivity (EC) was high at all survey sites with one site recording in excess of 6000 µS/cm. It is not known what factors contributed to this, but they could include the influence of local geology, heavy groundwater input during periods of low flow, salinity issues due to agricultural practices, or a combination of these factors. These high salinities are outside the known tolerance range for some sensitive macroinvertebrate species (Hart 1991).

Dissolved oxygen levels were generally low, with only one site recording a value greater than 80 per cent saturation. While caution is advised when interpreting spot dissolved oxygen levels taken at different times of the day, it is likely that the low dissolved oxygen levels are due to a combination of low flow conditions and nutrient enrichment. Water pH varied little between sites and was close to base. Turbidity levels were, somewhat surprisingly, not particularly high, with only three sites recording values above 50 NTU. Alkalinity levels were indicative of moderately to very hard waters. Sites with high alkalinity were also those with elevated EC, so some of the high EC at those sites relates to elevated calcium and carbonate ion levels.

Table 49 In-situ water quality measurements

Site	Date	Time	Temp. °C	EC µS/cm	DO % sat.	DO mg/L	pH	Turb. NTU	Alk. mg/L
ANZECC & ARMCANZ Guidelines[1]			No guideline	125-2,200	85-110		6.5-8.5	6-50	
Airport guidelines			An increase of 2ºC above the seasonal mean temperature	>1000 mg/L or an increase of >5%[2]	80% of the average level for a normal 24 h period or <6.0 mg/L[3]		6.5-9.0	A reduction of 10% clarity in the euphotic zone from the seasonal mean	
BCUS	14/3/15	11:05	19.2	2278	21.3	2.78	7.51	12.0	230
BCMC	13/3/15	14:05	20.0	2219	36.0	3.28	7.30	7.71	110
BCDS	13/3/15	16:40	20.4	3164	8.6	0.75	7.48	13.0	275
SCUS	13/3/15	15:15	21.5	1631	20.1	1.75	7.38	9.44	175
SCDS	16/3/15	16:30	22.4	1929	68.2	5.86	7.65	58.2	120
SCREC	15/3/15	15:15	21.9	1542	50.1	4.29	7.61	24.9	125
OCUS	28/5/15	12:00	13.85	1703	81.1	2.10	7.34	26.9	210
OCDS	15/3/15	17:45	19.8	4301	55.4	4.99	7.19	38.1	150
CCUS	15/3/15	16:50	20.4	6524	73.6	6.50	7.28	4.25	350
CCDS	16/3/15	16:00	19.1	1120	42.0	1.55	7.28	10.4	145
TCUS	13/3/15	10:55	20.1	1365	52.3	4.64	7.50	56.8	100
DCDS	16/3/15	10:15	17.9	876	52.5	4.96	7.55	89.2	95
DCUS	28/5/15	-	-	-	-	-	-	-	-
OCDAM	28/5/15	14:00	19.58	796	57.4	5.27	7.22	27.2	135
OSDAM	28/5/15	17:00	17.98	848	41.2	3.89	8.92	73.9	140

Note: Temp. °C = Temperature in degrees celcius; EC µS/cm = Electrical Conductivity Unit; DO = Dissolved Oxygen; Turb. NTU = Turbidity Nephelometric Turbidity Units; Alk. = Alkalinity; mg/L = milligrams per litre; guidelines not relevant for OCDAM and OSDAM as these sites are within dammed sites; yellow highlight indicate exceedance of the ANZECC & ARMCANZ (2000) guidelines.

[1] Trigger values for South- East Australia based on 95% ecosystem protection for SMD waterways.
[2] It is unclear what an increase of >5% means – no indication if this is for a single sample or above the baseline measured over a defined period of time
[3] Lower DO limit

Analytical water quality parameters

The detailed water quality results collected in March and May are provided in Appendix C.

Results show that the majority of the BTEX and Total Petroleum Hydrocarbons (TPH) analysed were below the detectable limits at all survey sites. Dissolved and Total metals were also for the most part, below the detectable limits for each parameter. The exceptions were zinc, nickel and copper. While these metals do occur naturally, high levels of each can indicate specific catchment related impacts such as industry, fertilizers and run off from roads.

Iron varied considerably between water bodies with the highest concentrations occurring in Oaky Creek, regardless of habitat or water body type. This may indicate localised differences in geochemistry and/or a higher groundwater / surface water ratio at these sites. Other toxicants such as fumigants, mercury and halogenated aliphatic and aromatic components were also all below detection limits, as were the Trihalomethanes and Polynuclear Aromatic Hydrocarbons.

All sites were classified as having moderately high to extremely high electrical conductivity levels. The major cation in the system is sodium which ranged from 92 mg/l at OCDAM to 846 mg/L at CCUS. These high sodium levels may be natural, but given the surrounding land-use there may also be a significant contribution from road salts and fertilisers.

The high nutrient concentrations throughout the project area suggest an agricultural land use signature. All of the total nitrogen (TN) and total phosphorus (TP) concentrations exceeded ANZECC and AEPR guidelines. Nitrates exceeded the ANZECC guideline values at four of the 14 sites (28%). Badgerys Creek (mid catchment) had very high TN and Nitrate values which can be indicative of animal waste and / or fertilisers. High level total organic carbon (TOC) values were also recorded at BCMC which is consistent with the high levels of organic deposits in the isolated pools at this site.

In terms of the aquatic environment, the existing habitat within the airport site is considered to be a series of highly modified and largely intermittent water courses. On the whole the survey sites are subject to the impacts of surface water run off which, based on the water quality data at hand, appears to be dominated by agricultural – based impacts including high nutrients and salts. However, part of the water quality signature across the survey sites (i.e. low DO and high EC) may be due partly to low flows in the broader area which seems to be the dominant feature at the time of the surveys. However, the low dissolved oxygen may also reflect the high detrital content and die back of the extensive stands of macrophytes surveyed in the study area.

4.4.4 Aquatic flora

Macrophytes that were observed during both survey events comprised species belonging to emergent, floating and submerged vegetation types. The majority of macrophytes observed at all sites were native (see Table 46). Two declared noxious weeds were recorded during surveys. Salvinia (*Salvinia molesta*) was found in a dense mat at BCDS upstream of the road crossing (ie within the airport site), and was observed in small clumps downstream. Water Hyacinth (*Eichhornia crassipes)* was seen in small clumps at SCDS (not within the airport site), but was not widespread. Both of these weeds are known to grow and disperse quickly under favourable conditions and are also recognised as weeds of national significance (WONS). Where exotic or declared species were found, they tended to dominate the waterway, such as Para Grass (*Urochloa mutica*) found at DCDS, SCDS and TCUS.

There is no marine vegetation as listed under the FM Act at the airport site.

Table 50 Macrophyte species recorded in the study area

Scientific name	Common name	Status
Azolla sp.	Ferny Azolla	Native
Bolboschoenus fluviatilis	Marsh Clubrush	Native
Cyperus difformis	Dirty Dora	Native
Eichhornia crassipes	Water Hyacinth	Declared noxious weed
Juncus usitatus	Common Rush	Native
Persicaria decipiens	Smartweed	Native
Potamogeton crispus	Curly Pondweed	Native
Salvinia molesta	Salvinia	Declared noxious weed
Schoenaplectus validis	Clubrush	Native
Triglochin sp.	Water Ribbons	Native
Typha sp.	Cumbungii	Native
Urochloa mutica	Para Grass	Exotic
Wolffia sp.	Duckweed	Native

4.4.5 Aquatic fauna

Fish

A total of eight fish species were recorded during fish surveys (Table 51). These included five native species and three exotic species. Of the native fish species collected, the Firetail Gudgeon (*Hypseleotris galii*) was the most widespread. Long-finned Eels (*Anguilla reinhardtii*) were also collected and released from fyke nets at BCDS and SCDS. Eels, most likely the Long-finned Eel, were also observed at dams at the airport site during the terrestrial fauna surveys.

Exotic species where present at almost all sites and accounted for the majority of the individuals caught. Large numbers of Eastern Gambusia (*Gambusia holbrooki*) were caught throughout the surveys but particularly at dam sites. Also caught were Common Carp (*Cyprinus carpio*) and Goldfish (*Carassius auratus*). Eastern Gambusia and Common Carp are both listed as Class 3 noxious fish under the FM Act, which restricts their sale and possession. A control plan for carp has been published for NSW (I&I NSW). The main objective of this plan is to prevent the introduction of carp into areas that are carp-free, and is not particularly relevant to the airport site. Predation by Eastern Gambusia is listed as a key threatening process under the TSC Act (see Section 8.1).

The presence and abundance of exotic species is not surprising considering the degraded nature of most of the sampling locations and the significant hydrological impacts from the large number of farm dams. There are populations of both Firetail Gudgeons and Western Carp Gudgeons (*Hypseleotris klunzingerii*) in the study area which showed relatively high abundances, considering the high level of competition by the exotic species. These native species have been found to prefer low flows and the high levels of aquatic vegetation found at these sites (Gomon 2011; Lintermans 2007).

No threatened fish species listed under the EPBC Act and for the FM Act identified in the database searches as potentially occurring in the locality were collected during the surveys. No suitable habitat for these species was observed during the site visits, which is in agreement with the findings of the SMEC (2014).

Table 51 Fish species caught at each survey site

Scientific Name	Common Name	BCDS	SCUS	SCDS	SCREC	OCUS	OCDS	CCUS	CCDS	TCUS	DCDS	DCUS	OCDAM	OSDAM
Anguilla reinhardtii	Long Finned Eel	2												
Carassius auratus	Goldfish*		1											
Cyprinus carpio	Common Carp*			1										
Gambusia holbrooki	Gambusia*	80	134	188	55	89		20	47	12	30		290	3220
Hypseleotris galii	Firetail Gudgeon			21	4	14	12				1		19	
Hypseleotris klunzingerii	Western Carp Gudgeon			10	8	17							41	
Hypseleotris sp.	Gudgeon Species (unidentified)					5							30	
Retropinna semoni	Australian Smelt				1									

Note: * denotes introduced species.

The fish communities are also indicative of a disturbed habitat. Low surface flows and poor water quality are likely to have caused reductions in native fish populations over the years and the increase in farm dams and the impacts they play on water shed hydrology are also likely part of the broader picture in the project area. The intermittent nature of these creeks are likely to be natural inhibitors to rare or endangered species populating the area but this has likely been exacerbated by land clearing and the flow-on effects of erosion, deteriorating water quality and population increases in exotic fish species, creating competition for resources which potentially did not exist previously. However, fish habitat assessment largely indicated that fish habitat was moderate or minimal at most sites and this was reflected in the dominance of exotic speices at all sites. .

Aquatic macroinvertebrates

A total of 1075 individual macroinvertebrates were identified in the March and May 2015 surveys. The macroinvertebrate communities were dominated by Dipterans (true flies) (31%), Acarina (water mites) (25%) and Odonata (Dragonflies) (10%) (see Table 52). The remaining components of the community comprised low numbers of taxa belonging to 12 other taxonomic groups with low to moderate SIGNAL scores indicating that the communities were generally made up of groups that have a high tolerance to moderate to severe pollution (Plate 1).

The tolerance to poor water quality, or inversely the absence of taxa sensitive to poor water quality is reflected in the poor representation of EPT taxa, which ranged from 3 at BSUS to 0 at 7 of the sites surveyed (see Table 53) and the significantly impaired to extremely impaired AUSRIVAS rating for all sites (see Table 54). The analysis of SIGNAL 2 scores against the total number of families collected at all survey sites show very low SIGNAL 2 scores (Range 1.31 – 3.75). This indicates that these sites at some stage have been subject to or are consistently exposed to severe pollution, according to the SIGNAL 2 interpretation method of Chessman (2003).

The SIGNAL / Richness biplot (see Table 53 and Figure 5) shows that all of the samples collected belong to either Quadrant 2 or Quadrant 4, which indicates high salinity or nutrient levels – these may be natural. The majority of the edge samples fall into Quadrant 2, as well as the only riffle sample collected. The remaining samples fall into Quadrant 4, which indicates urban, industrial or agricultural pollution, or may indicate the downstream effects of dams or

other impoundments, which is consistent with the water quality results. This quadrant contains all of the pool samples, but also three of the edge samples (SCDS, SCUS and SCREC).

Odonata (Dragonflies and Damselflies) made up approximately 10% of the total number of individuals collected. The majority of these individuals were immature nymphs meaning that the taxonomy of these groups could not be determined to species or genus level. However, no individuals belonging to either of the families from which the endangered dragonfly species belong (*Archaeophya adamsi*: Gompomacromiidae; *Austrocorrdulia leonardi*: Austrocorduliidae) were recorded. As such, this broad resolution to family level for the majority of the samples has not influenced the ability of the field assessment to detect these threatened taxa had they been present.

Table 52 Relative abundance of the major taxonomic groups of macroinvertebrates collected from the March 2015 survey

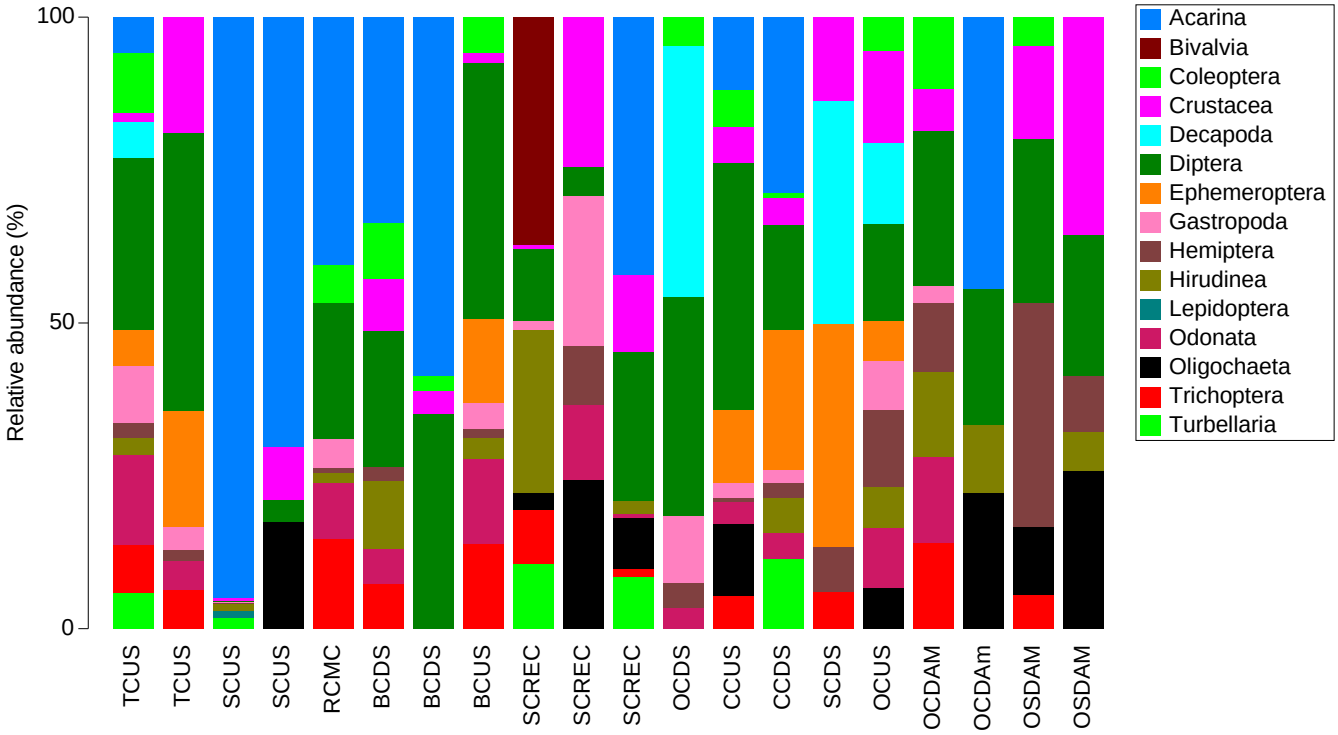


Table 53 Univariate index summary for all survey sites

Site	SIGNAL 2	Taxa Richness	EPT Richness	Habitat
TCUS	2.65	21	2	Edge
TCUS	2.33	7	2	Pool
SCUS	2.88	9	0	Edge
SCUS	2.83	4	0	Pool
RCMC	3.94	18	1	Edge
BCDS	2.94	11	1	Edge
BCDS	3.75	4	0	Pool
BCUS	3.03	17	3	Edge
SCREC	3.17	11	2	Riffle
SCREC	1.77	9	0	Edge
SCREC	2.44	7	1	Pool

Site	SIGNAL 2	Taxa Richness	EPT Richness	Habitat
OCDS	2.69	12	0	Edge
CCUS	2.92	12	2	Edge
CCDS	2.95	13	1	Edge
SCDS	2.63	7	2	Edge
OCUS	2.36	15	1	Edge
OCDAM	2.59	17	1	Edge
OCDAM	3.00	4	0	Pool
OSDAM	2.14	9	1	Edge
OSDAM	1.31	8	0	Pool

Table 54 AUSRIVAS scores for the macroinvertebrate survey

Site	O/E AUSRIVAS ratio		AUSRIVAS Band		SIGNAL 2 score	
	Edge	Riffle	Edge	Riffle	Edge	Riffle
BCUS	0.56	NA	B	NA	3.03	NA
RCMC	0.62	NA	B	NA	3.94	NA
BCDS	0.48	NA	B	NA	2.94	NA
SCUS	0.15	NA	C	NA	2.88	NA
SCDS	0.30	NA	C	NA	2.63	NA
SCREC	0.28	0.25	C	D	3.17	1.77
OCUS[4]	NA	NA	NA	NA	NA	NA
OCDS	0.52	NA	B	NA	2.69	NA
CCUS	0.59	NA	B	NA	2.92	NA
CCDS	0.48	NA	B	NA	2.95	NA
TCUS	0.69	NA	B	NA	2.65	NA
DCDS[5]	NA	NA	NA	NA	NA	NA
OCUS	0.54	NA	B	NA	2.36	NA
OCDAM	0.35	NA	C	NA	2.59	NA
OSDAM	0.44	NA	C	NA	2.14	NA

[4] Not sampled due to very low surface water volume (see photographs in section 4.3.7
[5] Not sampled due to unsafe access

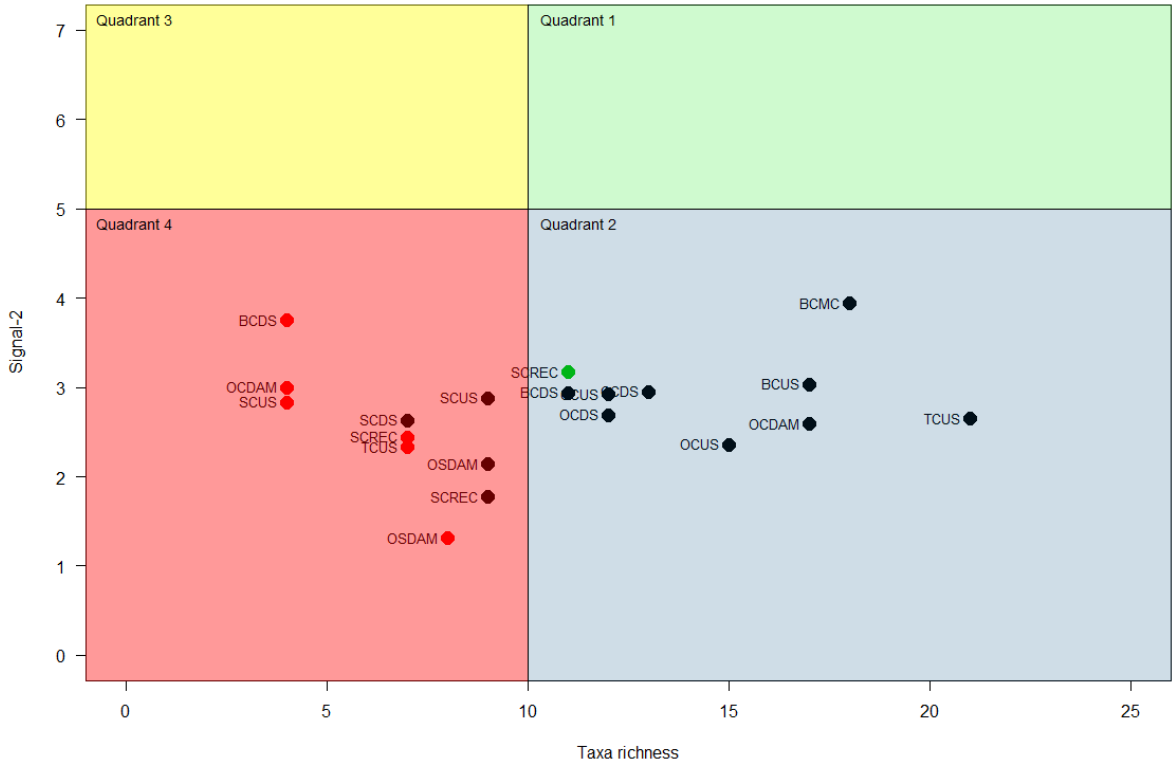


Plate 1: SIGNAL/Richness biplot

Note: Colours of the data points indicate habitat type: green = riffle; red=pool; black =edge

The generally poor water quality is a likely factor affecting the poor state of health of the macroinvertebrate communities which is reflected in the low SIGNAL scores, but not necessarily in the number of families. A bi plot was used as an interpretation tool and is in agreement with the interpretation that the aquatic sampling sites are all subject to one or another form of agricultural, urban or industrial pollution, or the macroinvertebrate communities reflect high nutrient and or EC values (which may be natural). Poor water quality has not resulted in an overall loss of taxa, just a loss of the more pollution-sensitive taxa (and replacement by pollution-tolerant taxa). This is more likely to result in a moderate degree of degradation of the macroinvertebrate community.

4.5 Conservation significance

4.5.1 Threatened ecological communities

Larger and better condition patches of Grey Box - Forest Red Gum grassy woodland on flats, Grey Box - Forest Red Gum grassy woodland on hills and Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest at the airport site comprise occurrences of 'Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest' (Cumberland Plain Woodland). Cumberland Plain Woodland is listed as a critically endangered ecological community (CEEC) under the EPBC Act. Patches of woodland at the airport site that comprise an occurrence of Cumberland Plain Woodland are shown on Figure 5. There are 155.7 hectares of Cumberland Plain Woodland as defined under the EPBC Act at the airport site.

Derived native grassland and moderate/good – poor condition vegetation at the airport site does not meet the condition criteria for a local occurrence of the CEEC Cumberland Plain Woodland as defined under the EPBC Act and associated guidelines. This vegetation does not qualify because native tree species are not present with a minimum projected foliage cover of greater than 10% (DEWHA 2010d). Patches with native tree cover greater than 10% but that are isolated from other native vegetation and are less than 0.5 hectares in area have also been excluded in accordance with the guidelines (DEWHA 2010d).

All of the native woodland and forest vegetation at the airport site, including derived native grasslands, comprise local occurrences of TECs listed under the TSC Act (see Figure 5) as follows:

- Both good and poor condition patches of Grey Box - Forest Red Gum grassy woodland on flats and Grey Box - Forest Red Gum grassy woodland on hills comprise the CEEC 'Cumberland Plain Woodland in the Sydney Basin Bioregion'.
- Both good and poor condition patches of Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest comprise the EEC 'Shale-Gravel Transition Forest in the Sydney Basin Bioregion'.
- Both good and poor condition patches of Forest Red Gum - Rough-barked Apple grassy woodland comprise the EEC 'River-Flat Eucalypt Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions'.

Patches of good condition artificial freshwater wetlands on floodplains at the airport site feature predominantly native plant species but are associated with dams and flooded depressions that have been formed by the construction of barriers across small drainage lines. They are clearly not natural geomorphic features. They do not comprise a local occurrence of the TEC 'Freshwater wetlands on coastal floodplains' because artificial wetlands created on previously dry land for purposes such as sewerage treatment, stormwater management and farm production are not regarded as part of this community (DECC 2008e).

Exotic grassland, cropland and cleared land at the airport site occupy former habitat for the TECs described above but are dominated by exotic plants or bare earth. They could not regenerate into functional ecological communities, even with assisted natural regeneration and do not comprise part of the occurrences of these TECs.

No threatened ecological communities listed under the FM Act occur at the airport site or in adjoining or downstream areas.

4.5.2 Threatened flora species and populations

Threatened species recorded or likely to occur

Four individuals of *Pultenaea parviflora* were recorded on the southern side of Longleys Road between Ferndale and Taylors Road by SMEC (2014) and these records were verified by GHD during the current field surveys (Figure 5D). *Pultenaea parviflora* is listed as a vulnerable species under the EPBC Act and an endangered species under the TSC Act. This is a significant reduction from the 68 individuals previously recorded along both sides of Longleys Road in this location in 1999 (Biosis 1999; SMEC 2014). The former locations of the 64 specimens currently contain cleared, ploughed cropland or severely weed infested road edges and do not comprise occupied or potential habitat for this species (see photo in Table 26). Seed and cutting collections were made from this population by the Royal Botanic Gardens Trust on a number of occasions in 1990 and 1991, with the aim of testing propagation methods for the species and also ultimately replanting the species at the airport as part of landscaping works (RBGS 1992).

Endangered populations recorded

A total of 93 stems of *Marsdenia viridiflora* subsp. *viridiflora* have been recorded at the airport site, with the majority recorded in Grey Box - Forest Red Gum grassy woodland on flats adjacent to Longleys Road in the centre of the airport site (see Figure 5). These comprise part of the endangered *Marsdenia viridiflora* R. Br. subsp. *viridiflora* population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas listed under the TSC Act. No other threatened flora species or populations listed under the TSC Act have been recorded at the airport site.

Threatened species or populations with a moderate likelihood of occurrence

No other threatened flora species listed under the EPBC Act have been recorded at the airport site. There is potential habitat for up to five threatened flora species listed under the EPBC Act: Spiked Rice-flower (*Pimelea spicata*); Downy Wattle (*Acacia pubescens*); White-flowered Wax Plant (*Cynanchum elegans*); Small-flowered Grevillea (*Grevillea parviflora* subsp. *parviflora*) and Austral Toadflax (*Thesium australei)*.

There is potential habitat at the airport site for at least two additional threatened plant species listed under the TSC Act: *Dillwynia tenuifolia* and *Grevillea juniperina* subsp*. juniperina*. *Dillwynia tenuifolia* is also listed as the Kemps Creek endangered population. The Kemps Creek endangered population is located around three kilometres to the east of the airport site in the area bound by Western Road, Elizabeth Drive, Devonshire Road and Cross Street, Kemps Creek (OEH 2015b). Any *Dillwynia tenuifolia* individuals or habitat at the airport site would not be part of this endangered population.

Threatened species not likely to occur

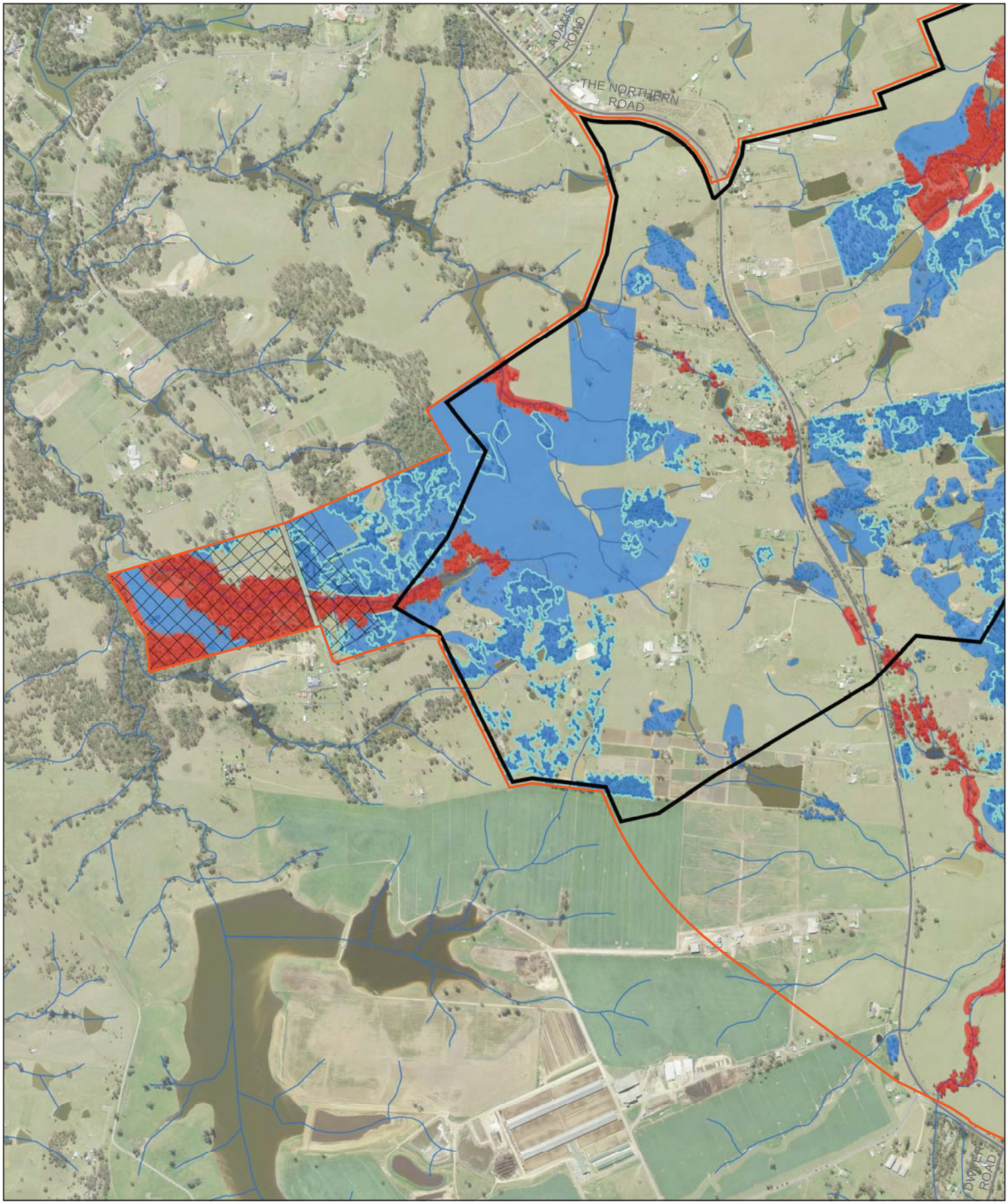
The remainder of the threatened flora species previously recorded or predicted to occur in the locality would not occur because the airport site is outside of their known distribution and/or does not contain suitable habitat (Appendix A). The airport site does not contain any sandstone outcrops or sandstone-derived soils, shale-sandstone transition soils, or deep Tertiary alluvial deposits and does not contain any threatened plant species that have habitat requirements specific to these soil types. These threatened flora species would not occur at the airport site and would not be impacted by the airport.

A summary of flora species recorded or with a moderate likelihood of occurrence is provided in Table 55.

Table 55 Threatened flora recorded or that may occur at the airport site

Species	Common Name	EPBC Act Status	TSC Act Status	Likelihood of occurrence
Pultenaea parviflora		V	E	Present
Marsdenia viridiflora subsp. *viridiflora*			EP	Present
Cynanchum elegans	White-flowered Wax Plant	E	E	Possible
Pimelea spicata	Spiked Rice-flower	E	E	Possible
Acacia pubescens	Downy Wattle	E	V	Possible
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	V	V	Possible
Grevillea juniperina subsp. *juniperina*	Juniper-leaved Grevillea		V	Possible
Thesium australe	Austral Toadflax	V	V	Possible
Dillwynia tenuifolia			V	Possible

Key: E – endangered; EP – endangered population; V - vulnerable



LEGEND

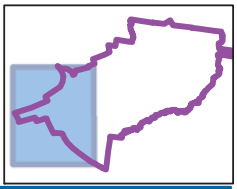
- Airport site
- Stage one construction impact zone
- Environmental conservation
- Roads
- Watercourses

EPBC Act

- Cumberland Plain Shale Woodlands and Shale Gravel Transition Forest (CEEC under EPBC Act and TSC Act)
- *Pultenaea parviflora* (endangered species under the EPBC Act and TSC Act)

TSC Act

- Cumberland Plain Woodland (CEEC under the TSC Act)
- River Flat Eucalypt Forest (EEC under the TSC Act)
- Shale/gravel Transition Forest (EEC under the TSC
- *Marsdenia viridiflora subsp. viridiflora* (endangered population under the TSC Act)



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Map Projection: Transverse Mercator
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Grid: GDA 1994 MGA Zone 56

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Western Sydney Airport
Biodiversity Assessment

Job Number	21-24265
Revision	A
Date	28 Aug 2015

Threatened flora and ecological communities

Figure 5A

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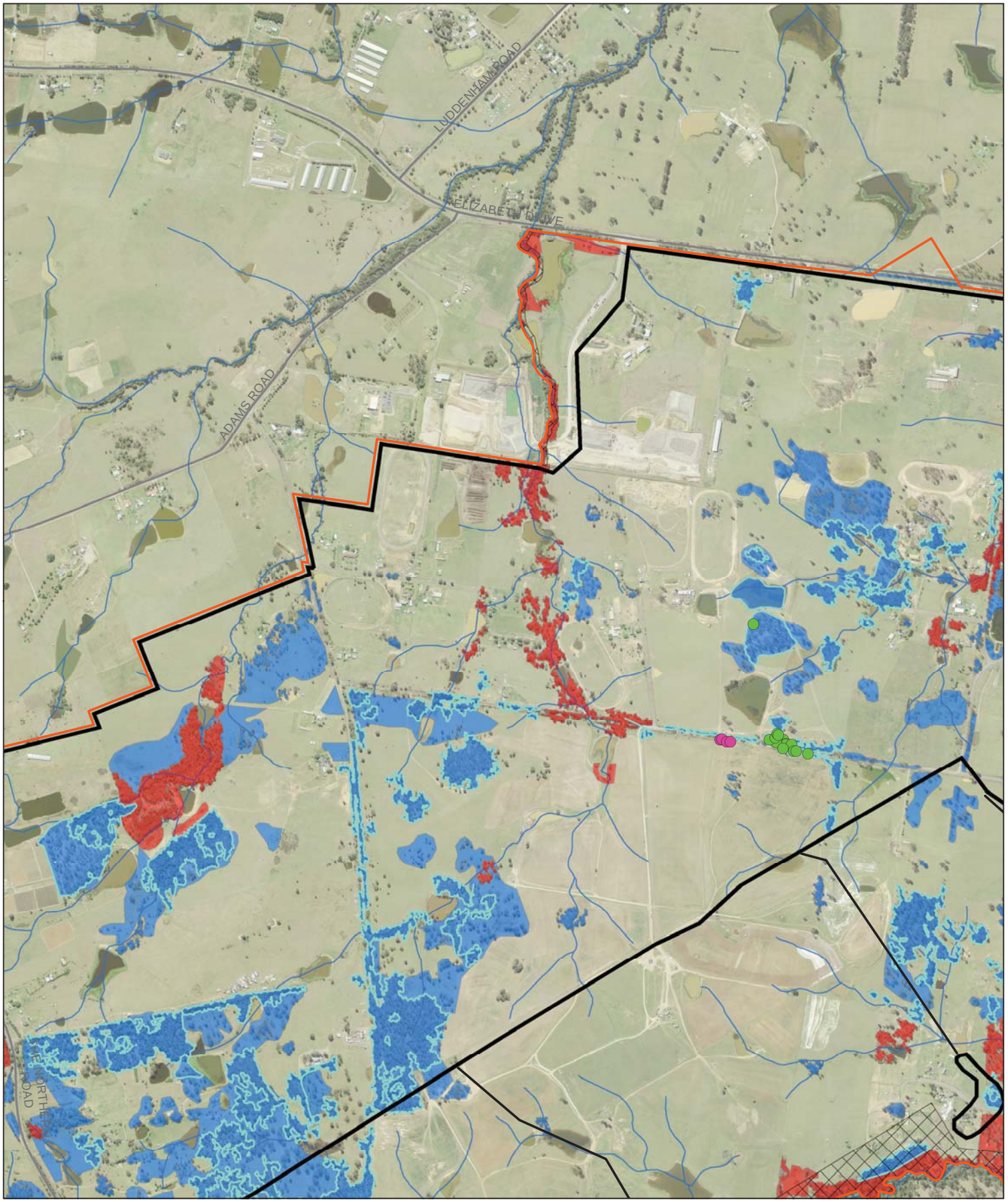


LEGEND

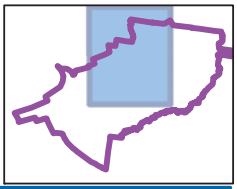
- Airport site
- Stage one construction impact zone
- Environmental conservation
- Roads
- Watercourses

EPBC Act

- Cumberland Plain Shale Woodlands and Shale Gravel Transition Forest (CEEC under EPBC Act and TSC Act)
- *Pultenaea parviflora* (endangered species under the EPBC Act and TSC Act)

TSC Act

- Cumberland Plain Woodland (CEEC under the TSC Act)
- River Flat Eucalypt Forest (EEC under the TSC Act)
- Shale/gravel Transition Forest (EEC under the TSC
- *Marsdenia viridiflora subsp. viridiflora* (endangered population under the TSC Act)



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Western Sydney Airport
Biodiversity Assessment

Job Number	21-24265
Revision	A
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Threatened flora and ecological communities

Figure 5B

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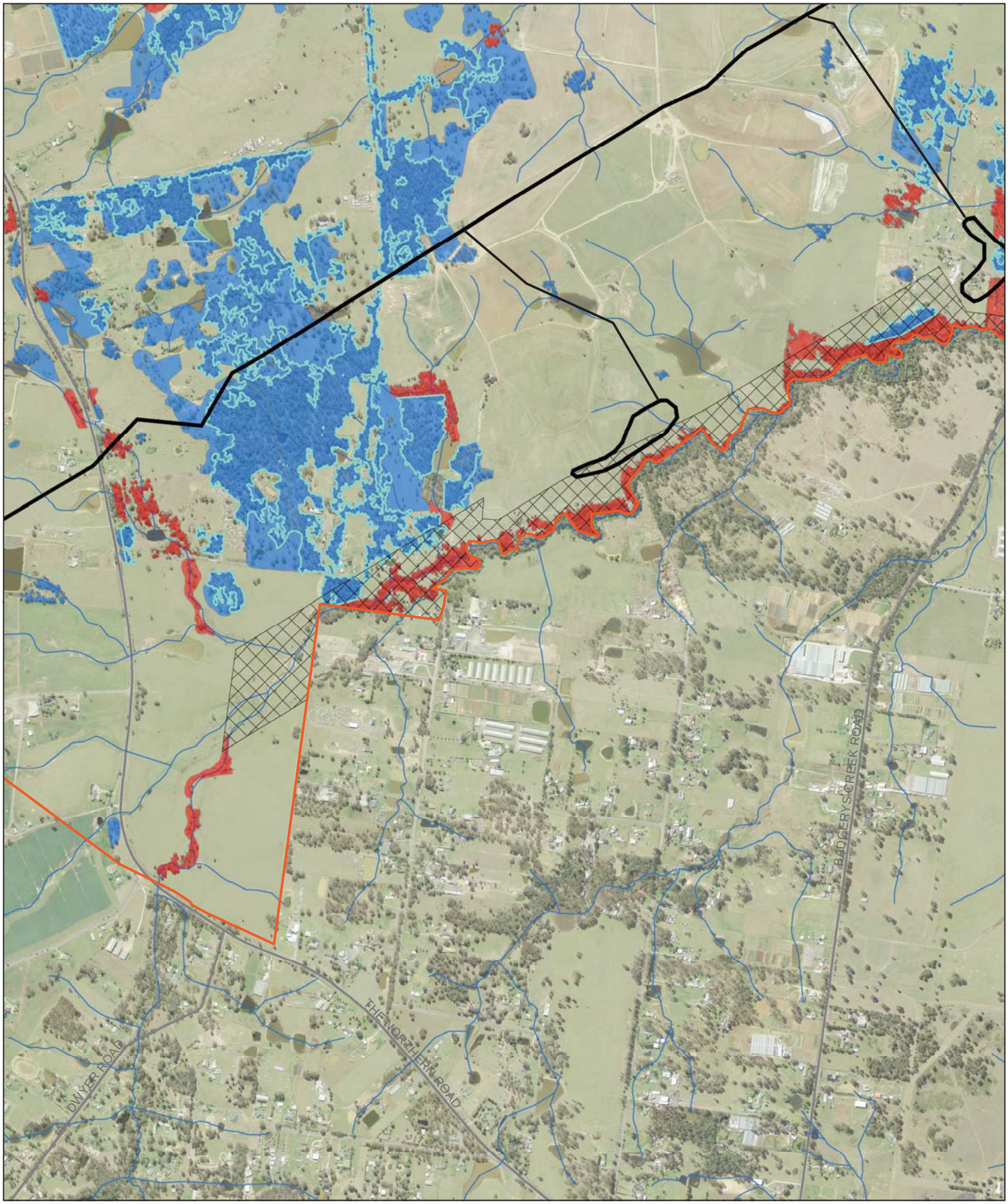

LEGEND

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Roads
- Watercourses

EPBC Act

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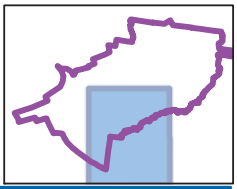
- *Pultenaea parviflora* (endangered species under the EPBC Act and TSC Act)

TSC Act

- Cumberland Plain Woodland (CEEC under the TSC Act)
- River Flat Eucalypt Forest (EEC under the TSC Act)
- Shale/gravel Transition Forest (EEC under the TSC
- *Marsdenia viridiflora subsp. viridiflora* (endangered population under the TSC Act)



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Job Number 21-24265
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Threatened flora and ecological communities

Figure 5C

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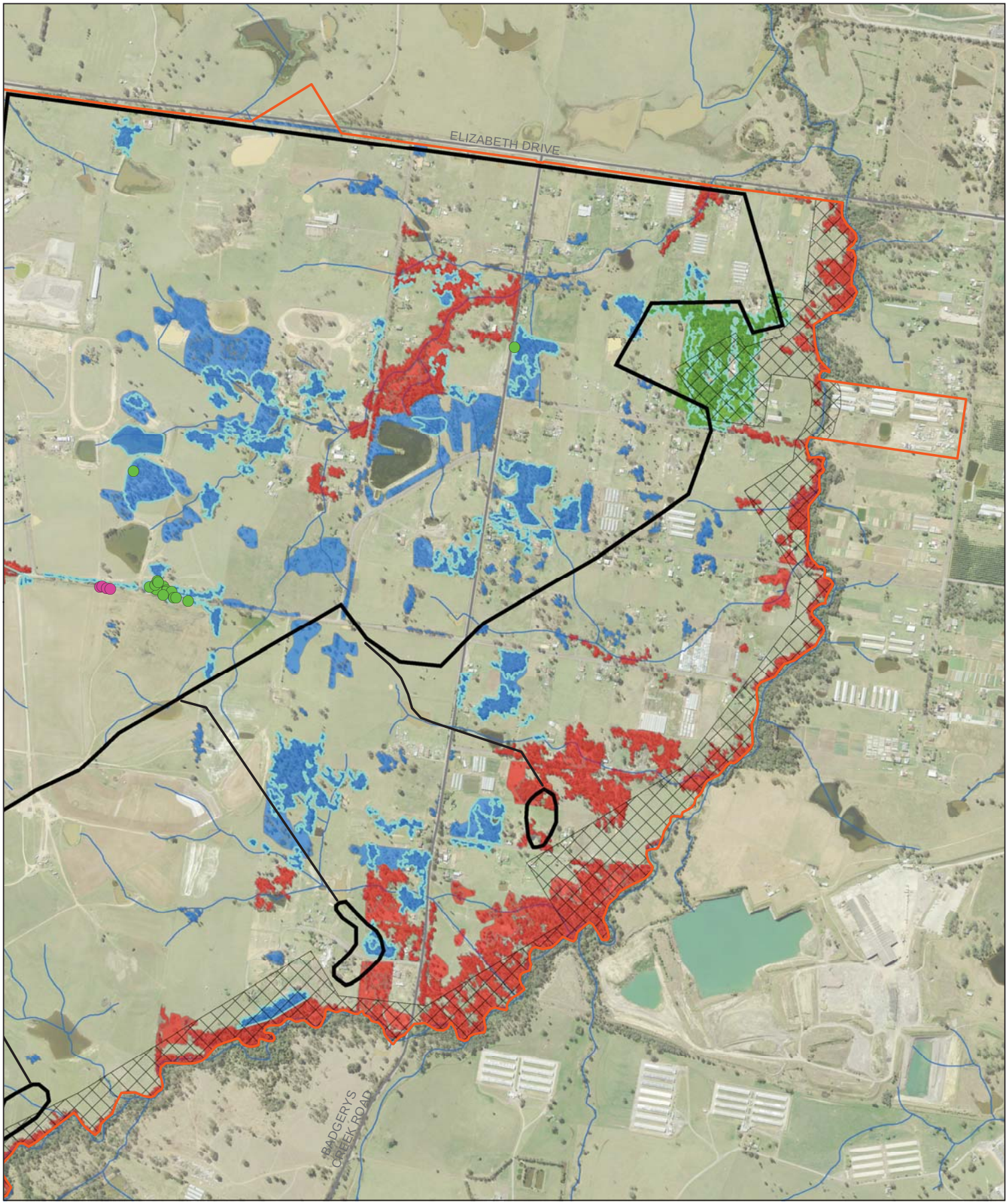

LEGEND

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Roads
- Watercourses

EPBC Act

- Cumberland Plain Shale Woodlands and Shale Gravel Transition Forest (CEEC under EPBC Act and TSC Act)
- *Pultenaea parviflora* (endangered species under the EPBC Act and TSC Act)

TSC Act

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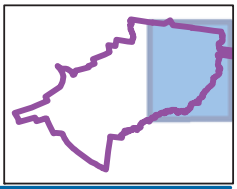
- Shale/gravel Transition Forest (EEC under the TSC
- *Marsdenia viridiflora subsp. viridiflora* (endangered population under the TSC Act)



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Date 28 Aug 2015

Threatened flora and ecological communities

Figure 5D

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4.5.3 Threatened fauna species

Threatened species recorded or likely to occur

One threatened fauna species listed under the EPBC Act was recorded at the airport site during the recent surveys: the Grey-headed Flying-fox (*Pteropus poliocephalus*). This species is listed as a vulnerable species under the EPBC Act and under the TSC Act. The Grey-headed Flying-fox was also recorded at the airport site during previous surveys for the 1999 EIS (PPK 1999). There are no Grey-headed Flying-fox camps located at the airport site, although there are at least seven known camps within 20 kilometres. All native woodland and forest in the airport site provides foraging habitat for this species. Dominant canopy species include Forest Red Gum (*Eucalyptus tereticornis*), Grey Box (*Eucalyptus mollucana*) and Broad-leaved Ironbark (*Eucalyptus fibrosa*). Forest Red Gum and Grey Box are recognised as 'significant species' in the blossom diet of the Grey-headed Flying-fox (Eby and Law 2008) however none of these species are highly productive flowering species. Forest Red Gum scores in the upper quartile of all diet plants for the region for productivity and reliability of flowering (0.67). This species flowers in late winter and spring, partly during the 'food bottleneck'. Grey Box has low productivity and reliability (0.35). It flowers in late summer and early autumn. Broad-leaved Ironbark has high productivity but is an unreliable flowerer (0.54) (Eby and Law 2008). This species flowers in summer and early autumn, providing forage habitat during the Grey-headed Flying-fox breeding period. Habitat at the airport site is thus somewhat productive during food bottlenecks, and may be habitat critical to the survival of the Grey-headed Flying-fox, as defined in the draft recovery plan (DECCW 2009).

The Swift Parrot (*Lathamus discolor*) may occur on occasion during its winter migration, but was not detected during targeted surveys. This species is listed as an endangered species under the EPBC Act and under the TSC Act. There are eight local records of the species. Targeted surveys were conducted for this species following confirmation of its arrival in Western Sydney since May 2015. Eucalypts had started to flower prior to the second survey in June. Swamp Mahogany (*Eucalyptus robusta*), Spotted Gum (*Corymbia maculata*), Grey Box (*Eucalyptus moluccana*) and Red Bloodwood (*Corymbia gummifera*) are important nectar sources in coastal parts of the non-breeding range. Commonly used lerp infested trees include Grey Box (*Eucalyptus microcarpa)*, Grey Box (*Eucalyptus moluccana)* and Blackbutt (*Eucalyptus pilularis)*. Forest Red Gum (*Eucalyptus tereticornis*) is also considered a food tree in coastal areas, including the Sydney Metro and Hawkesbury-Nepean areas (Saunders and Tzaros 2011). The occurrence of Swift Parrots at foraging sites has been linked with the abundance of lerp, nectar and non-aggressive competitors (Swift Parrot Recovery Team 2001). Swift Parrots have been found to preferentially forage in large, mature trees that provide more reliable foraging resources than younger trees (Saunders and Tzaros 2011). Dominant canopy species in the airport site include Grey Box (*Eucalyptus mollucana*) and Forest Red Gum (*Eucalyptus tereticornis*), which would provide nectar and lerp resources. Much of the airport site is vegetated with relatively young regrowth which reduces habitat quality, although patches containing large, old-growth trees are also present. A range of aggressive competitors such as the Noisy Miner (*Manorina melanocephala*) and the Bell Miner (*Manorina melanophrys*) are common at the airport site, potentially further reducing habitat suitability for the Swift Parrot. The airport site would not provide core winter foraging resources for the Swift Parrot (*Lathamus discolor*) given the presence of mostly young regrowth and aggressive competitors, although it may provide shelter or supplementary foraging resources for migrating individuals.

Ten threatened fauna species listed under the TSC Act were positively recorded during recent and previous surveys:

- Cumberland Plain Land Snail (*Meridolum corneovirens*), listed as an endangered species.
  - Habitat for the Cumberland Plain Land Snail occurs in larger patches with remnant trees. Live snails and shells of this species were recorded at a variety of locations where moist, deep leaf litter was present. In general, this species was recorded at locations where it had previously been recorded for the 1999 EIS, as well as some additional locations. In some locations, including some where the species had previously been recorded, appropriate potential habitat with good leaf litter was present but no individuals were found. This may have been as a result of individuals burrowing deep into the soil and not being found, or previous local extinction of a population. This species was not detected where leaf litter was shallow, woodland patches were small and no remnant trees were present. It is likely that in isolated patches of regrowth woodland, the species has not been able to recolonise due to distance between patches and inhospitable habitat (ie cleared land). The native Common Southern Carnivorous Snail (*Austrorhytida capillacea*) was also found in woodland patches in deep leaf litter. The introduced Garden Snail (*Cantareus aspersa*) was recorded at a number of locations, generally in the open, or in grassy areas, and the Asian Tramp Snail (*Bradybaena similaris*) was recorded in a weedy area near Elizabeth Drive.
- Little Eagle (*Hieraaetus morphnoides*), listed as a vulnerable species.
  - The Little Eagle was observed on a number of occasions soaring above open grassland at the airport site. The Little Eagle would prey upon small to medium sized mammals such as rodents and rabbits that occur at the site. It is likely that the airport site forms part of the home range of a number of breeding pairs. The species may use tall trees to nest in, although no raptor nests were observed during surveys.
- Little Lorikeet (*Glossopsitta pusilla*), listed as a vulnerable species.
  - A pair of Little Lorikeets was observed flying over the western portion of the airport site. Individuals within a regional population of this nomadic species are likely to forage at the airport site when eucalypts are in flower. While hollow-bearing trees are present in some locations, the species is unlikely to breed at the airport site given the level of fragmentation.
- Scarlet Robin (*Petroica boodang*), listed as a vulnerable species.
  - One individual Scarlet Robin was recorded foraging with a mixed species group in River-flat Eucalypt Forest near Badgerys Creek and may also occur in larger patches of Cumberland Plain Woodland. The Scarlet Robin may breed and forage in larger woodland patches in the airport site, although it tends to breed in woodland on foothills and ridges, moving to lower more open habitats in winter (OEH 2015b).
- Varied Sittella (*Daphoenositta chrysoptera*), listed as a vulnerable species.
  - About three or so individuals were recorded foraging with a mixed species group in River-flat Eucalypt Forest near Badgerys Creek and this species may also occur in larger patches of Cumberland Plain Woodland. It is likely to breed and forage in larger woodland patches at the airport site.

- Black Bittern (*Ixobrychus flavicollis*), listed as a vulnerable species.
  - One individual was observed in the northern section of Badgerys Creek. This species may breed and forage in the riparian corridor and at dams with good cover at the airport site.
- Blue-billed Duck (*Oxyura australis*), listed as a vulnerable species.
  - Three individuals were observed on the large, deep constructed dam on Taylors Road. This species only rarely occurs in coastal areas as a vagrant generally during times of drought. This species is unlikely to rely on habitats present at the airport site.
- East Coast Freetail Bat (*Mormopterus norfolkensis*), listed as a vulnerable species.
  - The East Coast Freetail Bat was recorded at many locations, and was often the most common bat species recorded. It may roost and breed in hollow-bearing trees at the airport site. It would forage in woodland and open areas at the airport site.
- Eastern False Pipistrelle (*Falsistrellus tasmaniensis*), listed as a vulnerable species.
  - The Eastern False Pipistrelle was recorded during the surveys for the 1999 EIS. Possible calls of the species were recorded during recent surveys. The Eastern False Pipistrelle prefers large tracts of vegetation, and would mainly occur along the Badgerys Creek riparian corridor and nearby large patches of vegetation.
- Eastern Bentwing Bat (*Miniopterus schreibersii oceanensis*), listed as a vulnerable species.
  - This species was recorded during the surveys for the 1999 EIS. Possible calls of the species were recorded during recent surveys. No breeding habitat for this species is present at the airport site, although it may roost under bridges and in buildings. This species forages in cleared and wooded areas, and could therefore forage throughout the airport site.

One additional microchiropteran bat species was probably recorded at the airport site during the surveys above based on call echolocation analysis:

- Large-footed Myotis (*Myotis macropus*), listed as a vulnerable species.
  - Probable calls of the Large-footed Myotis were recorded at a number of locations. Calls were considered to be most likely the Large-footed Myotis given habitat preferences and local records. However due to the lack of local reference calls and known overlap with *Nyctophilus* species, a definitive identification from analysis of echolocation call recordings could not be made.
  - Farm dams and creeks would provide foraging habitat for this species. It may roost in tree hollows, under bridges and in old buildings at the airport site. A colony of bats (possibly this species) was recorded under the Badgerys Creek Road bridge over Badgerys Creek. A large number of probable calls of this species were recorded at this location.

Two additional threatened bat species were possibly recorded at the airport site during the recent surveys based on echolocation call analysis. Poor data quality and/or interspecific call similarities precluded definitive identification of these species:

- Greater Broad-nosed Bat (*Scoteanax rueppellii*), listed as a vulnerable species; and
- Eastern Cave Bat (*Vespadelus troughtoni*), listed as a vulnerable species. The calls of three different Vespadelus species are very similar, and could not be distinguished to confirm the presence of this species. The airport site is near the limit of this species' distribution. It is known to occur in the Blue Mountains area.

A number of other threatened fauna species listed under the TSC Act are likely to occur at the airport site, based on a combination of recent records in the locality and the presence of potential habitat (see Appendix A). The airport site contains extensive areas of habitat in moderate to good condition for each of these species and is likely to support viable local populations or would provide foraging habitat for transient species. Species likely to occur include:

- Small woodland birds: Potential foraging and breeding habitat for a range of woodland birds previously recorded in the locality is present at the airport site. These include the Flame Robin and Diamond Firetail (*Stagonopleura guttata*).
- Hollow-dependent birds: Potential foraging and breeding habitat for a range of woodland birds previously recorded in the locality is present at the airport site. These include the Gang-gang Cockatoo (*Callocephalon fimbriatum*), Powerful Owl (*Ninox strenua*) and Masked Owl (*Tyto novaehollandiae*).

Notwithstanding the generally moderate condition of fauna habitat at the airport site it has high conservation significance as a result of the presence of threatened species described above and the generally limited extent and quality of similar habitat in the Western Sydney region.

No threatened aquatic fauna species listed under the EPBC Act or the FM were recorded at the airport site or in upstream or downstream habitats and none are likely to occur given known distributions and the absence of suitable habitat (see below).

Threatened species with a low likelihood of occurrence

A number of species listed under the EPBC Act identified through the desktop review have a low likelihood of occurrence at the airport site based on low habitat suitability, lack of nearby records or lack of previous records (see Appendix A). In particular, two species identified in the *Guidelines for the Content of a Draft Environmental Impact Statement – Western Sydney Airport* (DotE 2015f) as potentially being significantly impacted by the airport (the Large-eared Pied Bat and Green and Golden Bell Frog) have a low likelihood of occurrence at the airport site and are therefore unlikely to be significantly impacted by the proposed development. In addition, the Australian Painted Snipe and the Koala were assessed as having a low likelihood of occurrence given the habitats present and lack of records or low numbers of records in the locality (see Appendix A). These species are discussed below.

The Large-eared Pied Bat (*Chalinolobus dwyeri*) appears to roost predominantly in caves and overhangs in sandstone cliffs and forage in nearby high-fertility forest or woodland near watercourses (DERM 2011). This species has not been recorded at the airport site during either the recent or previous surveys. Local records are present at Bents Basin State Conservation Area to the south-west of the airport. Large expanses of suitable habitat are present to the west in the Blue Mountains National Park, however extensive areas of cleared agricultural land between these areas and the airport site make it unlikely that this species would occur in the airport site other than on a very occasional basis. There is no suitable roosting habitat at the airport site or in the immediate vicinity.

No Green and Golden Bell Frogs (*Litoria aurea*) were recorded during the recent targeted surveys carried out in March 2015, despite the presence of suitable habitat at the airport site. Similarly, none were recorded during the surveys conducted for the EIS in October 1998 (Lemckert 1999) and there are no other previous records of this species at the airport site (OEH 2015a). Numerous farm dams are present and many of these appear to provide good quality potential habitat, with a range of emergent flora species, including *Typha orientalis*, *Eleocharis cylindrostachys*, and *Eleocharis sphacelata*. Surrounding grassland would provide basking sites for frogs if present. Mosquitofish (*Gambusia holbrooki*) were observed at many of the dams, potentially reducing habitat quality for this species.

Targeted surveys for the Green and Golden Bell Frog were conducted at a reference site at Homebush Bay in unison with the surveys at the airport site. Targeted surveys had been conducted at the Homebush Bay reference site earlier in 2015 but concluded at the end of February. Green and Golden Bell Frogs had not been heard calling at Homebush Bay through March 2015 after a surge in activity with the stormy weather of January/February 2015. Through March there were a large number of juvenile Green and Golden Bell Frogs dispersing from a breeding event in early summer and tadpoles from a late January breeding event (O'Meara, J. Sydney Olympic Park Authority, pers. comm.). Several juvenile Green and Golden Bell Frogs and a mature adult were observed on two out of three nights that surveys were conducted at the reference site (Harrington, J. Sydney Olympic Park Authority, pers. comm.).

Large numbers of nine other species of frogs were recorded during the most recent surveys at the airport site, showing that frogs in general were active at this time and suggesting that if Green and Golden Bell Frogs were present, they would have been recorded. As described above and in Section 3.4.3, targeted surveys were conducted late in the 2014-15 breeding season and no frogs were calling at the reference site which may have reduced the chances of detecting the species. However given the observed Green and Golden Bell Frog activity at the reference site and the number of individuals of other frog species recorded at the airport site, it is likely that this relatively conspicuous species would have been detected if present. It is likely that the Green and Golden Bell Frog does not occur at the airport site. According to Lemckert (1999) this is a typical situation for this species, as it appears to have become extinct through most of its range, despite the presence of apparently excellent habitat. Many populations in western Sydney have become extinct over recent decades. According to White and Pyke (2008), formerly known populations at Liverpool, Merrylands, Milperra, and Mount Druitt, also in western Sydney, are extinct or probably extinct.

The Australian Painted Snipe (*Rostratula australis*) may occur on rare occasions at wetlands and nearby flooded grassland within the airport site. This species is most common in eastern Australia, although most records in NSW are from the Murray-Darling Basin (DotE 2015b). The Australian Painted Snipe inhabits many different types of shallow, brackish or freshwater terrestrial wetlands, especially temporary ones which have muddy margins and small, low-lying islands (Birdlife Australia 2015). There are no local records of this species, and none were recorded during surveys, however the species is cryptic and could potentially occur but not be detected.

The Koala was also identified as having a low likelihood of occurrence at the airport site despite the presence of primary food tree species (DECC 2008c) (see Appendix A). There are few records of the Koala in the locality. It has been recorded to the west in the Blue Mountains National Park, and to the east in the Western Sydney Parklands area, however there is minimal connectivity between these areas and the airport site. No Koalas have been observed at the airport site, and no scats were recorded during targeted searches.

The vegetation at the airport site has been assessed to determine if it comprises 'habitat critical to the survival of the Koala' as defined in the referral guidelines for the species (DotE 2014). In accordance with the guidelines, an attribute score of five or over indicates habitat critical to the survival of the Koala. The assessment of Koala habitat in the airport site is summarised in Table 56. The outcome of this assessment (a total attribute score of 2) is that potential Koala habitat at the airport site is not habitat critical to the survival of the species.

Table 56 Assessment of Koala habitat in the airport site

Attribute	Score	Habitat appraisal	
Koala occurrence	+0	Desktop	EPBC PMST report identified the koala as 'known to occur' in the locality. There are no records of Koalas within 2 km of the airport site from the last 5 years (OEH 2015b). No evidence of the species was noted during previous surveys (Biosis1999).
		On-ground	No Koala scats or Koalas were recorded during diurnal habitat searches or nocturnal spotlighting surveys.
Vegetation structure and composition	+2	Native vegetation at the airport site contains *Eucalyptus tereticornis* (a primary feed tree) or *Eucalyptus moluccana* (a secondary feed tree).	
Habitat connectivity	0	Native woodland at the airport site is patchy with minimal connectivity both within the airport site and the surrounding locality.	
Key existing threats	0	Three 80 km/hr roads are located at the airport site. Many domestic dogs were observed at the airport site and feral dogs are also likely to occur.	
Recovery value	0	Vegetation at the airport site is unlikely to be important for achieving recovery objectives given the lack of connectivity and presence of existing threats.	
Total	2	Decision: The total habitat score for the airport site is 2 and therefore the habitat present does constitute habitat critical to the survival of the Koala.	

Threatened species not likely to occur

The remainder of the terrestrial threatened fauna species previously recorded or predicted to occur in the locality would not occur due to a lack of suitable habitat, and/or a lack of local records (see Appendix A). These species would not occur at the airport site and would not be impacted by the airport.

The Giant Burrowing Frog (*Heleioporus australiacus*) was identified in the assessment process notice following determination of the airport as a controlled action, as potentially being significantly impacted by the airport (DotE 2015c). This species has a strong habitat association with sandstone geology, especially the Hawkesbury Sandstone plateaux surrounding Sydney, where it occurs on sandy soils supporting heath, woodland or open forest. It does not occur on the Shale and alluvium substrates of the Cumberland Plain and would not occur at the airport site.

There is no suitable aquatic habitat for EPBC Act-listed threatened fish predicted to occur in the broader catchment, such as the Macquarie Perch (*Macquaria australiasica*) or the Australian Grayling (*Prototroctes maraena*), at the airport site or in habitats sampled downstream. Potential indirect impacts of the project on downstream water quality and flows would not be of a magnitude or extent to impact habitat for such species that may occur within the broader catchment at considerable distance downstream of the site.

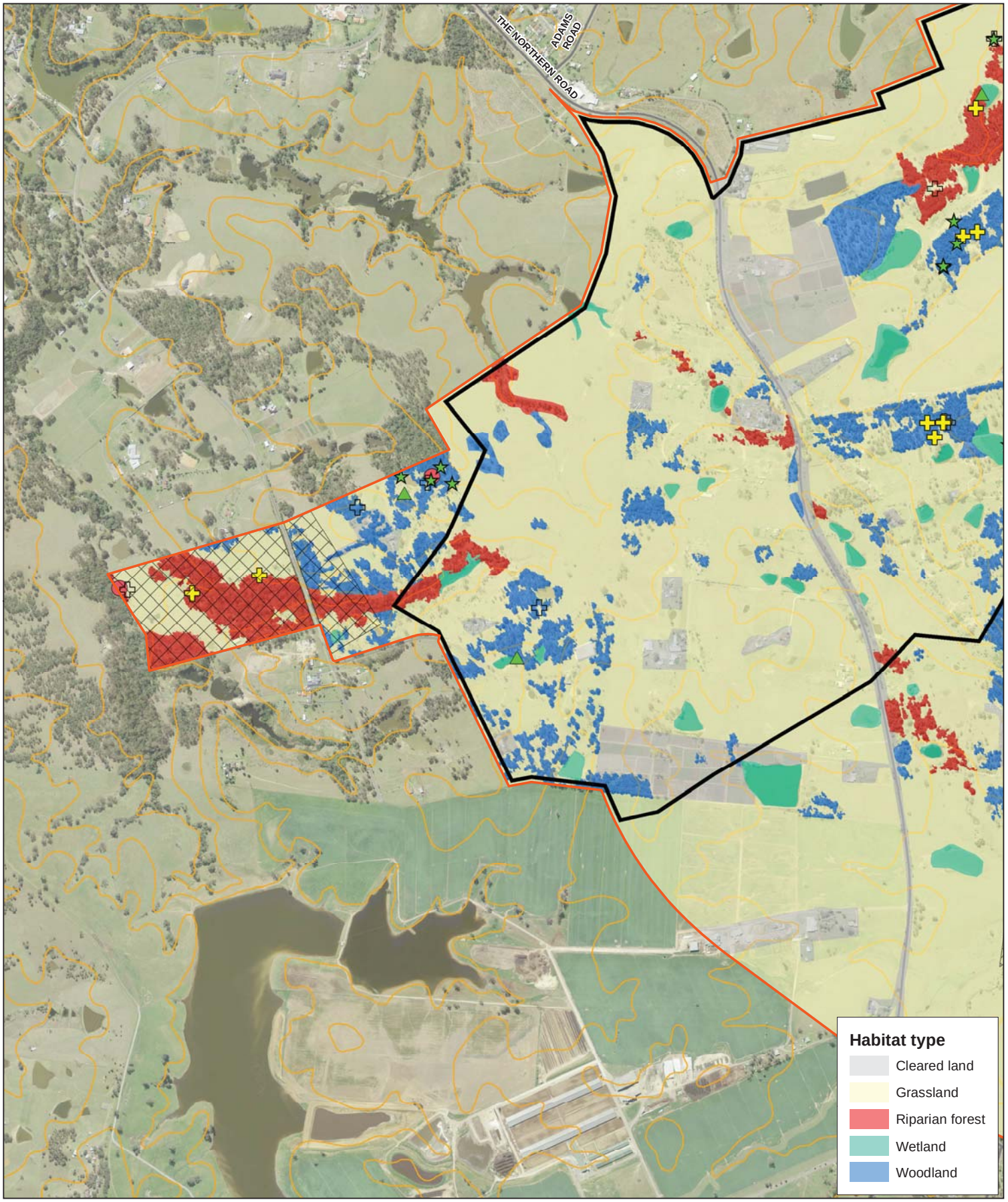
Similarly, it is unlikely that the airport site or areas immediately downstream support habitat for threatened dragonflies listed under the FM Act that are known from the greater Sydney region and that have been predicted to occur in the broader catchment. Larvae of the Sydney Hawk Dragonfly (*Austrocorrdulia leonardii*) are found in small creeks with gravel or sandy bottoms, in narrow shaded riffle zones with moss and rich riparian vegetation. Riffle zone habitat is very limited at the airport site and in downstream areas and where present, does not occur with other required habitat features. Similarly, there is no suitable habitat for the Adams Emerald Dragonfly (*Archaeophya adamsi*) which is generally found in steams and small rivers amongst rocks and litter and in riffle areas. No larval specimens belonging to the families from which these species belong were recorded during the macroinvertebrate surveys at the site or in downstream or upstream habitats and given the absence of suitable habitat and lack of local records neither is considered likely to occur or be impacted by the project.

A summary of threatened fauna species recorded or that may occur at the airport site is provided in Table 57.

Table 57 Threatened fauna recorded or that may occur at the airport site

Species	Scientific name	EPBC Act Status	TSC Act Status	Likelihood of occurrence
Grey-headed Flying-fox	*Pteropus poliocephalus*	V	V	Present
Cumberland Plain Land Snail	Meridolum corneovirens		E	Present
Little Eagle	*Hieraaetus morphnoides*		V	Present
Little Lorikeet	*Glossopsitta pusilla*		V	Present
Scarlet Robin	*Petroica boodang*		V	Present
Varied Sittella	*Daphoenositta chrysoptera*		V	Present
Black Bittern	*Ixobrychus flavicollis*		V	Present
Blue-billed Duck	*Oxyura australis*		V	Present
East Coast Freetail Bat	Mormopterus norfolkensis		V	Present
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*		V	Present
Eastern Bentwing Bat	*Miniopterus schreibersii oceanensis*		V	Present
Large-footed Myotis	*Myotis macropus*		V	Probably recorded (anabat)
Greater Broad-nosed Bat	*Scoteanax rueppellii*		V	Possibly recorded (anabat)
Eastern Cave Bat	*Vespadelus troughtoni*		V	Possibly recorded (anabat)
Yellow-bellied Sheath-tail Bat	*Saccolaimus flaviventris*		V	Possible
Swift Parrot	*Lathamus discolor*	E	E	Likely
Powerful Owl	*Ninox strenua*		V	Likely
Masked Owl	*Tyto novaehollandiae*		V	Likely
Flame Robin	*Petroica phoenicea*		V	Likely
Hooded Robin	*Melanodryas cucullata*		V	Possible
Diamond Firetail	*Stagonopleura guttata*		V	Likely
Speckled Warbler	*Pyrrholaemus sagittatus*		V	Possible
Black-chinned Honeyeater	*Melithreptus gularis*		V	Possible
Gang-gang Cockatoo	*Callocephalon fimbriatum*		V	Possible
Glossy Black-cockatoo	*Calyptorhynchus lathami*		V	Possible
Barking Owl	*Ninox connivens*		V	Possible
Square-tailed Kite	*Lophoictinia isura*		V	Possible
Australian Painted Snipe	*Rostratula australis*	E	E	Possible
Freckled Duck	*Stictonetta naevosa*		V	Possible

Key: E – endangered; V - vulnerable



Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Contour
- Roads

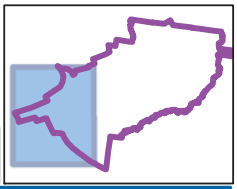
Threatened species

- Black Bittern (V)
- Cumberland Plain Land Snail (E) (absent)
- Cumberland Plain Land Snail (E) (present)
- East Coast Freetail Bat (V)
- Large-footed Myotis (V)
- Little Eagle (V)
- Scarlet Robin (V)
- Varied Sittella (V)

Migratory species

- Cattle Egret
- Latham's Snipe
- Rufous Fantail
- White-bellied Sea-Eagle
- Habitat trees

Notes: V - vulnerable species under the TSC Act;
E - endangered species under the TSC Act;
M - migratory species under the EPBC Act.



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Western Sydney Airport
Biodiversity Assessment

Job Number	21-24265
Revision	A
Date	06 Oct 2015

Threatened fauna and habitat features

Figure 6A

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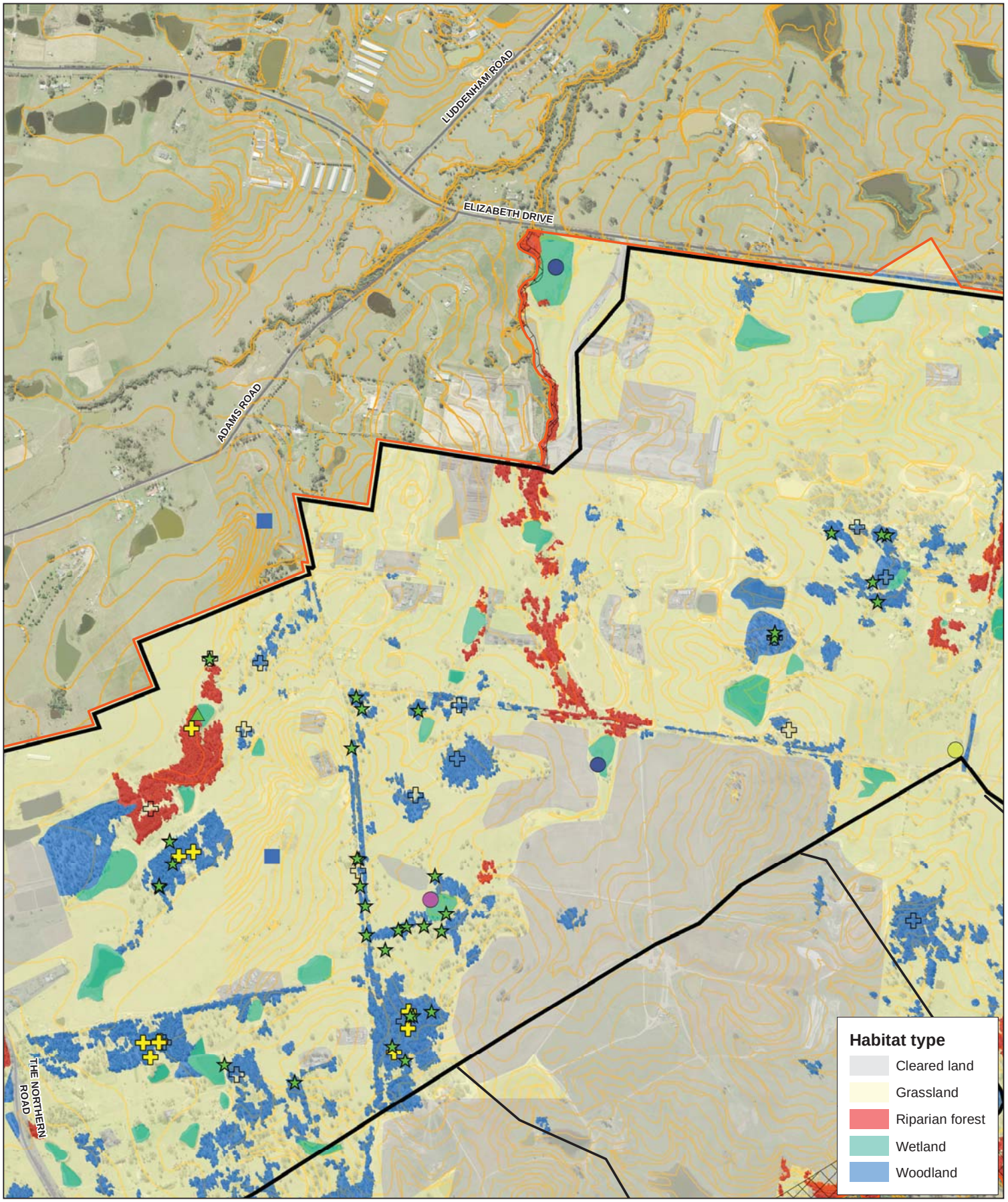

Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Contour
- Roads

Threatened species

- Black Bittern (V)
- Cumberland Plain Land Snail (E) (absent)
- Cumberland Plain Land Snail (E) (present)
- East Coast Freetail Bat (V)
- Large-footed Myotis (V)
- Little Eagle (V)
- Scarlet Robin (V)
- Varied Sittella (V)

Migratory species

- Cattle Egret
- Latham's Snipe
- Rufous Fantail
- White-bellied Sea-Eagle
- Habitat trees

Notes: V - vulnerable species under the TSC Act;
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M - migratory species under the EPBC Act.

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Western Sydney Airport
Biodiversity Assessment

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Revision	A
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Threatened fauna and habitat features

Figure 6B

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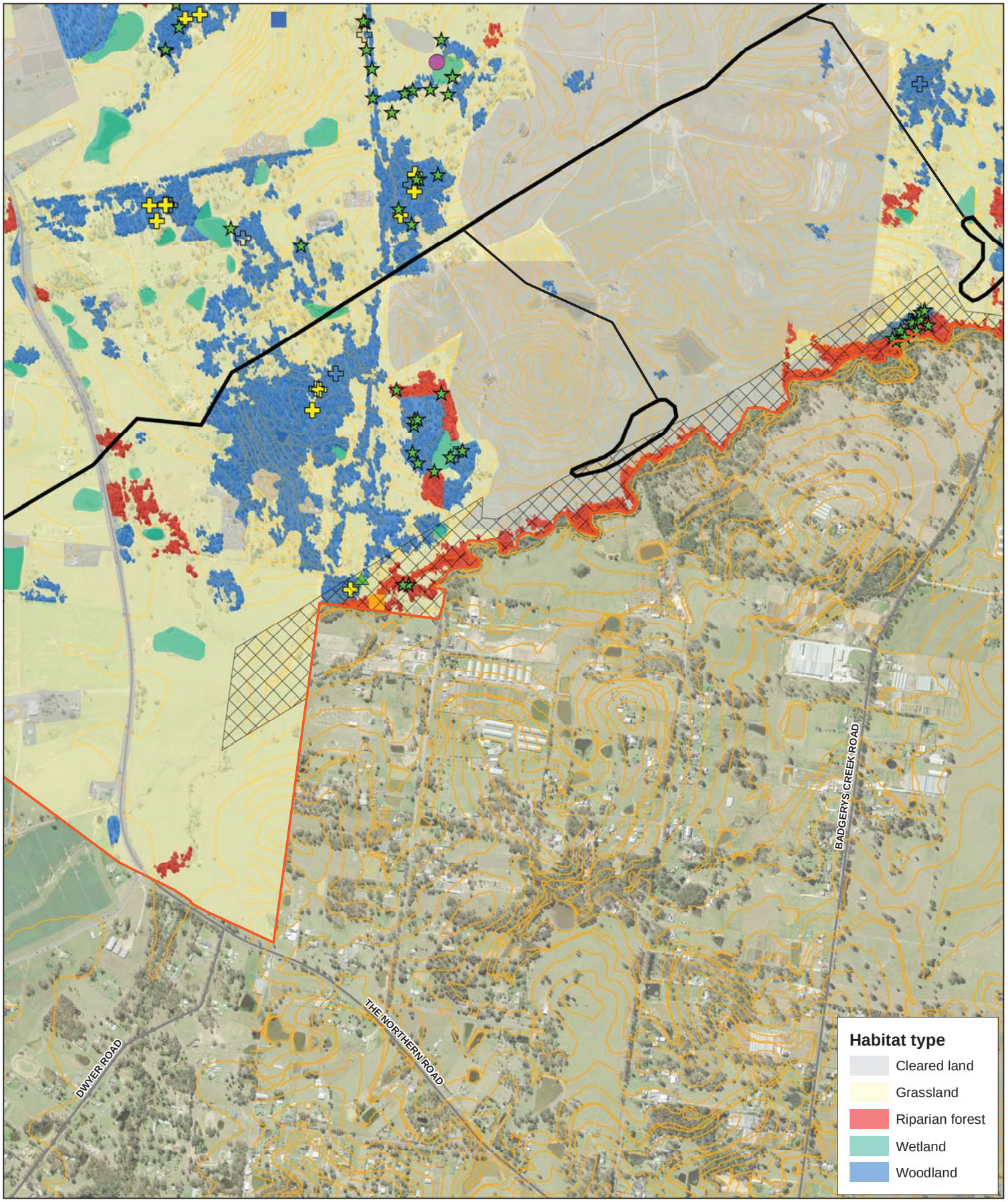


Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Contour
- Roads

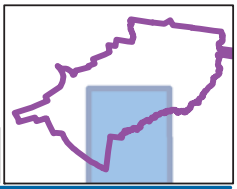
Threatened species

- Black Bittern (V)
- Cumberland Plain Land Snail (E) (absent)
- Cumberland Plain Land Snail (E) (present)
- East Coast Freetail Bat (V)
- Large-footed Myotis (V)
- Little Eagle (V)
- Scarlet Robin (V)
- Varied Sittella (V)

Migratory species

- Cattle Egret
- Latham's Snipe
- Rufous Fantail
- White-bellied Sea-Eagle
- Habitat trees

Notes: V - vulnerable species under the TSC Act;
E - endangered species under the TSC Act;
M - migratory species under the EPBC Act.



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Revision	A
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Threatened fauna and habitat features

Figure 6C

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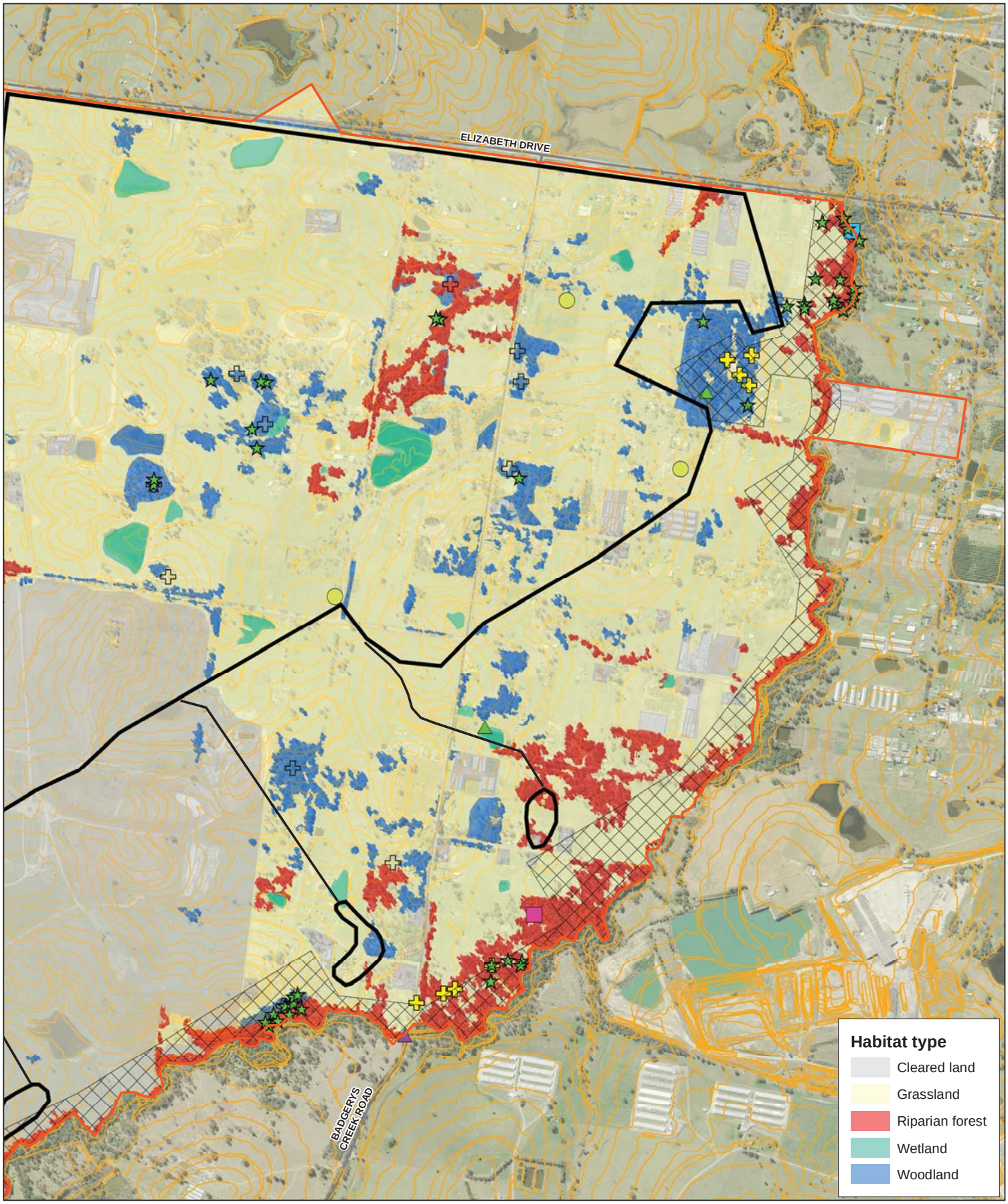

Legend

- Airport site
- Stage one construction impact zone
- Environmental conservation
- Contour
- Roads

Threatened species

- Black Bittern (V)
- Cumberland Plain Land Snail (E) (absent)
- Cumberland Plain Land Snail (E) (present)
- East Coast Freetail Bat (V)
- Large-footed Myotis (V)
- Little Eagle (V)
- Scarlet Robin (V)
- Varied Sittella (V)

Migratory species

- Cattle Egret
- Latham's Snipe
- Rufous Fantail
- White-bellied Sea-Eagle
- Habitat trees

Notes: V - vulnerable species under the TSC Act;
E - endangered species under the TSC Act;
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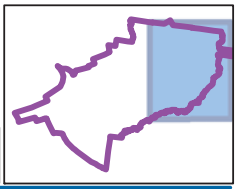

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Threatened fauna and habitat features

Figure 6D

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4.5.4 Migratory species

Overview

Seven migratory bird species listed under the EPBC Act have been positively recorded at the airport site.

Three migratory wetland species were recorded at the airport site. Cattle Egrets (*Ardea ibis*) were observed at a number of locations in paddocks and near dams and on several occasions flocks of about 30 individuals were recorded. Occasional individual Eastern Great Egrets (*Ardea alba*) were observed at dams and one Latham's Snipe (*Gallinago hardwickii*) was disturbed from exotic grassland adjacent to a dam. In addition, a flock of about 40 shorebirds was disturbed one night during frog surveys. These were not able to be identified, however are likely to be a type of sandpiper, based on the body shape in flight and the calls. Potential species include the Marsh Sandpiper (*Tringa stagnatilis*) and the Sharp-tailed Sandpiper (*Calidris acuminata*), which are known to occur on farm dams or the Common Greenshank (*Tringa nebularia*) previously recorded in the locality.

The White-bellied Sea-eagle (*Haliaeetus leucogaster*) was observed, either flying over dams or perching on large trees near dams. A flock of White-throated Needletails (*Hirundapus caudacudatus*) was also recorded foraging high above the airport site. The Rainbow Bee-eater (*Merops ornatus*) was heard on a number of occasions in patchy woodland remnants in the vicinity of the Badgerys Creek riparian corridor. The Rufous Fantail (*Rhipidura rufifrons*) was observed in a number of woodland patches at the airport site.

The EPBC Act lists migratory species that are listed under international agreements, as well as families of birds (such as ducks, waders, eagles and hawks) that are also known to be migratory but are not listed under international agreements. A range of waterfowl and waders have been recorded at the airport site. Other seasonally migratory or nomadic species would also be likely to utilise habitats at the airport site on occasion.

An assessment of the importance of habitat at the airport site for these migratory birds has been prepared with reference to the *Draft significant impact guidelines* (DEWHA 2009b) and is provided below.

Migratory wetland species

Two migratory shorebird species were recorded at the airport site: one Latham's Snipe (*Gallinago hardwickii*)) and a flock of an unidentified sandpiper species (see section 4.3.2). Potential species include the Marsh Sandpiper (*Tringa stagnatilis*) and the Sharp-tailed Sandpiper (*Calidris acuminata*). Note that the Great Egret and Cattle Egret are not considered within DEWHA (2009b), as they are not migratory shorebirds.

A critical consideration in assessing the significance of potential impacts on listed migratory shorebird species is whether or not a proposed action is likely to affect 'important habitat' (DEWHA 2009b). Important habitat is defined separately for 35 of the listed migratory shorebird species and Latham's Snipe (*Gallinago hardwickii*).

Important habitat for Latham's Snipe occurs at sites that have previously been identified as internationally important for the species, or sites that:

- support at least 18 individuals of the species; and
- are naturally occurring open freshwater wetlands with vegetation cover nearby (for example, tussock grasslands, sedges, lignum or reeds within 100 m of the wetland) (DEWHA 2009).

The airport site has not been previously identified as an internationally important site for Latham's Snipe. This species has been recorded five times previously in the locality. Only one Latham's Snipe was recorded at the airport site, but given the size of the airport site and other local records, it is possible that the airport site could support 18 or more individuals of the species. Wetlands at the airport site are artificial farm dams rather than naturally occurring freshwater wetlands and the airport site therefore does not meet the criteria for important habitat.

An area of 'important habitat' for the 35 migratory shorebird species identified in DEWHA (2009b) is defined as either:

- a site that is identified as internationally important; or
- a site that supports either:

a) at least 0.1 per cent of the flyway population of a single species; or

b) at least 2000 migratory shorebirds; or

c) at least 15 shorebird species (DEWHA 2009b).

One unidentified migratory shorebird species was recorded at a farm dam in the airport site. The flock of about 40 individuals is highly unlikely to make up 0.1 per cent of the species' population. For example, the Australian population of the Common Greenshank (*Tringa nebularia*) is estimated to be about 60,000 (DotE 2015b). No other shorebird species were recorded at the airport site. Given the low number of birds recorded and the low species diversity present, the airport site is unlikely to comprise important habitat for migratory shorebird species.

As no important habitat for migratory shorebirds is present at the airport site, the airport is unlikely to have a significant impact on any of these species. Consequently, assessments of significance for these species have not been prepared.

Other migratory species

Other migratory species recorded at the airport site included the Great Egret (*Ardea alba*); Cattle Egret (*Ardea ibis*); White-bellied Sea-eagle (*Haliaeetus leucogaster*); Rufous Fantail (*Rhipidura rufifrons*); and Rainbow Bee-eater (*Merops ornatus*). Important habitat for these migratory birds is defined in the significance criteria for listed migratory species (DotE 2013) as follows:

- Habitat utilised by a migratory species occasionally or periodically within the region that supports an ecologically significant proportion of the population of the species
- Habitat that is of critical importance to the species at particular life-cycle stages
- Habitat utilised by a migratory species which is at the limit of the species range
- Habitat within an area where the species is declining.

The small migratory birds could forage and breed throughout the airport site. Other areas of potential habitat are present in the locality.The White-bellied Sea-eagle would forage at larger dams, and the Cattle Egret in paddocks. The airport site is not considered important habitat for any of these species, according to the significant impact criteria for migratory species (DEWHA 2009) because:

- The habitat for migratory species in the study area is equivalent to similar habitats present throughout the locality and region. There are many thousands of hectares of such habitat in the region, including extensive areas in National Parks. The study area would only ever support a small number of individuals of any migratory species and never an ecologically significant proportion of the population of any species.

- The study area does not contain any specific habitat resources that would be of critical importance to any migratory species at particular life-cycle stages. Shelter, foraging and breeding habitat within the study area is also available in many thousands of hectares of similar vegetation in the region.
- The habitat for migratory species in the study area is surrounded in all directions by equivalent habitat and is not the terminal patch of habitat near the limit of any species' range.

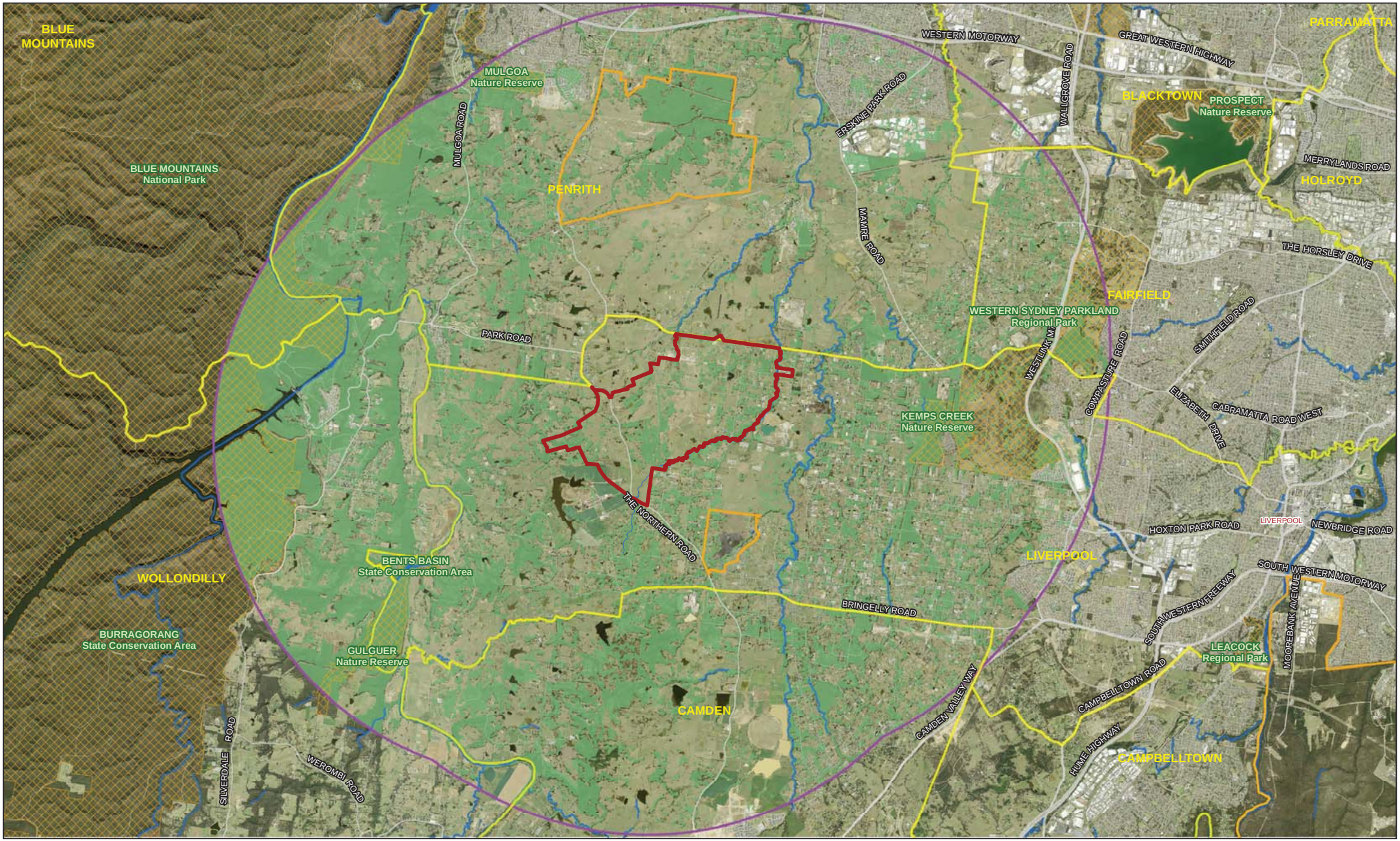
4.5.5 Greater Blue Mountains World Heritage Area

The Greater Blue Mountains Area which is listed as a declared World Heritage Property and a National Heritage Place under the EPBC Act is located around 10 km to the west of the airport site. The Greater Blue Mountains World Heritage Area (GBMWHA) is separated from the airport site by extensive areas of residential and agricultural land, fragmented patches of native vegetation, roads and the Nepean River.

The GBMWHA consists of 1.03 million hectares of sandstone plateaux, escarpments and gorges dominated by temperate eucalypt forest. It is noted for the diversity of eucalypts associated with its wide range of habitats as well as significant numbers of rare or threatened species, including endemic and evolutionary relict species. A significant proportion of the Australian continent's biodiversity occurs in the area. (UNESCO 2015). The GBMWHA protects a large number of pristine and relatively undisturbed catchment areas, some of which make a substantial contribution to maintaining high water quality in a series of water storage reservoirs supplying Sydney and adjacent rural areas (DECC 2009b). A detailed discussion of the GBMWHA is provided in section 8.2.5.

4.5.6 Other MNES

No other MNES of relevance to this report occur at or in the locality of the airport site.



Paper Size A3

0 1,300 2,600 5,200
Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

LEGEND

- Airport site
- The locality
- Defence land
- Native woodland and forest
- LGAs
- Highways
- Major roads
- Secondary and other roads
- Waterways
- Reserves

Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Assessment

Job Number	21-24265
Revision	A
Date	06 Oct 2015

Regional vegetation and habitat

Figure 7

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Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015, Inset - Geoscience Australia. Created by:jrichardson

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5. Construction impacts

5.1 Stage 1 development

5.1.1 Construction framework

Construction activities for the Stage 1 development are anticipated to occur in three major work phases comprising the following:

- site preparation works, including activities such as the establishment of site services and temporary construction facilities, clearing of vegetation, and a major earthworks programme;
- aviation infrastructure works, including activities such as construction of the runway, taxiways, apron areas, internal road network, the terminal complex, air traffic control tower, freight, cargo and maintenance facilities and a fuel farm; and
- site commissioning activities at the completion of the aviation infrastructure works, involving activities such as testing and commissioning of all facilities in readiness for the operation of the proposed airport.

It is expected that construction would proceed from the north-east to the south-west of the airport site to allow relocation of existing infrastructure such as The Northern Road and the TransGrid 330 kilovolt (kV) transmission line. The relocation of existing infrastructure would be subject to separate approvals, but may occur concurrently with other site preparation works.

The Stage 1 construction impact zone would include the area of bulk earthworks in the northern half of the airport site, which would facilitate the development of the runway, terminal and aviation support facilities, as well as areas of disturbance outside the bulk earthworks boundary that would be used for ancillary infrastructure such as drainage controls, detention ponds, perimeter roads, security fencing and site services. No significant construction would occur outside the Stage 1 construction impact zone.

Clearance of vegetation would be restricted to the construction impact zone for the Stage 1 development, and remnant vegetation in the southern portion of the site would remain largely intact. The clearing would be undertaken before the construction of the majority of the southern perimeter fence, to allow mobile fauna to relocate off site.

Site preparatory works would be expected to commence in mid-2016 and continue for around six and a half years. Sectors of the site would be subject to progressive handover to the aviation infrastructure works which would be completed over approximately five years to December 2024. The hours of construction would generally be between 6.00 am and 6.00 pm, Monday to Saturday. However, some works are likely to occur outside these work hours.

Further detail regarding the construction framework is provided in Chapter 6 of the EIS.

5.1.2 Removal of vegetation

The Stage 1 construction impact zone is shown on Figure 2. The boundary of this area depicts the extent of vegetation clearing and grubbing, earthworks, permanent detention basins and the permanent infrastructure that would be constructed for Stage 1 of the proposed airport. Construction of the Stage 1 development would result in direct impacts within a 1065 hectare disturbance footprint, including 280.8 hectares of native vegetation as shown on Figure 4. The extent of clearing of vegetation and habitats within the Stage 1 construction impact zone is summarised in Table 58 below.

There may be minor additional earthworks or other disturbance associated with works such as drainage swales up and downstream of the proposed sediment basins. These features would be defined at the detailed design stage. Based on a general assessment of their likely size and location they would affect a small area (typically around 25 metres in cross section including construction access) and would coincide with existing drainage lines located in exotic grassland and crop land. Constructing these features would have a minor effect on the overall extent of vegetation removal.

There may also be additional earthworks or other disturbance associated with the removal of the section of The Northern Road that passes through the southern portion of the airport site (should this occur), since the road is to be realigned to go around the proposed airport. This additional disturbance would affect only cleared land and exotic vegetation associated with the existing carriageway and would have a negligible effect on the overall extent of vegetation removal.

Land clearance is listed as a Key Threatening Process (KTP) under the EPBC Act. Land clearance consists of the destruction of the above ground biomass of native vegetation and its substantial replacement by non-local species or by human artefacts. Substantial replacement by non-local species or human artefacts is defined as the achievement of more than 70% of the total cover by species or human artefacts that did not occur previously on the site (Threatened Species Scientific Committee 2001). The Stage 1 construction impact zone would be completely developed and converted to airport infrastructure or managed open space with minimal native vegetation cover. The removal of 280.8 hectares of native vegetation in the Stage 1 construction impact zone would comprise land clearance as defined under the EPBC Act and would constitute a notable increase in the operation of this KTP in the locality. The effect of the proposed airport on the operation of KTPs is assessed further in Section 8.1.

The net impact of the extent of vegetation removal for construction of Stage 1 of the proposed airport is mitigated by the generally poor quality of the disturbance area. Around 146.1 hectares of the 1065 hectare impact zone contains good condition native vegetation with an intact natural structure. This vegetation frequently comprises small, fragmented patches with moderate weed infestation. There is a further 134.7 hectares of poor condition vegetation that comprises derived native grassland or scrub with moderate to severe weed infestation. The remaining 784 hectares of the Stage 1 construction impact zone contains exotic grassland, crop land or cleared land (see Figure 4).

Impacts would be further mitigated by the retention of around 122 hectares of land in the environmental conservation zone, including around 61 hectares of native vegetation and representative areas of each of the vegetation types at the airport site (see Figure 4). All or part of the 61 hectares of land within the conservation zone that does not currently contain native vegetation could be revegetated (see Section 9.2).

Table 58 Estimated area of vegetation removal in the Stage 1 construction impact zone

Vegetation Zone	TSC Act Status	EPBC Act Status	Area in Stage 1 construction impact zone (hectares)	Area in environmental conservation zone (hectares)
Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	CEEC	CEEC	71.3	2.9
Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	CEEC		107.8	4.9
Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	CEEC	CEEC	17.3	1.8
Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	CEEC		22.3	1.7
Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	EEC		29.8	40.6
Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	EEC		4.2	3.8
Good condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	EEC	CEEC	2.2	3.9
Poor condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	EEC		0.4	1.3
Good condition artificial freshwater wetland on floodplain (HN630)			25.4	0.4
Total native vegetation			**280.8**	**61.2**
Exotic grassland			628.8	48.6
Cleared land or cropland			155.4	11.9
Total			**1064.9**	**121.7**

The Stage 1 development would include impacts on a local occurrence of Cumberland Plain Woodland, patches of which are commensurate with the EPBC Act listed form of this TEC. There would also be impacts on a number of TECs listed under the TSC Act and on populations of threatened plants listed under the EPBC Act and/or TSC Act as shown on Figure 5. Impacts on this threatened biota are assessed in Section 8.

The majority of the earthworks footprint is disturbed, cleared land containing exotic pasture species or environmental weeds. These areas contain little native vegetation cover and have limited habitat value for native plants. Any vegetation clearing required in these areas would remove a small number of individuals of non-threatened native plants and noxious and environmental weeds.

The clearing of around 280.8 hectares of native vegetation would involve the removal of a large number of individuals and a moderately diverse range of non-threatened native plants. The Stage 1 earthworks footprint includes around 120.6 hectares of native woodland and forest vegetation in high condition that contains an over storey of mature trees. Mature trees have particular value within plant populations because they take longer to replace and are sources of pollen and seed. There are moderate areas of these vegetation types and plant species in the locality, including around 12,568 hectares of similar woodland and forest on shale or alluvial substrates within a 10 kilometre radius of the site (see Figure 7).

Under the land use plan in the draft Airport Plan, around 61 hectares of native vegetation would be retained in the environmental conservation zone at the airport site. This zone contains representative areas of each of the vegetation types at the airport site and would support many of the plant species in the impact area. The environmental conservation zone is placed along the south-eastern perimeter of the airport site to help maintain vegetation connectivity and to allow pollination, seed fall and other ecological processes that are necessary to maintain plant populations. Flora populations are also likely to persist within adjoining areas of alternative habitat beyond the airport site.

Plant species with a limited distribution in the locality would be most affected by vegetation clearing for the proposed airport. Notably the endangered population of *Marsdenia viridiflora* subsp. *viridiflora* at the airport site would be completely removed, which would comprise a significant impact at the local scale (see Section 8.4.2).

This reduction in the extent of native vegetation is less significant at the regional scale and is unlikely to threaten the persistence of any populations of native plants and vegetation communities. It is unlikely that an ecologically significant proportion of any regional plant populations would be located entirely within the airport site. At the regional scale flora populations would persist in habitat that is conserved in Kemps Creek Nature Reserve, Mulgoa Nature Reserve, existing and proposed Biobank sites at Mulgoa and in the Ropes and South Creek riparian corridors, the Western Sydney Regional Park and other offset sites linked to the North and South West Growth Centres. Notably there is a parcel of land with shale/gravel transition habitat located at Kemps Creek around three kilometres to the east of the site that is to be set aside as an offset for the South West Growth Centres. This site contains local populations of *Pultenaea parviflora* and other threatened plant species that may be affected by construction of the proposed airport (OEH 2015a).

5.1.3 Removal of terrestrial and wetland fauna habitat

Construction of the Stage 1 development would result in the removal of fauna habitat and associated resources within a maximum disturbance footprint of around 1065 hectares as shown on Figure 6A to D. The extent of fauna habitat removal and associated features and resources within the Stage 1 construction impact zone is summarised in Table 58 below.

Table 59 Estimated area of fauna habitat in the Stage 1 construction impact zone, environmental conservation zone and locality

Habitat type	Area in Stage 1 construction impact zone (hectares)	Estimated extent in the locality (hectares)[1]	Percentage of the estimated extent in the locality)	Area in environmental conservation zone (hectares)
Woodland	90.8	10,014	0.91%	8.5
Riparian forest	29.8	2555	1.16%	40.6
Sandstone woodland, forest and scrub		4825	0.00%	0
Total woodland and forest	**120.6**	**17,393**	**0.69%**	**49.1**
Wetlands[2]	25.4			0.4
Grassland[2]	763.5			60.3
Cleared land and cropland	155.4			11.8

Notes: 1) Based on GHD mapping within the airport site and on a composite of Tozer et al. (2010) and NPWS (2002) mapping in the locality. 2) Grassland and wetland vegetation has not been mapped by Tozer et al. (2010) or NPWS (2002).

The airport site provides habitat for a range of fauna groups typical of the Cumberland Plain (see Section 4.3). Native fauna present include species of macropods, flying-foxes and bats, a wide variety of birds, reptiles including goannas, snakes and lizards, frogs and small fish. A discussion of specific impacts of habitat loss on threatened and migratory biota is provided in Section 8. Fauna that would be most impacted include those that occur in grassland areas, artificial wetlands and dams and those that can use fragmented patches of woodland vegetation, as the site does not provide habitat for species that need extensive patches of vegetation. Key habitats that would be lost include those associated with grassland areas, farm dams, riparian habitat and woodland stands.

The majority of the proposal would result in the disturbance of exotic grassland or cropland which provides only limited habitat values for fauna in isolation, but is valuable as it is part of the mosaic of habitat over a large area. The loss of these areas would remove foraging, breeding and shelter habitat for small grassland animals such as skinks, and would result in the loss of entire populations of these species. The loss of this habitat would remove foraging habitat for a wide range of species, including macropods, open-country microchiropteran bats, and bird species such as the Australian Magpie, Australian Raven, Magpie-lark, Straw-necked Ibis and Cattle Egret in particular.

A large number of artificial wetlands (farm dams), minor drainage lines and associated damp soaks would be removed. In total, 25.4 hectares of wetland habitat and 29.8 hectares of riparian habitat would be lost. This would result in the loss of local populations of frog species. Large areas of habitat for waterbirds, including migratory species, would be destroyed. Foraging habitat for a range of microchiropteran bat species, including in particular the Large-footed Myotis, would be removed.

Construction would require the permanent removal of a maximum of 120.6 hectares of woodland and forest habitat. Clearing of this vegetation would permanently remove foraging and breeding resources for native fauna, particularly in forest and woodland habitats, which comprise a canopy of eucalypt trees of varying age classes. Eucalyptus and other native canopy species provide nectar resources as well as foraging substrate for a diverse range of arboreal species, such as birds and arboreal mammals, as well as bats.

Construction of the Stage 1 development would result in the loss of at least 50 hollow-bearing trees, which occur as scattered trees across the airport site. Note that this is an underestimate of the total numbers present, as not all patches of vegetation were able be visited, and some smaller or less obvious hollows may have been missed in stands that were surveyed. Hollow-bearing trees occur at low densities across the airport site due to the previous clearing of vegetation. Much of the woodland present is young regrowth, and often no hollow-bearing trees are present in woodland patches. Hollow bearing trees are critical habitat components for many tree-dwelling fauna species at the airport site, including arboreal mammals, microchiropteran bats and woodland birds that rely on hollows for shelter and breeding habitat. Due to the long timeframe it takes for hollows to form in eucalypts (usually greater than 150 years) (Gibbons et al 2000), the loss of these hollows represents a long-term reduction in habitat resources for fauna.

Shrub layers and leaf litter would also be removed as a result of construction. This would result in the loss of habitat for small woodland birds that rely on these resources for foraging and breeding. In addition, loss of leaf litter would remove habitat for small reptiles and gastropods that rely on this feature for shelter, breeding and foraging.

5.1.4 Removal of aquatic fauna habitat

The proposed Stage 1 construction would involve the infilling of stream reaches, including the upper reaches of Oaky Creek and smaller drainage lines that feed into Badgerys, Cosgroves and Duncans Creeks within the construction impact zone and the permanent loss of riparian and aquatic habitats associated with these features. All of the affected reaches are small and ephemeral and largely intermittent. The net impact of the removal of these stream reaches is mitigated in part by their degraded nature. All are highly modified and in poor condition as a result of historical and current land use and disturbance. Water quality is poor and the macroinvertebrate and fish communities are dominated by species indicative of disturbed habitats. Fish habitat is moderate or minimal at most sites and the habitats present are not suitable for threatened fish or invertebrate species (dragonflies) known or predicted to occur in the wider locality.

Badgerys Creek, which comprises the largest watercourse at the airport site would be retained within a conservation area.

A large number of artificial wetlands (farm dams) would be removed. In total, 25.4 hectares of wetland habitat would be removed. These provide only limited habitat for native fish species, with most dams dominated by the exotic Eastern Gambusia. Farm dams are not key fish habitat and do not provide habitat for threatened species listed under the FM Act.

5.1.5 Habitat fragmentation

Habitat fragmentation can result in reduced dispersal and reproductive success of biota within the fragment, a decline in populations resulting from increased predation by introduced species or native species that do not normally occur in the community, and an increased probability that stochastic events (e.g. fire) may reduce population numbers below critical levels required for their survival (Andrews 1990). In general, larger fragments are less susceptible to adverse impacts than are smaller fragments.

Construction of Stage 1 of the proposed airport would contribute to fragmentation at a local and regional scale by removing patches of habitat, severing vegetated corridors and by creating an extensive, permanent footprint that would comprise a significant barrier to movement of many species. These include in particular those that rely on connectivity of woodland patches to move through the landscape, such as small woodland birds and certain microchiropteran bats.

The proposed airport would be located in a highly fragmented, rural landscape. Fragmentation of native vegetation and associated fauna habitats in the locality has previously occurred through clearing for agriculture, residences and farm buildings and construction of linear infrastructure (such as transmission lines and roads). These land uses have created barriers to movement for some fauna species, particularly those that are limited by dispersal abilities and habitat preferences. More mobile species such as birds and bats can readily traverse this landscape. The suite of fauna species recorded in field surveys is dominated by generalist species of open country, reflecting the fragmented nature of vegetation at the airport site (see Section 4.3.1).

The geographic distribution of native vegetation on the Cumberland Plain has undergone a very large reduction since European settlement (NSW Scientific Committee 2009). The remaining area of the Cumberland Plain Woodland ecological community is severely fragmented, with more than half of the remaining tree cover mapped by Tozer *et al.(*2010) occurring in patches of less than 80 hectares and half of all mapped patches being smaller than 3 hectares (NSW Scientific Committee 2009). Any patches of the community that are greater than five hectares in area are considered inherently valuable due to their rarity (DotE 2015b). Construction within the Stage 1 airport earthworks footprint would contribute to fragmentation at a regional scale by removing patches of woodland, including a total of about 91 hectares of Cumberland Plain Woodland in mostly regenerating patches. Some patches are at least five hectares in area and include large, mature and hollow-bearing trees and as such meet the criteria for the most valuable remnant patches of this community (DotE, 2015c).

Overall, despite the current patchy and fragmented distribution of vegetation at the airport site and in the locality, construction of Stage 1 would comprise a significant increase in the degree of habitat fragmentation in the locality. Construction of Stage 1 would create a gap in habitat that is around 1065 hectares in area and about 1.5 km wide from north to south and almost 7 km long from east to west. This area would be mostly inhospitable to fauna given the presence of cleared areas, fences, infrastructure and lights. The gap would create a barrier to ecological processes such as dispersal, pollination and seed fall. Mobile, aerial species such as larger birds, flying foxes and microbats of open country (i.e. those that do not need connected woodland patches to traverse the landscape) would be able to traverse the site. Birds typical of open areas such as ibises and magpies or small grassland reptiles may continue to occur in areas of open space at the airport site and move through it, however there would be specific management measures incorporated into the proposed airport to make the site unattractive to birds to deter them from using the site, as they can pose a risk of aircraft strike (see Section 6.1.1). The proposed runway, terminals, carpark and other built features would comprise a significant barrier to the majority of fauna species particularly in combination with security fences. Light, noise, aircraft and vehicle movement may further deter fauna species from crossing these gaps in habitat. Many generalist species of open country that currently occur at the airport site would not be able to move over or through the proposed airport.

Longer term development at the airport site, including construction of a second runway and associated infrastructure, would increase the total area up to 1653 hectares and further increase habitat fragmentation in the locality and region. The likely realignment of the Northern Road, orbital road links, realigned transmission lines and rail links to the proposed airport would further fragment habitat in the area. The South West Growth Centres structure plan shows that the area to the east and south east of the airport site will be set aside for industrial / employment lands. The Badgerys Creek riparian corridor is identified as flood prone land and non-certified land and would be conserved under the strategic assessment (DoP 2010).

These impacts on habitat connectivity would be partially mitigated by the retention of habitat in the proposed environmental conservation zone. The conservation zone comprises around 122 hectares of land, including 61 hectares of woodland and forest and 61 hectares that could be

revegetated. It is located around the perimeter of the airport site, encompassing the riparian corridors of Badgerys Creek and Duncans Creek and some moderate sized patches of Cumberland Plain Woodland east and west of the airport site. The environmental conservation zone would help to maintain vegetated fauna movement corridors around the airport site, and would provide habitat stepping stones to assist movement.

5.1.6 Fauna injury, mortality or displacement

Clearing of native vegetation and removal of grassland and wetland habitat would result in fauna injury, mortality and displacement of individuals. The proposed airport would cause displacement or mortality of less mobile fauna that are within the area to be cleared for the proposed airport at the time of construction activities. The magnitude of likely impacts would vary between types of fauna, depending on their size and ecology. Some fauna may be able to seek refuge and persist in alternative habitat outside the airport site; however given the size of the airport site, entire local populations of some small animals (e.g. skinks, snails) could be destroyed.

Birds are relatively mobile and so most individuals would be able to avoid vegetation clearing (which is minimal) or construction operations. Most individuals that would be directly affected by construction of the proposed airport would be displaced initially rather than killed. Continued survival of displaced fauna would depend on the carrying capacities of neighbouring remnants and the existing fauna present and their territories. Many of the small patches in nearby areas are likely to be at carrying capacity already. Given the large area of fauna habitats that would be removed and fauna that would be displaced, it is likely that many displaced individuals would not be able to compete for resources with existing resident fauna. Mortality of less mobile individuals, such as nestlings, old or sick birds would also occur. Birds that currently breed at or in the vicinity of the proposed airport, are likely to include common and widespread species such as Noisy Miners and Australian Magpies, may have breeding success disrupted for one or more seasons.

Macropods and other large terrestrial mammals are likely to readily avoid vegetation clearing or construction operations and so individuals directly affected by the proposed airport would be displaced rather than killed. Staged vegetation clearing would provide some opportunity for fauna to move to other adjacent areas, including conservation areas and areas of the site outside of Stage 1.

There would be mortality of terrestrial animals less able to avoid the disturbance. There would also be mortality of individuals sheltering in leaf litter, woody debris, tree hollows, crevices or under bark. These would include the Cumberland Plain Land Snail, smaller terrestrial mammals, nocturnal species and especially arboreal mammals and microbats which may be sheltering in felled trees. Displaced individuals would be vulnerable to predation since they would be disturbed in daylight hours and would experience energy costs, increased risk of predation and increased competition for resources (especially for alternative hollows). This may result in impacts beyond the disturbance area by favouring aggressive or generalist species, such as the Brush-tailed Possum, over less aggressive species such as the Sugar Glider.

There will be mortality of aquatic fauna, including fish, eels, turtles and frogs, associated with the infilling of steams and draining of artificial wetlands within the Stage 1 area. The magnitude of impacts on aquatic fauna is limited to some extent by the highly modified nature of much of the aquatic habitat present and the predominance of common and widespread species that are typical of similar habitats on surrounding lands.

Recommended mitigation measures including pre-clearing surveys, fauna rescue and relocation protocols, and draining of dams are outlined in Section 9.2 to minimise the risk of mortality of

fauna as a result of clearing. The southern perimeter fence would not be installed until clearing is completed to allow fauna to escape to adjacent areas.

5.1.7 Weed invasion and other edge effects

'Edge effects' refers to factors, including increased noise and light, weed invasion, tree failure or erosion and sedimentation, at the interface of intact vegetation and cleared areas. Edge effects may result in impacts such as changes to plant community type and structure, increased growth of exotic plants, increased predation of native fauna or avoidance of habitat by native fauna. Edge effects would result from construction activities and then continue to affect vegetation and habitats adjoining the proposed airport.

Altered environmental conditions along new edges can allow invasion by pest animals specialising in edge habitats and/or change the behaviour of resident animals. Edge zones can be subject to higher levels of predation by introduced mammalian predators and native avian predators. A comparison of edge effects in a variety of different habitat types estimated that on average edge effects generally occur up to 50 metres away from the disturbed edge (Bali 2005).

Vegetation in the airport site and adjacent areas mainly occurs as small, isolated patches already subject to edge effects. Construction of the proposed airport may result in some novel edge effects where vegetation to be retained is located immediately adjacent to the Stage 1 construction impact zone. Novel edges would be created along the western and north western boundaries of the airport site and sections of the riparian corridors of Badgerys Creek and Duncans Creek that currently adjoin intact native vegetation within the airport site. The proposed environmental conservation zone would provide a buffer between the proposed airport and adjoining areas of native vegetation along its eastern, southern and western boundaries, including the majority of the vegetation within and adjoining the riparian corridors of Badgerys Creek and Duncans Creek. The northern and south western boundaries of the Stage 1 construction impact zone adjoin extensively cleared agricultural land. No new edges would be created.

The extent or severity of weed infestations may increase along the novel edges created by the proposed airport. Construction activities may further increase the degree of weed infestation in adjacent areas through dispersal of weed propagules (seeds, stems and flowers) into areas of native vegetation via erosion (wind and water), workers shoes and clothing or construction vehicles.

There is also the potential for the proliferation of noxious terrestrial and aquatic weeds in reaches downstream through discharge of water from the Stage 1 area containing weed propagules. This may result in the invasion of pools and establishment in stream channels during dry conditions, resulting in deterioration of water quality, loss of native species, restrictions in flow and pool connectivity and degradation of riparian vegetation and aquatic habitats.

Edge effects can increase the incidence of aggressive bird species such as the Noisy Miner, which can in turn reduce the habitat value for smaller, less aggressive woodland birds, In particular, this may reduce habitat quality for threatened bird species such as the Varied Sittella, recorded along the Badgerys Creek riparian corridor.

Recommendations have been made in Section 9.2 to minimise the spread of weeds.

Overall given the fragmented nature of habitat in the locality and the extent of exotic plant cover, the proposed airport would have a minor effect on the extent or seriousness of edge effects in the locality and is unlikely to introduce any new weed species or increase the significance of weed infestations.

5.1.8 Altered hydrology

Sampling in this and previous studies (as outlined in SMEC 2014) has shown that the water quality of the project area is poor with high levels of nutrients and suspended solids and elevated electrical conductivity levels due to salinity issues. The combination of elevated nutrients and elevated flows also probably contributed to the low dissolved oxygen levels observed in this study. The locality features numerous dams on the main stem channels of local waterways. These are often a source of nutrient rich, low oxygen water due to their accumulation of organic material and the long residence times for nutrients entering them. Nutrient loads in the existing waterways are generally high and do not achieve Australian and New Zealand Environment and Conservation Council (ANZECC) water quality objectives for total phosphorus and total nitrogen. However, total suspended solids loads are generally low and below ANZECC Guideline levels (GHD 2015c).

Construction of Stage 1 involves substantial alteration of the existing landform and hydrology within the Stage 1 area and has the potential to alter the hydrological regime downstream of the airport site through:

- the permanent loss of nearly all of Oaky Creek and parts of the catchments of Badgerys Creek, Cosgroves Creek and Duncans Creek. The total length of watercourse that would be removed is 36.5 kilometres. The majority of these watercourses are minor drainage lines and less defined channels.
- the replacement of a large tract of land with impervious surfaces, particularly in terms of the runway area, roads and other paved surfaces. This will increase surface runoff (notwithstanding the capture of that runoff by stormwater treatment infrastructure as outlined below) and potentially decrease groundwater recharge to the downstream reaches; and
- the capture and treatment of surface water prior to discharge from the site, a change in the quantity of discharge as opposed to that recycled for use on site and the time required for water treatment on site before discharge off site.

There is a potential for a reduction in baseflow through the reduced groundwater percolation below the new airport facility compared to the current situation. Such flow helps maintain aquatic ecosystems during lower rainfall periods, as the local groundwater has high salinity which can have a detrimental effect on aquatic flora and fauna. This will be combined with a reduction in catchment area through creek infilling. Countering this, however, will be an increase in surface runoff, though the release of that runoff will be controlled.

Depending on the nature of surface runoff water treatment, releases downstream could be more or less persistent or intermittent based on the time it takes to treat water to a sufficient level prior to release. A persistent release strategy would represent the greatest departure from current conditions given that the streams in the project area are small and ephemeral in nature. However, it would result in aeration of the waterway and the creation or enhancement of downstream riffle habitat, which would provide a beneficial outcome. An intermittent release strategy would have the opposite effect, though it may be in keeping with the existing hydrological modification associated with the presence of numerous farm dams on streams within this system. If baseflows were to be lowered, habitat deterioration in reaches downstream could occur. Results of the current study show that many of the sites downstream had low dissolved oxygen concentrations, which is probably one of the factors that contributed to the poor status of the aquatic health in those reaches. Few native species were recorded in creeks assessed in field surveys. No habitat for threatened species listed under the FM Act is present in the creeks.

The airport site would include substantial and large-scale earthworks which would modify drainage direction and overland flow paths, changing the nature of flooding on site. As construction progresses and the impervious area expands, runoff from the airport site would increase. Detention basins have been incorporated into the indicative site design which would mitigate the increase in runoff, reducing offsite impacts of surface water flows. The detention basins would be established at the start of construction (GHD 2015b).

Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands is listed as a Key Threatening Process (KTP) under the TSC Act and the FM Act. Given the above considerations, the proposed airport would increase the operation of this KTP in the locality (see Section 8.1).

At this stage it is not possible to determine the extent and magnitude of the potential impacts associated with this altered hydrological regime apart from them being likely limited to within tens of kilometres downstream or less given the size of the overall catchment affected. However, the waterways within the airport site only cover 0.14 km^2 out of a total catchment area for South Creek of 690 km^2. Therefore, these represent a small portion of the overall catchment. Therefore a modification to the local hydrology associated with construction of Stage 1, is likely to have only a relatively small influence on downstream flows in the catchment.

The proposed airport design and land use plan includes measures purposefully designed to avoid substantial alteration of hydrological regimes downstream of the airport site. These measures should mitigate any impacts of changed hydrology on aquatic and riparian communities downstream of the site (see Section 9). Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.

5.1.9 Erosion, sedimentation and contamination

There is the potential for indirect impacts on habitats adjoining and downstream of the airport site as a result of erosion and sediment mobilisation and accidental spills or release of contaminants.

Potential sources within the airport site would include:

- runoff from areas stripped of vegetation;
- runoff from soil stockpiles;
- runoff from hardstand areas, including temporary roads, processing areas and site facilities;
- leakage or spillage of hydrocarbon products from vehicles, wash down areas and workshops;
- refuelling bays and fuel, oil and grease storages; and
- release of contaminants contained in soil disturbed during earthworks.

There is a considerable risk of biodiversity impacts arising from these factors because of the scale of the construction impact zone and especially the volume of earthworks. Clearing and bulk earthworks would increase the surface area and in some instances the slope of exposed soil surfaces at the airport site. These conditions would present a risk of erosion and associated surface water quality impacts (see to GHD 2015b).

There are sensitive environmental receptors adjacent to the Stage 1 construction impact zone, including the Badgerys Creek riparian corridor and associated native vegetation. The downstream riparian corridors of Cosgrove Creek, Badgerys Creek and Duncans Creek would be particularly susceptible to impacts.

There is a risk of sediment mobilisation and transportation to downstream environments given the extent and magnitude of clearing and earthworks proposed. Increased sediment mobilisation could result in short term elevations in turbidity, but in worse cases, could result in the short to medium term infilling of pool habitat and smothering of riffle habitat downstream. This would markedly reduce the habitat quality for aquatic fauna. Elevated turbidity can have both direct and indirect effects on aquatic flora and fauna. Suspended sediment particles, if in high enough concentrations, can clog the gills of macroinvertebrates, abrade and damage the gills of fish and clog the filter feeding apparatus of some macroinvertebrate species. Prolonged periods of elevated turbidity can lead to reduced growth of periphyton and submerged aquatic macrophytes, which are a food and habitat source for resident aquatic fauna. Unless there is catastrophic uncontrolled sediment runoff, it is likely that elevated turbidity will be short lived. Local aquatic flora and fauna are likely to be adapted to experiencing short pulses of elevated turbidity during rainfall events. Given these considerations and proposed mitigation measures, potential impacts are likely to be both short term and limited.

Contamination of downstream waterways as a result of fuel, oil or chemical spills may occur during construction. If not properly contained, these could potentially result in reduced habitat quality and potentially the direct mortality of aquatic fauna and flora. In general, most fuel and oil spills will be small in size such that their potential impacts will be highly localised. Fuel also volatilises such that small spills are likely to result in short-lived impacts to aquatic flora and fauna. There is always the potential for larger spills to occur, which could lead to more extensive and medium term impacts in reaches downstream. Surfactants used to clean up large fuel and oil spills can also be toxic to aquatic flora and fauna.

The airport site has historically comprised a variety of land uses including rural residential, agricultural, poultry farming and light commercial activities. High risk areas for potential contamination typically comprised sites of demolished buildings, significant disturbance of earth (indicating filling with material of unknown origin), the dumping and/or stockpiling of waste material that may contain asbestos and current or historic fuel storage areas (refer to chapter 14 of the EIS). Given the historic landuse at the airport site, it is possible that soil excavation could result in contaminants being unearthed. If not properly identified and contained/removed, those chemicals could be mobilised to local waterways as part of surface water runoff. It is possible that these chemicals may result in acute toxicity effects to local aquatic fauna, though it is likely that their influence would be temporary, small in extent and somewhat nullified by dilution during runoff events.

The design capacity and placement of detention basins would ensure that all drainage water from disturbed areas would be captured prior to discharge. The drainage system would include the main detention basins (see Figure 1–1) and a series of upstream interim detention basins. The drainage system would have the effect of improving the quality of the surface water prior to release by allowing sediment to settle within the basins. The drainage system, in combination with other standard construction erosion control measures would readily mitigate the potential impacts of sedimentation (GHD 2015b).

Erosion and sedimentation impacts would be readily avoided, mitigated and managed by implementing standard stormwater and erosion control measures (refer to GHD 2015c). Recommended soil protection measures and techniques and management of chemicals and spills are outlined in Section 9.2. Any localised increases in erosion hazard or sources of other contaminants as a result of construction would be limited to the immediate earthworks footprint and there would be appropriate control devices and buffers between the earthworks footprint and sensitive receptors, staged clearing and rapid stabilisation of soil surfaces.

With the sediment basins and other mitigation measures in place, construction is not expected to have any significant impact on existing water quality concentrations in the receiving waters

downstream of the site. Any exceedances would likely be localised and short term (GHD 2015c). As such the Stage 1 development is not likely to affect water quality of downstream aquatic habitats, including key fish habitat. Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.

5.1.10 Dust generation

Construction of the Stage 1 development would result in dust emissions generated during both the bulk earthworks and the aviation infrastructure works. High dust levels could reduce habitat quality for flora and fauna species by reducing plant and animal health in adjacent areas of vegetation. Dust may affect photosynthesis, respiration and transpiration in plants and allow the penetration of gaseous pollutants. This then leads to decreased productivity, and in the long-term can alter community structure (Farmer 1993). Dust would also impact health of fauna, such as through respiratory disease, and the reduction in health of animals would be exacerbated by changes to plant health and community structure. Recommended mitigation measures to minimise impacts of dust are identified in section 9.2.

5.1.11 Generation of light, noise and vibration

There would be noise impacts during construction as a result of vegetation clearing, the movement of vehicles and operation of plant. Much of the airport site currently experiences ongoing noise from vehicles travelling along roads, from agricultural activities and from light aircraft operating from existing aerodromes. Given the existing noise levels in the vicinity of the proposed airport, clearing and construction noise is not likely to be a novel impact for most fauna species. Background noise levels associated with clearing and construction would increase, and would persist for many years. This would impact fauna both within the site and in adjacent areas. There is the potential for individuals that nest or den in trees that are close to the proposed airport edge abandoning their nests and dens as a result of noise during construction. Noise may also affect general fauna activity in these areas. Many fauna individuals are, however, likely to become habituated to the increased noise levels in the long-term.

Light spill from construction areas may occur at night. Parts of the airport site are already subject to light from streetlights, residences and other buildings. Construction would change the location of lighting, introducing light to areas previously not subjected to artificial light, and increasing light levels in areas already subject to existing light. This may disturb fauna in adjacent vegetation, changing their behaviour patterns. Fauna are likely to become habituated to light in the long-term.

Vibration impacts may result from works associated with the proposed airport, such as heavy vehicle movement and construction activities. Vibration may deter native fauna from using the area surrounding the source of vibration. This may potentially interrupt dispersal within the locality if an individual is unwilling to travel through an area where vibration is detectable, or may cause some species to abandon an area in search of areas where vibration is not detectable. Within the airport site, some level of vibration is already present as a result of vehicles travelling along roads in the area. Vibration throughout the airport site and adjacent areas during construction would increase.

5.1.12 Spread of pests and pathogens

Construction activities within the airport site have the potential to introduce or spread pathogens such as Phytophthora (*Phytophthora cinnamomi*), Myrtle Rust (*Uredo rangelii*) and Chytrid fungus (*Batrachochytrium dendrobatidis*) into adjacent native vegetation through vegetation disturbance and increased visitation. There is little available information about the distribution of these pathogens within the locality, and no evidence of these pathogens was observed during surveys. Phytophthora and Myrtle Rust may result in the dieback or modification of native vegetation and damage to fauna habitats. Chytrid fungus affects both tadpoles and adult frogs and can cause 100% mortality in some populations once introduced into an area. Recommended mitigation measures to prevent the introduction or spread of disease that could potentially impact threatened biota in adjacent areas are identified in section 9.2.

5.1.13 Fire

Construction of the proposed airport has a risk of fire, for example from storage of combustible fuels or ignition from works areas. The risk of fires spreading to adjacent areas would be expected to be minimal given the fire hazard management plan and other measures to contain and control the outbreak of fire.

5.2 Longer term development

5.2.1 Direct impacts

The construction impact zone for longer term development at the airport site is assumed to comprise the entire area of the airport site outside of the Stage 1 construction impact zone and the environmental conservation zone. This comprises the maximum extent of vegetation clearing and grubbing, earthworks and the permanent infrastructure that would be constructed for longer term development at the proposed airport. Construction of longer term development would result in direct impacts within a maximum 588 hectare disturbance footprint, including 127 hectares of native vegetation as shown on Figure 4. The extent of clearing of vegetation and habitats within the longer term development impact zone is summarised in Table 60.

Longer term development at the airport site would further increase the degree of fragmentation of native vegetation and habitat in the locality and the region as well as increase the loss of streams, artificial wetlands and associated aquatic habitats. A second runway and associated infrastructure would increase the gap in habitat at the airport site to a total area around 1650 hectares and would be around 2.5 km wide from north to south. The likely realignment of The Northern Road, orbital road links, realigned transmission lines and rail links to the proposed airport would further isolate or fragment habitat.

Longer term development at the airport site would further reduce the extent of native vegetation and habitat and result in additional direct and indirect impacts on flora and fauna populations. Longer term development at the airport site would further increase the significance of impacts of Stage 1 and would comprise a substantial impact in its own right.

Table 60 Estimated area of vegetation removal for longer term development

Vegetation Zone	TSC Act Status	EPBC Act Status	Maximum longer term development area of impact (hectares)
Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	CEEC	CEEC	43.0
Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	CEEC		21.3
Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	CEEC	CEEC	11.1
Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	CEEC		7.0
Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	EEC		21.9
Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	EEC		10.4
Good condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	EEC	CEEC	2.5
Poor condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	EEC		0.6
Good condition artificial freshwater wetland on floodplain (HN630)			9.6
Total native vegetation			**127.5**
Exotic grassland			279.2
Cleared land or cropland			181.4
Total			**588.0**

Notes: EEC – endangered ecological community; CEEC – critically endangered ecological community.

5.2.2 Indirect impacts

Longer term development at the airport site would result in a similar set of indirect impacts as for Stage 1 (see Section 5.1). Potential indirect impacts include:

- weed invasion of adjacent vegetation or aquatic areas, which may reduce habitat quality for native flora and fauna;
- edge effects, which may reduce habitat quality for native flora and fauna in adjacent areas;
- erosion, mobilisation and transportation of sediment, which could reduce habitat quality for flora and fauna species by reducing plant and animal health in adjacent areas of vegetation and aquatic areas downstream;
- generation of dust, which could reduce plant and animal health in adjacent areas of vegetation;
- the risk of toxicity or degradation of habitat due to generation of contaminants from accidental spills of fuel or mobilisation of contaminants due to earthworks;

- further alterations to the hydrology of catchments (noting that the proposed airport would be designed to avoid adverse changes to hydrology and may result in an overall improvement in water quality);
- generation of noise, light and vibration, resulting in disturbance of fauna that reside or use habitats near the construction area; and
- potential spread or introduction of pathogens such as Phytophthora, Myrtle Rust and Chytrid fungus into adjacent native vegetation and downstream habitats through vegetation disturbance and increased visitation.

Environmental management and mitigation measures to prevent the introduction or spread of disease, minimise sedimentation and erosion, limit the generation of dust and minimise the potential spread of pathogens would be implemented with longer term development at the airport site. These measures would be similar to those proposed for stage 1 (see Section 9.2) but would be refined as appropriate to the specific infrastructure and receiving environments associated with longer term development.

6. Operation impacts

6.1 Stage 1 development

6.1.1 Bird and bat strike

The presence of the proposed airport would create a risk of mortality for birds and bats at or near the proposed airport. Birds are often attracted to airports because of grass, lights, water, feeding trees, or roosts, while flying-foxes tend to come in contact with aircraft while transiting between roosting sites and foraging areas (Parsons et al 2009). Most bird strikes occur within the confines of aerodromes (less than 5 km) for all types of aerodromes (ATSB 2009). Analysis of strike data from 2002-2009, found that in general lapwings and plovers were the most common species to be involved in aircraft strike in Australia (597 incidences), followed by flying-foxes (542 incidences) and Galahs (532 incidences). In NSW, this order is reversed, with Galahs being the most common species struck by aircraft, followed by flying-foxes then lapwings and plovers (ATSB 2009). Galahs are the species for which strikes of more than one bird (i.e. a flock) are most likely to occur, according to data collected between 2004 and 2014 (ATSB 2014). Combining raptor groups, kites, hawks and eagles were struck 769 times over the period in Australia, and 98 times in NSW (ATSB 2009). Large water birds, such as ibis and herons, were struck 170 times between 2002 and 2009 (ATSB 2009) and waders such as curlews and sandpipers (i.e. migratory waders), were hit 187 times in this period, the majority (180) being from Queensland and the Northern Territory (ATSB 2009). The highest rate of bird strike was found to occur at Darwin and Cairns, likely due to the higher bird populations present in tropical areas (ATSB 2009).

A high diversity of bird species was recorded at the airport site, including many species that occur in large flocks, or would fly at heights where aircraft strike is a risk A small number of large raptors were observed in the airport site, including Wedge-tailed Eagles, White-bellied Sea-eagles, Little Eagles, Black Kites and Whistling Kites. It is most likely that one or two pairs of each species occur in or near the airport site. Large flocks of ibis and herons occur in and around the airport site, due to the large number of farm dams as well as fertilised crop fields, as do a wide variety of ducks and other water birds. Few migratory wader species are likely to occur in and around the airport site, although at least two species were recorded. A wide range of other bird species is also likely to be at risk of aircraft strike, including magpies, swallows, ducks and ravens.

The bird and bat strike risk assessment prepared for the proposed airport (Advisor 2015) found that these species would be likely to remain in the area and present at least a moderate strike risk during operation of the proposed airport. Farm dams are common in the surrounding area and present the greatest bird hazard for the proposed airport. Nearby landfills, such as Spring Farm Landfill, also support high numbers of large birds, which may result in birds transiting operational airspace (Advisor 2015). Although potentially moderate and high risk species were recorded in surveys by both Advisor and GHD, their numbers were not unusually large and there were limited transits through the air (Advisor 2015). While birds are likely to be struck on occasion, management measures (see Section 9.2) would minimise the risk of this occurring, and as such the viability of populations in the local area are not likely to be threatened.

As noted above, flying-foxes are one of the more common species hit by aircraft in Australia and NSW. Flying-foxes can be resident at a camp, may migrate locally between nearby camps, or may move nomadically long distances (Eby 1996). Camp populations do not function as a unit. Individuals or small groups move independently of other flying-foxes (Eby 1991), and may therefore move between camps at different times. A radio-tracking study of Grey-headed Flying-foxes in Sydney found that individuals or small groups were frequently found to roost at various

sites throughout metropolitan Sydney, and interchange between the Cabramatta and Gordon colony sites was observed. Gordon colony bats were also recorded at various camps on the NSW north and south coasts (Augee and Ford 1999). A previous radio-tracking study had also found considerable interchange between bats in adjacent colonies (Spencer et al 1991). Based on bat strike data collected at Australian airports between 1996 and 2006, most bat strikes occurred around sunset, and about three quarters of recorded bat strikes occurred during landing of aircraft. Grey-headed Flying-foxes typically leave their day roost within 30 minutes after sunset. Bat strike rates differed in airports depending on location, with the five highest rates of bat-strike occurring in tropical regions (Parsons et al 2009).

Given these results, movement of flying-foxes can occur between the camps present near the proposed airport at any time. There are at least seven camps located within 20 km of the proposed airport (Advisor 2015), and the locations of these may result in individual bats flying across the proposed airport and approaches and being at risk of mortality from aircraft strike. In addition, bats travelling from local camps to foraging areas may also fly across the proposed airport and approaches and be at risk of mortality from aircraft strike. While occasional bats may be killed by aircraft strike, this is not likely to substantially change the population numbers in nearby camps.

Despite the risk of bird and bat strike due to species presence and abundance, habitat availability on and around the site, and projected aircraft movements, the location of the proposed airport would reduce the overall risk relative to other possible locations. For example, the airport site is not located in a tropical area, is not near an estuary, is not within a major bird migratory route, and does not have flying-fox camps in close proximity. As such the overall abundance of birds and bats would be lower than if these were the case. In addition, the available habitat in the locality would reduce over time as areas around the proposed airport urbanise (Advisor 2015). Furthermore, each potential contributor to bird and bat strike risk at the proposed airport can be managed to an acceptable risk level so the overall bird and bat strike risk for the proposed airport is low (Avisure 2015).

Recommended mitigation measures to minimise the risk of bird and bat strike are outlined in Section 9.2.

6.1.2 Terrestrial fauna strike

Movement of aircraft and support vehicles on the tarmac has the potential to result in mortality or injury of fauna that reside or forage in cleared areas alongside the tarmac. These fauna species may attempt to cross the tarmac and thus be struck by aircraft and support vehicles. Fencing of the proposed airport is likely to prevent large mammalian fauna such as kangaroos and wallabies occurring within the proposed airport, thus minimising the potential for impact. The proposed airport would be designed to be unattractive to wildlife and would be managed to deter occurrence. Recommended mitigation measures to minimise the risk of terrestrial fauna strike are outlined in Section 9.2.

Operation of the proposed airport would increase general traffic in the area surrounding the proposed airport, and could result in increased risk of fauna mortality on surrounding roads. Vehicle strike on surrounding roads is already likely to be high, given the presence of vegetated and agricultural areas. As further development occurs as a result of the proposed airport and more areas of agricultural and forested land are removed, fauna mortality from vehicle strike would reduce.

6.1.3 Noise and vibration

Increased noise and vibration would occur in adjacent vegetated areas from the operation of the proposed airport, via both aircraft and vehicle movements. Fauna most at risk would be those residing in close proximity to the proposed airport. Most fauna species are likely to become accustomed to the noise and vibration, as many species that occur in the surrounding area are already accustomed to noise from roads and agricultural areas. The increased noise and vibration may result in the displacement of less-tolerant species.

Noise would extend into surrounding areas as a result of landing and take-off of aircraft. Indicative flight paths for the Stage 1 operation of a single runway are included in the conceptual airspace design. This will be refined closer to the commencement of operations, and will include consideration of potential noise abatement opportunities at that time. Aircraft may approach the proposed airport from the south-west and take off to the north-east or approach the proposed airport from the north-east and take off to the south-west, depending on meteorological conditions (refer to Chapter 7 of the EIS). The flight paths presented in Chapter 7 of the EIS show two major departure tracks in each direction, which each branch into other flight paths at distances that are relatively far from the proposed airport. For departures to the south-west there is a third flight path passing roughly over the township of Warragamba that is nominated to be used by non-jet aircraft only, in order to minimise environmental impacts, including noise, beneath this route. Total numbers of aircraft movements per day are predicted to be about 198 in 2030, increasing to over 1000 in 2063. The majority of aircraft movements are likely to be by large aircraft, such as the Airbus A320 (refer to Chapter 7 of the EIS).

An overall sound power level (noise level at source) of 151 dBA has been assumed for take-off of aircraft based on previous measurements of a number of aircraft types. Reverse thrust during landing would result in an overall sound power level (noise level at source) of 154 dBA. Taxiing aircraft may produce a sound power level (noise level at source) of 138 dBA. Noise levels above 65 DBA are expected to extend up to about 4 km outside the northern boundary of the airport (Wilkinson Murray 2015a).

Given the removal of vegetation during construction, there would be minimal impact of noise on fauna within the airport itself, as most fauna would no longer occur within the airport site. Aircraft operations to the north-east of the proposed airport will occur over areas where there is minimal native vegetation. Aircraft noise would impact fauna that occur along riparian corridors such as South Creek, and at farm dams in the area. Aircraft operations to the south-west of the proposed airport, would occur over relatively small patches of vegetation in close proximity to the proposed airport. Some aircraft noise would also occur over portions of the Greater Blue Mountains World Heritage Area closest to the proposed airport (see Section 8.2.5).

Noise has been shown to have a variety of impacts on fauna, including changing foraging behaviour, impacting breeding success and changing species occurrences (Barber et al 2009). A number of studies have investigated the effect of aircraft noise on fauna. Peregrine Falcons (*Falco peregrinus*) have been shown to be tolerant of aircraft noise in the range 80-87 dB, but low level aircraft flights have resulted in flight response, nest abandonment or reproductive failure (Ellis, Ellis, & Mindell, 1991). Anderson et al (1996) found that Red-tailed Hawks (*Buteo jamaicensis*) show strong avoidance behaviour as a result of novel impacts from low-level helicopter flights, but do habituate to the noise over time. Ducks have been shown to react to low-flying aircraft, but the energetic costs to each species were deemed low because disruptions represented a low percentage of their time-activity budgets, only a small proportion of birds reacted to disturbance, and the likelihood of resuming the activity disrupted by an aircraft disturbance event was high (Conomy et al 1998). Some animals have been shown to change their distributions in response to anthropogenic noise. The response of Sonoran

Pronghorn (*Antilocapra americana sonoriensis*) to military jets (avoiding high areas) could exacerbate habitat fragmentation and connectivity (Landon et al 2003).

A number of studies have investigated impacts of road traffic noise on fauna. Studies on bats have found that some species avoid foraging in noisy areas such as near highways (noise levels between 68-80dB) as the noise may interfere with listening for prey (Schaub et al. 2008). Similarly, highways have also been shown to have an impact on woodland birds, resulting in lower incidence of bird occurrence near noise (Reijnen et al 1995). Traffic noise has also been shown to interfere with frogs, resulting in decreases in calling activity, and preventing females from easily locating the source of male calls, both of which could reduce reproductive success (Bee and Swanson 2007, Lengagne 2008).

Most impacts on fauna are likely to occur near the proposed airport, where aircraft are low and noise levels are highest. Many species would have already relocated given the removal of vegetation associated with construction of the proposed airport. Given the patchy nature of surrounding vegetation, this may increase competition for resources in other areas of native vegetation. Species less tolerant to disturbance may be displaced as a result of the proposed airport. Constant noise from aircraft and other vehicles would make the surrounding area less suitable for species that are less tolerant of disturbance. Species that remain in the area may be affected by aircraft and other noise at the proposed airport. Some birds are known to abandon their nests in response to noise. This would be of particular concern for the White-bellied Sea-eagle and Little Eagle as these large raptors are likely to use permanent nest sites near the proposed airport. These species may have the initial breeding season disrupted when the operation of the airport commences, but are likely to relocate and breed elsewhere. Other more resilient fauna species are likely to become accustomed to the noise, and this increased or novel impact is unlikely to result in a decrease in population numbers or diversity of these species.

6.1.4 Light

Increased light would result from the operation of the proposed airport, via landing lights, tarmac lighting, terminal lighting and aircraft and vehicles. Impacts would be greatest in areas immediately adjoining the proposed airport. Some fauna species are likely to become accustomed to the light, including species such as possums and the Tawny Frogmouth which are common and widespread in areas with street lights across suburban Sydney. Many fauna individuals and species that are currently resident at the airport site would already be accustomed to existing residential and road lighting. The increased light may result in the displacement of less-tolerant species, but could also attract some birds and bats that forage on insects attracted to light. These species may then be susceptible to aircraft strike in the absence of mitigation (see section 6.1.1).

6.1.5 Fire

Operation of the proposed airport will create a risk of fire, for example from storage of combustible fuels, and ignition from works areas. The risk of fires spreading to adjacent areas would be expected to be minimal given the fire hazard management plan and other measures to contain and control the outbreak of fire.

6.1.6 Contamination

Operation of the proposed airport could result in spills of aviation fuel, vehicle fuel and other chemicals. Management of the proposed airport is also likely to require the use of pesticides and/or herbicides in mown areas near the tarmac and along roadsides. These chemicals could potentially enter local waterways and impact aquatic and riparian habitat downstream of the proposed airport. Appropriate mitigation measures would be incorporated into the management

of the proposed airport and other infrastructure to minimise the risk of impact of chemical spills. Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.

6.1.7 Water quality

The change in land use from a largely rural-residential area to an airport facility will have long-term effects on water quality in downstream reaches close to the airport site. As described in section 0, water quality of the airport site is poor with high levels of nutrients and suspended solids and elevated electrical conductivity levels due to salinity issues. The combination of elevated nutrients and elevated flows also probably contributed to the low dissolved oxygen levels observed in this study. Nutrient loads in the existing waterways are generally high and do not achieve ANZECC water quality objectives for total phosphorus and total nitrogen. However, total suspended solids loads are generally low and below ANZECC Guideline levels (GHD 2015c).

Eight bio-retention basins would be located along the perimeter of the airport site. Basins 1, 2, 3, 4, and 5 would be located along the southern boundary to provide water quality treatment of the stormwater flows prior to discharge to Badgerys Creek. Basins 6 and 7 would be situated along the northern boundary to manage the flows discharging into Oaky Creek and Cosgroves Creek. Basin 8 would be positioned to manage flows discharging into Duncans Creek. All the basins are proposed for construction during Stage 1 of the project, except for Basin 5, which would be constructed during the longer term development phase (GHD 2015c).

Under the proposed Stage 1 development conditions, with the proposed bio-retention basins in place, reduction of the post-development loads to pre-development loads (neutral or beneficial effect – NORBE) would not be achieved, except for suspended solids. Similarly, the bio-retention basins would be unable to satisfy the Water Sensitive Urban Design (WSUD) targets, except for flows discharging from the site into Oaky Creek and Cosgroves Creek. For Badgerys Creek where the percentage retention targets are not met, it is considered that additional design measures would be required, particularly in the residual catchment areas associated with Basin 2, Basin 4, and Basin 5. ANZECC water quality objectives would also not be achieved, except for suspended solids. This is notwithstanding the general improvements in water quality concentrations relative to the existing conditions, particularly in Badgerys Creek and South Creek (GHD 2015c).

Additional design measures would need to be assessed and designed for implementation during the detailed design phase. These would include the provision of enhanced bioretention swales along the drainage lines, the provision of diversion drains to convey flows from residual sub-catchment areas to the proposed bio-retention basin, and enlarging some of the bio-retention basins, where necessary. Additional mitigation and management measures, including water quality monitoring, should also be implemented during the construction and operational phases of the project (GHD 2015c). Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.

With the implementation of the above additional measures, it is expected that the proposed airport would have no adverse impact on downstream water quality (GHD 2015c). As such, the airport would have no adverse impact on downstream key fish habitat and other aquatic habitat, or on threatened species that may occur downstream of the airport site.

6.1.8 Hydrology

The alterations to the topography and permeability of the airport site made during construction would persist through operation of the Stage 1 development. The operating Stage 1

development would therefore affect flows in receiving watercourses upstream and downstream of the airport site, relative to existing conditions. The Stage 1 development would result in a portion of the airport site currently draining towards the catchments of Oaky and Cosgroves Creeks to the north being diverted south towards Badgerys Creek whilst a portion of the airport site draining to Badgerys Creek would be diverted to Duncans and Oaky Creeks.

Changes to flooding have the potential to affect the physical condition of watercourses. Hydrologic and hydraulic modelling indicates that duration, volume and velocity of surface water flows in watercourses would be generally similar or reduced when compared to existing flow conditions (GHD 2015b). Increases in flood depth at Cosgroves Creek and Oaky Creek have the potential to affect the physical stability of watercourses through bed or bank erosion. Localised increases are also expected to occur at basin outflows. These potential impacts would need to be mitigated through further refinement of the surface water drainage system. Changes to surface water flows elsewhere upstream and downstream of the airport site are not expected to affect the physical stability of watercourses (GHD 2015b). Impacts on aquatic habitat and key fish habitat may thus occur as a result of changed hydrology. These impacts are likely to be generally restricted to reaches close to the airport site. Further downstream, inflow from other creeks will dissipate these changes. Few native species (gudgeons) were recorded in the airport site, and these were generally located in the Oaky Creek sites. Eels were recorded at dams at in Badgerys Creek. Given the generally poor quality of aquatic habitats in and downstream of the airport site, the proposed airport is unlikely to have a substantial impact on fish habitat in downstream areas. No threatened species listed under the FM Act are likely to occur immediately downstream of the airport site. The proposed airport is unlikely to have an impact on terrestrial threatened species habitat that may occur downstream of the airport site. Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.

An estimated 2.5 ML of domestic wastewater per day would be generated during operation of the Stage 1 development. The wastewater be reticulated, treated and recycled (as grey water), or irrigated on site. Treatment and irrigation methods would be determined in detailed design but is expected that wastewater would be treated with Membrane Biological Reactor technology. This technology produces high quality reclaimed water suitable for beneficial reuse or irrigation (refer to GHD 2015b).

6.1.9 Fuel jettisoning

Fuel jettisoning (also known as fuel dumping) could result in impacts on biodiversity values by introducing harmful contaminants into sensitive environments. The region surrounding the proposed airport includes sensitive receptors, including native terrestrial vegetation and freshwater, estuarine and marine environments. However, given the infrequency of events and the small percentage, if any, of fuel reaching the ground, it is unlikely that fuel jettisoning from aircraft using the proposed airport would have a tangible impact on biodiversity values.

Fuel jettisoning is extremely rare and usually related to emergencies for civilian aircraft where aircraft need to make an unscheduled landing. Aircraft commonly used on shorter haul domestic routes (e.g. the Boeing 737) do not have fuel jettisoning capability as they can land fully fuelled in an emergency situation. Larger aircraft used on longer domestic routes such as the Airbus A330-300/400 do have fuel jettisoning capability. Civilian aircraft which may require the ability to dump fuel are most often used for long haul international flights. Fuel jettisoning occurs when either a declared medical emergency or mechanical fault on board necessitates an unscheduled landing.

Fuel jettisoning occurs very infrequently. Airservices Australia indicate that of the 730,201 aircraft movements in Australia in 2014, there were only 10 instances of fuel jettisoning, and there are currently no recorded cases of fuel from civil aircraft reaching the ground..

In Australia there are specific protocols in place to regulate fuel jettisoning in accordance with the Air Navigation (Fuel Spillage) Regulations 1999. For example, pilots must obtain authority from air traffic control before commencing the jettison of fuel and must receive instruction on where the fuel jettisoning is to be performed. The jettisoning of fuel is required to occur in clear air at 6,000 feet (approximately 2,000 metres) above ground level, and in an area nominated by air traffic control to ensure that all fuel is vaporised before reaching the ground. Due to improvements in fuel efficiency and lightweight aircraft material, the amount of fuel jettisoned from aircraft under emergency situations has decreased substantially, with this trend anticipated to continue (refer to Chapter 11 of the EIS).

The effects of fuel jettisoning on local air quality would be limited due to the inability of many aircraft to jettison fuel, the rapid vaporisation and wide dispersion of jettisoned fuel, the strict guidelines on altitudes and locations for fuel jettisoning, and the anticipated reduction in fuel jettisoning events and volumes in the future. For these reasons, fuel jettisoning is not considered likely to have a significant immediate or future impact on local air quality or biodiversity values.

6.1.10 Introduction of novel species

As with any international airport or seaport, operation of the proposed airport poses a biosecurity risk. There is the potential for the introduction of exotic species as a result of the transport of goods on aircraft. For example, the one record of Yellow Crazy Ants (*Anololepis gracilipes*) from New Zealand is likely to have been a transit passenger (on taro in air baggage) (Biosecurity New Zealand, undated). Invasion of Yellow Crazy Ants is listed as a key threatening process under the TSC Act (see section 8.1). Any escaped novel species could potentially establish in nearby vegetated areas, or be transported to other areas of native vegetation with cargo, and impact the local native flora and fauna.

All aircraft arriving in Australia from overseas are subject to Australian biosecurity requirements administered by the Department of Agriculture. Further, the proposed airport and airlines using the proposed airport would be expected to comply with all Australian laws relating to biosecurity, similar to existing airports already in operation.

6.2 Longer term development

Longer term development at the airport site would result in a similar set of operational impacts as for Stage 1 (see Section 6.1). Potential operational impacts arising from longer term development at the airport site would include:

- the risk of bird and bat strike would increase with the increased aircraft traffic;
- the risk of terrestrial fauna mortality through vehicle strike may increase, although the increased development of industrial and commercial areas around the proposed airport is likely to result in a reduced risk over time, as less habitat is available for these fauna species;
- the risk of toxicity or degradation of habitat due to generation of contaminants from accidental spills of fuel, pesticides, herbicides or transported goods;
- increased noise, light and vibration which may result in the further displacement of less-tolerant species from habitats adjoining the airport site;
- the risk of fires which may spread to adjacent vegetation; and
- introduction of novel species.

7. Cumulative impacts

The potential for cumulative impacts due to the Stage 1 development and the longer term development at the airport site has been considered.

Other planned and potential infrastructure developments in the locality include the likely realignment of The Northern Road around the airport site, implementation of the Western Sydney Infrastructure Plan which includes the M12 motorway and The Northern Road upgrades, potential future orbital road links, realignment of transmission lines and potential extension of the South West Rail Link, including a potential connection to the proposed airport. The South West Growth Centres structure plan shows that the area to the east and south east of the airport site will be set aside for industrial / employment lands (DoP 2010).

The proposed airport is likely to result in facilitated impacts on biodiversity values (i.e. impacts that are more likely to occur because the proposed airport has been developed). Construction of the proposed airport is likely to accelerate economic activity in the locality, commercial developments in the surrounding Broader Western Sydney Employment Area and housing development in the South West Growth Centre. These developments and activities would result in cumulative and facilitated impacts connected to Stage 1 of the proposed airport, including:

- additional removal of native vegetation and habitat resources;
- additional injury, displacement or mortality of individuals within local flora and fauna populations;
- increased fragmentation of habitat and creation of novel edge effects in remnant native vegetation;
- increased generation of noise and light and increased risk of plane strike associated with a second runway at the airport site and vehicle collisions associated with other transport infrastructure;
- increased risk of the spread of weeds, pathogens or pest fauna and/or increased negative impacts arising from these factors;
- increased risk of toxicity or degradation of habitat due to the generation of contaminants; and
- further alterations to the hydrology of catchments (noting that the proposed airport would be designed to avoid adverse changes to hydrology and may result in an overall improvement in water quality).

Many of these cumulative impacts would exacerbate the effect of already significant impacts of Stage 1, such as the reduction in extent of Cumberland Plain Woodland, removal of Grey-headed Flying Fox habitat and removal of small terrestrial fauna populations at the airport site (see Section 0). Impacts of construction of the longer term development would be significant in their own right. Other infrastructure proposals and larger-scale commercial developments in the locality would also likely result in a significant impact on Cumberland Plain Woodland and habitats for certain threatened fauna species.

The biodiversity values that are likely to be affected have relatively low ecosystem resilience because of the existing cumulative impacts of development in Western Sydney. At least 90% of the estimated pre-European extent of each of the native vegetation types at the airport site have been removed (OEH 2015c). Remnant vegetation is also severely fragmented at a regional scale, with more than half of the remaining tree cover mapped by Tozer *et al.* (2010) occurring in patches of less than 80 hectares and half of all mapped patches of Cumberland Plain Woodland being smaller than three hectares (NSW Scientific Committee 2009). Future

biodiversity assessments and development approvals will need to consider carefully the avoidance, mitigation and offsetting of impacts in order to ensure that cumulative impacts do not result in unacceptable impacts such as the local or regional extinction of any biota.

Cumulative impacts connected to the proposed airport would occur in the context of human induced climate change, which is recognised as a serious threat to biodiversity values. Climate change threatens biodiversity values directly, by affecting ecosystem processes and habitats, and indirectly, by compounding the impacts of existing and ongoing pressures on biodiversity values (Steffen et. al 2009; DotE 2015e). Stage 1 of the proposed airport, longer term development at the airport site and related development in the locality would contribute to the impacts of climate change through removal of vegetation and production of greenhouse gases.

'Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases' is listed as a key threatening process (KTP) under the EPBC act and consists of reductions in the bioclimatic range within which a given species or ecological community exists due to emissions induced by human production of greenhouse gases (DotE 2015d). Ecosystems in which the KTP occurs include: alpine habitats; coral reefs; wetlands and coastal ecosystems; polar communities; tropical forests; temperate forests; and arid and semi-arid environments (DotE 2015d). Although temperate forests such as the ecosystems at the airport site are included in this list, they would not be particularly susceptible to the impacts of climate change. The species ecosystems which are most at risk are those which function within a limited range of climatic parameters such as tropical coral reefs or alpine environments (Steffen et. al 2009). The temperate woodlands and forests at the airport site are associated with a comparatively broad and mild set of climatic conditions. The climate of Western Sydney includes pronounced seasonal and multi-annual variability in temperature and especially rainfall. It is widely accepted that the ecological communities associated with *Eucalyptus* woodlands of south eastern Australia are tolerant of this variability. This is apparent in the presence of adaptive characteristics or life history strategies that provide resilience to drought or wildfire.

The biodiversity values of sclerophyllous vegetation in south-eastern Australia may be at risk of negative impacts as a result of increased wild fire frequency or intensity due to climate change, with pockets of fire-sensitive vegetation that occur in flammable matrices most at risk (Steffen et. al 2009). Pockets of Western Sydney Dry Rainforests and Moist Shale Woodland in the locality would be susceptible to these impacts (TSSC 2013) however the majority of the region features grassy woodland or forest vegetation that is tolerant of fire (DEC 2005; NPWS 2006; Tozer 2010). The recommended fire regimes for grassy woodland or forest vegetation types on the Cumberland Plain is no more frequently than every five to seven years but no less frequently than every 35 years (DECCW 2010).

Climate change is not recognised as a specific threat in the conservation advice for Cumberland Plain Woodland (Threatened Species Scientific Committee 2008), *Pultenaea parviflora* or other threatened biota known or likely to occur at the airport site (DotE 2015b). Climate change is recognised as a threat, priority unknown, in the recovery plan for the Grey-headed Flying-fox due to the potential for changes in the distribution or reproduction of some *Eucalyptus* food tree species or the increased occurrence of extremely high temperatures (DECCW 2009a). Overall climate change is likely to have a relatively minor effect on ecosystem resilience and potential cumulative impacts on biodiversity values at the airport site when compared to more immediate threats such as removal of vegetation and habitat.

The biodiversity offset package included in Section 9.3 would help mitigate the impacts of Stage 1, including likely cumulative impacts. The biodiversity offset package would include the conservation and management of offset sites that support the biodiversity values affected by the proposed airport. The quantum of biodiversity offsets required has been calculated in accordance with the EPBC Act Offset Policy (DSEWPaC 2012). Offset sites would be

conserved in the locality and surrounding region and would be managed within the framework of BioBanking. The offset package would be delivered and biodiversity gains would be achieved prior to many of the impacts of Stage 1 of the proposed airport and the majority of the potential cumulative impacts occurring. Longer term development at the airport site would require separate calculation of any additional biodiversity offsets with reference to the prevailing airport master plan(s) and the EPBC Act Offset Policy. Other major developments in the locality would need to deliver biodiversity offsets in accordance with the NSW Framework for Biodiversity Assessment and/or the EPBC Act Offset Policy. The cumulative benefits of biodiversity offsets should help to compensate for the cumulative impacts of the various developments.

The Growth Centres strategic assessment has considered development impacts and biodiversity offsets at the regional scale and has provided for the conservation of the Western Sydney Parklands and other substantial conservation areas (DoP 2010). Through the strategic assessment the NSW Government has committed to delivering conservation outcomes for a range of matters of national environmental significance including:

- A minimum of 998 ha of Cumberland Plain Woodland that will be retained and protected within the Growth Centres, including a minimum of 363 ha of high management viability examples of these communities.
- At least 2,400 ha of either Cumberland Plain Woodland or other grassy woodland communities which are similar to Cumberland Plain Woodland in floristic structure will be protected outside of the Growth Centres (DoP 2010).

Conservation of Cumberland Plain Woodland and other biodiversity values as part of the Growth centres strategic assessment would help to conserve local and regional populations of these biota in conjunction with the offset package for the airport.

The Cumberland Plain Recovery Plan identified priority conservation lands that are intended to maintain the biodiversity values of the Cumberland Plain (DECCW 2010). Many of these priority conservation lands have been securely titled for conservation under BioBanking agreements, through the South West Growth Centres strategic assessment or other mechanisms. These conservation areas are located in the same region as the airport site and include Cumberland Plain Woodland, Grey-headed Flying-fox habitat and other biodiversity values that would be affected by the proposed airport. Future development in the region should be linked to the conservation of additional areas through the provision of biodiversity offsets. This approach should help to maintain biodiversity values at the local and regional scale despite potentially serious cumulative and/or facilitated impacts connected to the proposed airport.

8. Assessment of Significance

8.1 Key threatening processes and threat abatement plans

A threatening process is defined as a key threatening process (KTP) if it threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community (DotE 2015d). A process can be listed as a KTP if it could:

- cause a native species or ecological community to become eligible for inclusion in a threatened list (other than the conservation dependent category); or
- cause an already listed threatened species or threatened ecological community to become more endangered; or
- adversely affect two or more listed threatened species or threatened ecological communities.

KTPs are listed under the EPBC Act, TSC Act and FM Act. Some KTPs are listed under more than one Act.

Threat abatement plans (TAPs) establish a national framework to guide and coordinate Australia's response to key threatening processes registered under the EPBC Act. TAPs have also been listed under the TSC Act The plans identify research, management and other actions needed to ensure the long-term survival of native species and ecological communities affected by KTPs.

KTPs of relevance to the proposed airport are discussed in Table 61. Where TAPs have been published for the KTPs, these are also noted.

Mitigation measures have been recommended where relevant for KTPs detailed in Table 61 (see section 9.2). These have been developed with reference to the information provided in the KTP listing and the relevant TAPs. The construction and operation of the airport would result in any actions that would contravene any relevant TAPs.

Table 61 Key Threatening Processes and Threat Abatement Plans of relevance to the proposed airport

KTP	Status	TAP	Status	Comment
EPBC Act key threatening processes				
Clearing of native vegetation	EPBC Act, TSC Act			It is expected that approximately 280 hectares of native vegetation would be cleared in the Stage 1 construction impact zone. This includes around 120 hectares of good condition vegetation with a forest or woodland structure and 135 hectares of derived native grassland or scrub, as well as 25 hectares of wetlands. Given the extent of vegetation removal and habitat fragmentation on the Cumberland Plain this would comprise a substantial contribution to the operation of this KTP. Mitigation measures are proposed in Section 9.2 to minimise the impact of the proposed airport on native vegetation as far as possible.
Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants	EPBC Act, TSC Act			Garden plants are present at the airport site, particularly in proximity to existing or recently demolished residences. Garden plants were also observed in native vegetation that had regrown where a nursery used to be located. Clearing of vegetation for the proposed airport is not likely to further increase the spread of these garden plants. Alligator Weed was recorded at a large dam at the western end of Elizabeth Drive and Salvinia and Water Hyacinth were recorded in the broader study area. Construction of the proposed airport could result in the spread of these aquatic Weeds of National Significance to downstream areas outside the proposed airport. Mitigation measures are proposed in Section 9.2 to minimise the spread of weeds.
Novel biota and their impact on biodiversity	EPBC Act			Airports create a biosecurity risk by providing a means for novel biota to enter an area. Management of biosecurity at airports is carried out by the Australian Quarantine Inspection Service (AQIS). Mitigation measures are proposed in Section 9.2 to minimise the risk of impact during operation of novel biota in the area.
Infection of native plants by *Phytophthora cinnamomi*	EPBC Act, TSC Act	Disease in natural ecosystems caused by Phytophthora cinnamomi	EPBC Act	Construction activities have the potential to introduce Phytophthora into the airport site, through the transport and movement of plant, machinery and vehicles, as well as through any landscaping works following construction. The Construction and Environment Management Plan (CEMP) would include environmental management measures to reduce potential impacts on soil, water and native vegetation (see Section 9.2).

KTP	Status	TAP	Status	Comment
Infection of frogs by amphibian chytrid causing the disease chytridiomycosis	EPBC Act, TSC Act	Infection of amphibians with chytrid fungus resulting in chytridiomycosis	EPBC Act	Chytrid fungus is a water borne pathogen and could be spread through water or mud on vehicles, machinery, footwear and other equipment. Chytrid invades the skin of frogs causing skin legions, which can kill them or make them susceptible to other threats (e.g. predators, climate change). This highly virulent fungal pathogen of amphibians is capable at a minimum of causing sporadic deaths in some populations, and 100 per cent mortality in other populations. It is unknown if the disease occurs at the airport site. Construction activities have the potential to introduce or spread chytrid fungus in adjacent areas. Mitigation measures are proposed in Section 9.2 to minimise the risk of introduction or spread of chytrid fungus at the airport site.
Aggressive exclusion of birds from potential woodland and forest habitat by over-abundant noisy miners (*Manorina melanocephala*)	EPBC Act, TSC Act			Noisy Miners are a dominant species at the airport site. Clearing of vegetation for the proposed airport may increase the incidence of this species in adjacent woodland and forest habitat, either through displacement of individuals or an increase in patchiness which may encourage their presence, further exacerbating this KTP.
Predation by the European red fox	EPBC Act, TSC Act	Predation by the red fox (*Vulpes vulpes*)	EPBC Act TSC Act	The European Red Fox was recorded at the airport site during field surveys. Predation by the Red Fox has the potential to affect the Grey-headed Flying-fox and migratory species (mainly wetland birds) assessed in this report. Clearing of vegetation would remove habitat for this species at the airport site, but may result in displacement of individuals into adjacent areas, increasing the risk of predation by the species in the short term. The operation of the proposed airport is not likely to exacerbate the operation of this KTP as the site would be fenced.
Predation by feral cats	EPBC Act, TSC Act	Predation by feral cats	EPBC Act	The Feral Cat *Felis catus* was not recorded at the airport site during field surveys but it is likely that feral cats occur at the airport site and prey on individuals of relevant threatened fauna. Clearing of vegetation would remove habitat for this species at the airport site, but may result in displacement of individuals into adjacent areas, increasing the risk of predation by the species in the short term. The operation of the proposed airport is not likely to exacerbate the operation of this KTP as the site would be fenced.

KTP	Status	TAP	Status	Comment
Competition and land degradation by rabbits	EPBC Act, TSC Act	Competition and land degradation by rabbits	EPBC Act	The Rabbit was recorded at the airport site. The proposed airport is unlikely to lead to an increase in the abundance or distribution of rabbits within the airport site, but may displace individuals to adjacent areas in the short term. The operation of the proposed airport is not likely to exacerbate the operation of this KTP as the site would be fenced and feral animal control would likely be carried out.
Human-caused climate change	EPBC Act, TSC Act			Deforestation associated with construction of the proposed airport and combustion of fuels associated with construction and operation will contribute to anthropogenic emissions of greenhouse gases. The proposed airport would remove about 280 hectares of native vegetation. Construction and operation of the proposed airport would lead to considerable fuel combustion. Hence, the proposed airport would exacerbate this KTP. Mitigation measures are proposed in Section 9.2 to minimise the clearing of vegetation where possible. The proposed airport is located in western Sydney, a region undergoing substantial urban development. All development in the region would contribute to the increase in greenhouse gas emissions, further increasing the risks associated with climate change. Hence, the proposed airport would exacerbate this KTP.
TSC Act and FM Act key threatening processes				
Clearing of hollow-bearing trees	TSC Act			Hollows are not abundant at the airport site given the young age of much of the regenerating woodland. Some large hollow-bearing trees are present along riparian corridors and in larger patches of woodland that contain remnant vegetation. Given the area of vegetation to be cleared, a large number of hollows would be lost, reducing breeding habitat for species such as possums, bats and parrots. Few large hollows suitable for forest owls and large cockatoos are present. Habitat management procedures, including the use of nest boxes in the conservation areas, are recommended to limit impacts on fauna and their habitats (see Section 9.2).
Removal of dead wood and dead trees	TSC Act			The airport site contains areas with fallen timber. The proposed airport will result in the removal of this timber during construction of the proposed airport. The implementation of habitat management procedures, including the use of nest boxes in the conservation areas, is recommended to limit impacts on fauna and their habitats (see Section 9.2).

KTP	Status	TAP	Status	Comment
Introduction and establishment of Exotic Rust Fungi of the order Pucciniales pathogenic on plants of the family Myrtaceae	TSC Act			Construction activities have the potential to introduce Myrtle Rust to the airport site. The proposed airport would include environmental management measures, including specific consideration of measures to reduce potential impacts on soil, water and native vegetation (see Section 9.2).
Invasion of plant communities by perennial exotic grasses	TSC Act			The airport site features large areas of exotic grassland. There is the potential for perennial exotic grasses to invade adjacent native vegetation through disturbance during construction of the proposed airport. The CEMP would include weed management measures and specific consideration of potential impacts on soil, water and native vegetation (see Section 9.2).
Forest eucalypt dieback associated with over-abundant psyllids and Bell Miners	TSC Act			Bell Miners were recorded at the airport site. Clearing of vegetation for the proposed airport and associated displacement of birds may increase the incidence of this species in adjacent woodland and forest habitat, further exacerbating this KTP.
Invasion of native plant communities by African Olive *Olea europaea* subsp. *cuspidata* (Wall. ex G. Don) Cif.	TSC Act			The airport site contains areas already infested with African Olive. There is the potential for this species to invade adjacent native vegetation through disturbance during construction of the proposed airport. The CEMP would include environmental management measures, including weed management and specific consideration of potential impacts on soil, water and native vegetation (see Section 9.2).
Invasion of the Yellow Crazy Ant *Anoplolepis gracilipes* (Fr. Smith) into NSW	TSC Act			Crazy ants have been intercepted in Australian ports at least 161 times since 1988 (OEH 2014). Crazy ants have the potential to displace native fauna and to kill invertebrates, reptiles, hatchling birds and small mammals. The operation of the proposed airport has the potential to be a means by which this species enters the Western Sydney area and other areas of NSW and Australia. Management of biosecurity at airports is carried out by the Australian Quarantine Inspection Service (AQIS). Biosecurity measures are proposed in Section 9.2 to minimise the risk of impact of novel biota during operation of the proposed airport.
Predation by the Plague Minnow (*Gambusia holbrooki*)	TSC Act	Predation *by Gambusia holbrooki* (plague minnow)	TSC Act	Eastern Gambusia are the most abundant fish species at the airport site. Dewatering of farm dams during construction has the potential to increase the incidence of this species in local waterways. Implementation of a protocol for the management of removal of dams is recommended (see Section 9.2).

KTP	Status	TAP	Status	Comment
Alteration to the natural flow regimes of rivers and streams and their floodplains and wetlands	TSC Act; FM Act			Construction of the proposed airport would remove sections of creeks, including the upper reaches of Oaky Creek. The proposed airport would alter the natural landform through placement of fill, increasing the proportion of hardstand surfaces in the airport site and modifying surface water flows. The proposed airport has been designed to mitigate impacts on aquatic habitats downstream of the site (see Section 9.2). Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.
The degradation of native riparian vegetation along NSW water courses	FM Act			The riparian corridor along Badgerys Creek would be protected and managed as an offset. Other riparian vegetation within the airport site would be removed. There is the potential for downstream impacts on riparian vegetation resulting from the removal of vegetation upstream. Mitigation measures are recommended to limit the potential for adverse impacts on riparian vegetation during construction (see Section 9.2). The proposed airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site and to avoid substantial alteration of surface water drainage patterns outside of the airport site. Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.
The removal of large woody debris from NSW rivers and streams	FM Act			Construction of the proposed airport would remove sections of creeks, including the upper reaches of Oaky Creek, and would remove large woody debris from these creeks. The removal of creeks and large woody debris would reduce breeding habitat for fish in the locality. There would be no disturbance of large woody debris in Badgerys Creek..

8.2 Impacts on MNES

8.2.1 Threatened ecological communities

The Referral determination

The airport proposal was referred to the Department of the Environment on 4 December 2014 (DIRD 2014) and determined to be a controlled action under the EPBC Act. The proposal was considered likely to have a significant impact on the following TECs:

- critically endangered - Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest (Cumberland Plain Woodland); and
- critically endangered - Western Sydney Dry Rainforest and Moist Woodland on Shale.

Identification of affected TECs

Much of the native vegetation at the airport site is Cumberland Plain Woodland.

Western Sydney Dry Rainforest and Moist Woodland CEEC was not recorded at the airport site during the field surveys for this assessment (see Section 4.2.2). A patch of Moist Shale Woodland considered to comprise a local occurrence of the TEC was previously identified by SMEC (2014) at the airport site. Consequently, this ecological community was included in the EIS guidelines (DotE 2015f) as a TEC likely to be impacted significantly by the proposal. Additional assessment of this area conducted as part of the current surveys concluded that it contained Cumberland Plain Woodland (i.e. the vegetation types Grey Box - Forest Red Gum grassy woodland on hills and Grey Box - Forest Red Gum grassy woodland on flats) with relatively few species representative of Moist Shale Woodland. These vegetation types collectively comprise an occurrence of Cumberland Plain Woodland. 20m x 20m vegetation plot data was compared with Tozer (2010) diagnostic species lists to confirm the identity of these vegetation types. The absence of characteristic mesic trees, shrubs, climbers and ferns and a generally grassy rather than shrubby understorey (TSSC 2013) further support the classification as Cumberland Plain Woodland (noting that the only widespread shrub species present is Native Blackthorn which is a diagnostic species in all three vegetation types (Tozer 2010) and is widely recognised as indicating a response to fire regime or other disturbance within Cumberland Plain Woodland rather than any environmental factor characteristic of another ecological community (NSW Scientific Committee 1997; DECCW 2010; TSSC 2008).

Western Sydney Dry Rainforest and Moist Woodland is not present at the airport site and as such the construction and operation of the proposed airport would not have an impact on an occurrence of this TEC. Impacts on this TEC are not considered further in this assessment.

No other TECs listed under the EPBC act are known or likely to be affected by construction or operation of the proposed airport.

Table 62 Threatened ecological communities listed under the EPBC Act within the Stage 1 area

Species	EPBC Act Status	Likelihood of occurrence	Risk of impact	Quantum of impact	Significance of impact
Cumberland Plain Woodland	CEEC	Present.	Certain. Direct impacts within a local occurrence of the community.	Direct removal of up to 90.8 hectares of vegetation in a local occurrence of the community[1]	Likely.

Notes: 1) Comprising the areas of Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528), Grey Box - Forest Red Gum grassy woodland on hills (HN529), and Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512) as shown in Table 58.

Significance of Impacts on Cumberland Plain Woodland

An assessment of significance has been prepared in accordance with the '*Matters of National Environmental Significance Significant impact guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999'* (DotE 2013a) for impacts on Cumberland Plain Woodland and is included as Appendix D.

The Stage 1 development would include the permanent removal of 90.8 hectares of vegetation within the local occurrence of Cumberland Plain Woodland that is commensurate with the form of the community listed under the EPBC Act as shown on Figure 5. Longer term development at the airport site would further reduce the extent of the community by up to 57 hectares. A permanent reduction in extent of this magnitude would threaten the viability and persistence of Cumberland Plain Woodland within the locality.

The outcome of the assessment of significance included as Appendix D is that Stage 1 of the proposed airport is likely to have a significant impact on the local and regional occurrence of Cumberland Plain Woodland. A significant impact would occur through a substantial reduction in the extent of the community and increase in the degree of fragmentation which would in turn result in a substantial negative effect on the potential for recovery of the community. Longer term development at the airport site would further reduce the extent of the community, fragment habitat and interfere with its recovery. This additional reduction would further increase the significance of impacts of Stage 1 and would comprise a significant impact in its own right.

An offset package has been prepared for the proposed airport to compensate for these significant impacts (see Section 9.3). This would include the protection and management of Cumberland Plain Woodland at offset sites in perpetuity.

8.2.2 Threatened flora species

The Referral determination

The Department of the Environment determined the airport proposal to be a controlled action and considered it likely to have a significant impact on *Pultenaea parviflora*, listed as a vulnerable species under the EPBC Act. In addition, the Department indicated a significant impact could not be ruled out for the following species (DotE 2015f):

- White-flowered Wax Plant (*Cynanchum elegans*), listed as an endangered species under the EPBC Act;
- Spiked Rice-flower (*Pimelea spicata*), listed as an endangered species under the EPBC Act;

- Downy Wattle (*Acacia pubescens*), listed as a vulnerable species under the EPBC Act;
- Small-flower Grevillea (*Grevillea parviflora* subsp. *parviflora*), listed as a vulnerable species under the EPBC Act; and
- Austral Toadflax, Toadflax (*Thesium australe*), listed as a vulnerable species under the EPBC Act.

Identification of affected flora species

The desktop assessment, field surveys and habitat assessments described in this report have been used to identify the threatened plants that may be affected by the proposed airport, through either direct or indirect impacts. The outcome of these assessments is summarised in Appendix A.

The Stage 1 construction impact zone includes at least four individual *Pultenaea parviflora.* There is potential habitat for the additional five threatened flora species identified by the Department at the airport site. They are at a moderate risk of impact as a result of the proposed airport Table 63 based on an assessment of the numbers of local records and presence and quality of potential habitat (Appendix A).

The remainder of the threatened flora species previously recorded or predicted to occur in the locality would not occur because the airport site is outside of their known distribution and/or does not contain suitable habitat (Appendix A). The airport site does not contain any sandstone outcrops or sandstone-derived soils, shale-sandstone transition soils, or deep Tertiary alluvial deposits and does not contain any threatened plant species that have habitat requirements specific to these soil types. Construction and operation of the proposed airport would not have an impact on these threatened species or their habitat.

Table 63 Threatened species listed under the EPBC Act with a moderate to high risk of impact in the Stage 1 area

Species	EPBC Act Status	Likelihood of occurrence	Risk of impact	Quantum of impact	Significance of impact
Pultenaea parviflora	Vulnerable	Present. Four individuals were recorded at the airport site.	Certain. The recorded individuals and a large area of potential shale woodland habitat would be removed.	Four individuals and up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat.[1]	Unlikely.
White-flowered Wax Plant	Endangered	Possible. Not recorded at the airport site despite multiple rounds of targeted surveys. The species has been recorded in the locality and there is potential habitat at the airport site.	Possible. A large area of potential habitat in woodland and forest would be removed.	Up to 120.6 hectares of better quality potential habitat and a further 134.7 hectares of poor quality potential habitat.[2]	Unlikely.

Species	EPBC Act Status	Likelihood of occurrence	Risk of impact	Quantum of impact	Significance of impact
Spiked Rice-flower	Endangered	Possible. Not recorded at the airport site despite multiple rounds of targeted surveys. The species has been recorded in the locality and there is potential habitat at the airport site.	Possible. A large area of potential habitat in shale woodlands would be removed.	Up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat.[1]	Unlikely.
Downy Wattle	Vulnerable	Possible. Not recorded at the airport site despite multiple rounds of targeted surveys. The species has been recorded in the locality and there is potential habitat at the airport site.	Possible. A small area of potential habitat in Shale-Gravel Transition Forest would be removed.	Up to 2.2 hectares of better quality potential habitat and a further 0.4 hectares of poor quality potential habitat.[3]	Unlikely.
Small-flower Grevillea	Vulnerable	Possible. Not recorded at the airport site despite multiple rounds of targeted surveys. The species has been recorded in the locality and there is potential habitat at the airport site.	Possible. A small area of potential habitat in Shale-Gravel Transition Forest would be removed.	Up to 2.2 hectares of better quality potential habitat and a further 0.4 hectares of poor quality potential habitat.[3]	Unlikely.
Austral Toadflax	Vulnerable	Possible. Not recorded at the airport site despite multiple rounds of targeted surveys. There is potential habitat at the airport site.	Possible. A large area of potential habitat in grassy woodland or grassland would be removed.	Up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat.[1]	Unlikely.

Notes: 1) Comprising the areas of Good and poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528), Grey Box - Forest Red Gum grassy woodland on hills (HN529) and Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512) as shown in Table 58.

2) Comprising the areas of Good and poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528), Grey Box - Forest Red Gum grassy woodland on hills (HN529), Forest Red Gum - Rough-barked Apple grassy woodland (HN526) and Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512) as shown in Table 58.

3) Comprising the areas of Good and poor condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512) as shown in Table 58.

Significance of impacts on threatened plants

Assessments of significance have been prepared in accordance with the '*Matters of National Environmental Significance Significant impact guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999'* (DotE 2013a) for threatened plant species that are known or likely to be impacted by the proposed airport. Assessments of significance are included as Appendix D and the key findings are summarised below.

Construction of Stage 1 of the proposed airport would remove four individual *Pultenaea parviflora* which would remove the known local population at the airport site. The proposed airport would also require the removal of 90.8 hectares of potential habitat for Stage 1 and up to 57 hectares of potential habitat for longer term development at the airport site. The EPBC Act assessment of significance guidelines 1.1 includes specific criteria for assessing impacts on a vulnerable species, which primarily relate to impacts on an important population (DotE 2013a).

The population of *P. parviflora* at the airport site is not an important population because:

- it is not identified in a recovery plan;
- it would not be important for breeding or dispersal because it includes only four plants and it is in a comparatively isolated and poor quality patch of habitat that is surrounded by extensive areas of cleared cropland or grazing country;
- it is not important for maintaining genetic diversity because it comprises only four plants that are in close proximity and as such would be unlikely to contain much genetic diversity. Further, this genetic material has already been retained via the Royal Botanic Gardens Trust sampling and propagation program (RBGS 1992); and
- this population is near the limit of the species range as it is at the western extent of recognised outlier populations near Kemps Creek (OEH 2015b). The majority of the known population at Kemps Creek is associated with a parcel of land within tertiary gravel and shale/gravel transition habitat located around three kilometres to the east of the site (OEH 2015a). This land parcel is to be set aside as an offset for the South West Growth Centres. The population at the airport site would probably make a very minor contribution to the viability of this population.

Therefore the proposed airport would not result in any direct impacts on an important population of the species and would not substantially interfere with the recovery of *P. parviflora.* The proposed airport would not result in a significant impact on *P. parviflora*. As discussed in section 4.5.2, collection and propagation of this population has previously been carried out, with plants located at the Australian Botanic Garden, Mount Annan. Further propagation may be carried out as part of a threatened flora management plan (see section 9.2).

Construction and operation of the proposed airport would not affect any known populations of the White-flowered Wax Plant, Spiked Rice-flower and Downy Wattle; and the vulnerable species Small-flower Grevillea and Austral Toadflax. Despite targeted surveys there is no evidence that the airport site or any adjoining areas of vegetation contain populations of these threatened plants (Biosis 1999; SMEC 2014; OEH 2015a). There is a moderate risk of impacts on a local population of these threatened plants through the removal, modification or fragmentation of potential habitat at the airport site. Any populations of these threatened plant species at the airport site are likely to have relatively low viability since they are not abundant or extensive enough to have been detected by surveys, the airport site is extensively degraded and modified and there is limited potential for either recruitment or population expansion given the extent of habitat fragmentation. Any local populations of these species, if present, would probably make a minor contribution to the maintenance or recovery of these species. Given these considerations, the proposed airport is unlikely to interfere with the recovery of any of

these threatened plant species. The proposed airport would not result in a significant impact on these threatened plant species.

Changes to water quality or hydrology are unlikely to impact threatened flora habitat that occurs downstream of the airport site. Implementation of additional measures are proposed so that the proposed airport would have no adverse impact on downstream water quality (GHD 2015c). Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.

Since the proposed airport is not likely to result in a significant impact on any of these threatened plant species there is no requirement to calculate or to deliver direct biodiversity offsets in accordance with the EPBC Act Offset Policy (DSEWPaC 2012). However, any potential impacts on these threatened plant species and populations would be substantially offset through the conservation and management of Cumberland Plain Woodland and other native vegetation in the locality and region as part of the biodiversity offset package for the project (see Section 9.3).

8.2.3 Threatened fauna species

The Referral determination

The airport proposal is a controlled action under the EPBC Act. A significant impact could not be ruled out by the Department of the Environment for the following threatened fauna species (DotE 2015f):

- Grey-headed Flying-fox (*Pteropus poliocephalus*), which is listed as a vulnerable species under the EPBC Act;
- Giant Burrowing Frog (*Heleioporus australiacus*), which is listed as a vulnerable species under the EPBC Act;
- Green and Golden Bell Frog (*Litoria aurea*), which is listed as a vulnerable species under the EPBC Act; and
- Large-eared Pied Bat (*Chalinolobus dwyeri*), which is listed as a vulnerable species under the EPBC Act.

Identification of affected fauna species

The desktop assessment, field surveys and habitat assessments described in this report have been used to identify the threatened fauna species that may be affected by the proposed airport, through either direct or indirect impacts. The outcome of these assessments is summarised in Appendix A.

One threatened fauna species listed under the EPBC Act and identified in the EIS guidelines (DotE 2015f) as having the potential to be impacted significantly by the proposed airport was recorded at the airport site. The Grey-headed Flying-fox (*Pteropus poliocephalus*), was recorded foraging at the site or flying over the site during the current surveys, as well as in previous surveys (Biosis Research 1999). No other threatened fauna species listed under the EPBC Act have been recorded at the airport site. The Swift Parrot is likely to forage at the airport site on occasion during its winter migration to the mainland. Construction of the proposed airport would remove potential habitat for this species. This species was not identified in the referral or EIS guidelines as one that was likely to be significantly impacted by the proposed airport. The risk of impact and quantum of impact on these threatened fauna species is summarised in Table 64.

Table 64 Threatened fauna species listed under the EPBC Act with a moderate to high risk of impact in the Stage 1 area

Species	EPBC Act Status	Likelihood of occurrence	Risk of impact	Quantum of impact	Significance of impacts
Grey-headed Flying-fox	V	Present. Would forage in woodland stands at the airport site. No roost camps present at the airport site.	Certain. Large area of potential foraging habitat would be removed. Moderate risk of aircraft strike during operation.	120.6 hectares of foraging habitat. [1] Low numbers of bats likely to be subject to aircraft strike.	Likely
Swift Parrot	E	Likely. May forage on occasion in the airport site during winter when trees are flowering. 8 records within the locality (OEH 2015a).	Moderate. Large area of potential foraging habitat would be removed. Low risk of aircraft strike during operation.	Up to 120.6 hectares of potential foraging habitat.[1] Very low numbers of birds likely to be subject to aircraft strike.	Unlikely

Notes: 1) Comprising the area of woodland and forest habitat at the airport site as shown in Table 59.
2) Comprising the area of wetland habitat at the airport site as shown in Table 59.

As described in section 4.5.3, no habitat for the Giant Burrowing Frog is present at the airport site. The proposed airport would not directly impact a population of this species. Potential indirect impacts on the Blue Mountains World Heritage Area would be highly unlikely to impact a population of this species. The proposed airport would not have a significant impact on this species as there is no potential habitat for the species at the airport site.

No preferred habitat for the Large-eared Pied Bat is present. As described in section 4.5.3, good quality habitat for this species is present to the west of the airport site in the Blue Mountains World Heritage Area. This species could occur on a transient basis, but would not depend on any of the habitats present in the airport site. The proposed airport is highly unlikely to have a significant impact on this species as there is no roosting and breeding habitat and no preferred foraging habitat present at the airport site.

As described in section 4.5.3, no Green and Golden Bell Frogs were recorded during the current targeted surveys at the airport site, or during previous targeted surveys carried out at the airport site (Lemckert 1999). There are no previous records of the species at the airport site (OEH 2015a). This species is likely to have become extinct in the area many years ago, if it was present at all (Lemckert 1999). Based on this evidence, the proposed airport is highly unlikely to have a significant impact on this species.

Low quality potential habitat is present in the airport site for a number of other threatened fauna species listed under the EPBC Act as described in Appendix A. These species may occur on a transient or opportunistic basis only. The proposed airport is highly unlikely to have a significant impact on these species. These species are not considered further in this report.

No threatened aquatic fauna species listed under the EPBC Act were recorded or are likely to occur at the airport site or in upstream or downstream habitats.

Significance of impacts on threatened fauna

Assessments of significance have been prepared in accordance with the Significant impact guidelines 1.1 (DotE 2013a) for these threatened fauna species and are included as Appendix D. The conclusions of these assessments of significance are summarised below.

Grey-headed Flying-fox

The Grey-headed Flying-fox occurs along the eastern coastal plain of NSW extending into Queensland and Victoria. It roosts in camps, usually in dense riparian habitats. At dusk this species disperses in search of its preferred food source, mainly eucalypt blossom and rainforest fruits. Individuals may disperse over a 50 km radius from camp sites in search of food though commuting distances of around 20 km are more typical (OEH 2015b).

Two foraging periods of the year are identified as particularly important for the Grey-headed Flying-fox. The breeding period, which occurs from October to January, includes the final weeks of gestation, and the weeks of birth, lactation and conception. The 'food bottle neck', which occurs during the May to August period, is a time where foraging resources are limited. Resource demands during these periods are important to the Grey-headed Flying-fox. As detailed in section 4.5.3, none of the eucalypts at the airport site are highly productive of nectar, and as such, habitat in the airport site is only somewhat productive during these food bottlenecks. Habitat in the airport site is thus somewhat productive during food bottlenecks, and is not likely to qualify explicitly as habitat critical to the survival of the species, as defined in the draft recovery plan (DECCW 2009).

The draft recovery plan also notes that it is not possible to predict what localities will be productive in which months, and therefore what localities will provide essential habitat for the species. All foraging habitat has the potential to be productive during general food shortages and to therefore provide a resource critical to survival. The proposed airport would require the removal of 120.6 hectares of foraging habitat for Stage 1 and an additional 78.6 hectares of foraging habitat for longer term development, which is a substantial area of foraging habitat in a fragmented rural landscape. These habitat areas contribute to foraging resources at critical times in the lifecycle of the species, and may provide critical resources during food shortages. In this sense, habitat at the airport site provides a resource critical to survival. When considered in the context of further loss from longer term development at the airport site, and other facilitated and cumulative impacts in the locality, this clearing could contribute to the long-term decline of the Grey-headed Flying-fox important population. Given the size of foraging habitat at the airport site, and area of habitat that would be lost through cumulative and facilitated impacts, the proposed airport does have the potential to affect habitat critical to the long-term survival of the species.

As discussed in Section 6.1.1, while individuals may be at risk of mortality from aircraft strike during operation, this is unlikely to substantially impact the population as a whole. Operation of the proposed airport would increase general traffic in the area surrounding the airport site, and could result in increased risk of fauna mortality on surrounding roads. In the context of the current level of development and volume of traffic in the locality these additional impacts are unlikely to substantially impact any populations as a whole.

Changes to water quality or hydrology are unlikely to impact Grey-headed Flying-fox foraging or roosting habitat that occurs downstream of the airport site. Implementation of additional measures are proposed so that the proposed airport would have no adverse impact on downstream water quality (GHD 2015c). Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.

About 61 hectares of potential habitat would be retained within the environmental conservation zone along Badgerys Creek and in the western portion of the airport site. The construction of the proposed airport may interfere substantially with the recovery of the Grey-headed Flying-fox and is likely to have a significant impact on the species (see Appendix D). A significant impact would occur through:

- construction of the proposed airport, which would remove 120.6 hectares of potential habitat for Stage 1 which represents 0.70 per cent of the potential foraging habitat for the Grey-headed Flying-fox within the locality;
- reducing areas of habitat that contribute to the availability of foraging resources for local camps when resources are scarce and at critical lifecycle stages;
- further fragmentation of foraging habitat within an already highly fragmented landscape; and
- possible further clearing of foraging habitat for the species as a result of cumulative and facilitated development in the locality following construction of the proposed airport.

An offset strategy will be prepared for the proposed airport to try to compensate for these significant impacts (see Section 9.3). This would include the protection and management of Grey-headed Flying-fox habitat at offset sites in perpetuity.

Swift Parrot

The Swift Parrot has not been recorded at the airport site, however there are some records in the locality, and it may occur on occasion outside the breeding season when the eucalypts are in flower. The principal over-wintering habitats for the Swift Parrot on the mainland are the inland slopes of the Great Dividing Range and along the eastern coastal plains (DotE 2015b). Dominant canopy species in the airport site include Grey Box (*Eucalyptus moluccana*) and Forest Red Gum (*Eucalyptus tereticornis*), which may provide nectar and lerp foraging resources during the species' winter migration. Much of the airport site is vegetated with relatively young regrowth, which is not the preferred foraging habitat of the species. A range of aggressive competitors such as the Noisy Miner (*Manorina melanocephala*) and the Bell Miner (*Manorina melanophrys*) are common at the airport site, potentially further reducing habitat suitability for the Swift Parrot. The airport site would not provide core winter foraging resources for the Swift Parrot due to the presence of mainly young regrowth and aggressive competitors, although it may provide shelter or supplementary foraging resources for migrating individuals. Construction of Stage 1 of the proposed airport would remove 120.6 hectares of highly fragmented, relatively low quality potential foraging habitat. 61 hectares of potential habitat would be retained within the environmental conservation zone along Badgerys Creek and in the western portion of the airport site. A total of about 17,393 hectares of potential foraging habitat (woody native vegetation) is mapped in the locality, although not all of this vegetation is likely to be suitable for the species. There is a low risk of aircraft strike for this species given the low numbers that may forage in the area, and lack of good quality foraging habitat in surrounding areas. Operation of the proposed airport would increase general traffic in the area surrounding the proposed airport, and could result in increased risk of fauna mortality on surrounding roads. This is unlikely to substantially impact the Swift Parrot, given its low incidence in the area.

An assessment of significance for this species is provided in Appendix D. The proposed airport is unlikely to result in a significant impact on this species as:

- there is no evidence of Swift Parrots occurring in the airport site;
- only few records are known from the locality;
- native vegetation at the airport site is relatively young regrowth, which is not the preferred foraging habitat of the species;
- aggressive competitors such as the Noisy Miner are dominant species in the area; and
- there is a very low risk of individuals being subject to aircraft strike.

8.2.4 Migratory species

Migratory wetland species

Two migratory shorebird species were recorded in the airport site: one Latham's Snipe (*Gallinago hardwicki*) and a flock of an unidentified sandpiper species (see section 4.3.2). The Stage 1 development would remove 25.4 hectares of artificial wetlands. While birds are likely to be struck by aircraft on occasion, recommended management measures (see Section 9.2) would minimise the risk of this occurring, and as such the viability of populations in the local area are not likely to be threatened. Given the low numbers of migratory wetland birds recorded at the airport site, the risk to these species is very low. Changes to water quality or hydrology are unlikely to impact migratory wetland bird habitat that occurs downstream of the airport site. Implementation of additional measures are proposed so that the proposed airport would have no adverse impact on downstream water quality (GHD 2015c). Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts

Impacts on migratory shorebird species are assessed according to the Draft significant impact guidelines for 36 migratory shorebird species (DEWHA 2009b), and focus on impacts on important habitat. As described in section 4.5.4, the airport site is unlikely to be important habitat for these species, and as such, the proposed airport is unlikely to have a significant impact on any of these species. No assessments of significance have been prepared.

Other migratory species

Other migratory species recorded at the airport site included the Great Egret (*Ardea alba*); Cattle Egret (*Ardea ibis*); White-bellied Sea-eagle (*Haliaeetus leucogaster*); Rufous Fantail (*Rhipidura rufifrons*); Rainbow Bee-eater (*Merops ornatus*) and White-throated Needletail (*Hirundapus caudacutus*). The Stage 1 development would remove 25.4 hectares of artificial wetlands (habitat for the Great Egret, Cattle Egret and White-bellied Sea-eagle), 120.6 hectares of woodland and forest vegetation (habitat for the Rufous Fantail and Rainbow Bee-eater), and 628.8 hectares of exotic grassland (habitat for the Cattle Egret). No habitat for the White-throated Needletail would be removed as this species forages in the air well above the ground. While birds are likely to be struck by aircraft on occasion, management measures (see Section 9.2) would minimise the risk of this occurring, and as such the viability of populations in the local area are not likely to be threatened.

As described in section 4.5.4, the airport site is not considered important habitat for any of these species, according to the significant impact criteria for migratory species (DEWHA 2009b). This is due to the fact that the habitat in the airport site would not support an ecologically significant proportion of the population of these species, is not of critical importance to these species at particular life-cycle stages, is not at the limit of these species' ranges, and is not within an area where these species are declining. No assessments of significance have been prepared for these species. Based on the above considerations the airport is unlikely to impose a significant effect on these migratory fauna species.

8.2.5 Impacts on the Greater Blue Mountains World Heritage Area

The Referral determination

The project was referred to the Department of the Environment in 2014 (DIRD 2014) and was determined to be a controlled action. The Department of the Environment determined the proposal had the potential to have a significant impact on the Greater Blue Mountains World Heritage Area (GBMWHA).

Background

The statement of outstanding universal value for the GBMWHA identifies two criteria for which the property is listed on the World Heritage register:

- outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; and
- important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

Other important values of the GBMWHA include its:

- geodiversity (including bisected sandstone plateaux, karst landscapes, basalt capped peaks and quaternary alluvial deposits);
- water catchments (including wild rivers, pristine and relatively undisturbed catchment areas and substantial contribution to maintaining high water quality);
- wilderness (including extensive natural areas, absence of significant human interference, opportunity to maintain integrity, gradients and mosaics of ecological processes, opportunities for solitude and self-reliant recreation, and aesthetic, spiritual and intrinsic value);
- indigenous heritage values;
- historic heritage values;
- recreation and tourism;
- research and education; and
- scenic and aesthetic.

The GBMWHA consists of 1.03 million hectares of sandstone plateaux, escarpments and gorges dominated by temperate eucalypt forest. It is noted for the diversity of eucalypts associated with its wide range of habitats as well as significant numbers of rare or threatened species, including endemic and evolutionary relict species (such as the Wollemi Pine). A significant proportion of the Australian continent's biodiversity occur in the area (UNESCO 2015). The GBMWHA protects a large number of pristine and relatively undisturbed catchment areas, some of which make a substantial contribution to maintaining high water quality in a series of water storage reservoirs supplying Sydney and adjacent rural areas (DECC 2009b).

Threats to the GBMWHA identified in the Strategic Plan for the GBMWHA (DECC 2009b) and the Plan of Management (NPWS 2001) include:

- invasion by pest species including weeds and feral animals;
- loss of biodiversity and geodiversity at all levels; and
- impacts of human-enhanced climate change.

Following on from these, the key management objectives relevant to this impact assessment identified by the Strategic Plan (DECC 2009b) include:

- to maintain, and wherever possible, improve the current and future integrity of the GBMWHA;
- to reduce the potential for major impacts to adversely affect the integrity of the GBMWHA;
- to conserve the GBMWHA's biodiversity and ensure the ecological viability and capacity for ongoing evolution of its World Heritage and other natural values is maintained;

- to maintain and improve the water quality and water catchment values of the GBMWHA; and
- to protect the landscape, natural beauty and aesthetic values of the GBMWHA.

This report focuses on impacts the proposed airport may have on biodiversity values of the GBMWHA.

Assessment of potential construction impacts

Construction of the proposed airport is unlikely to have any impact on the biodiversity values of the GBMWHA. Construction of the proposed airport could result in reduced water quality as a result of erosion, sedimentation and introduction of pollutants into waterways that drain to the Nepean River. Given the distance between the proposed airport and the area of the GBMWHA that is located adjacent to the Nepean River, and the design of the proposed airport, any impacts would likely have dissipated by the time the water reaches the GBMWHA. Mitigation measures are included to minimise the risk of sediments and pollutants entering local waterways (see section 9.2).

Assessment of potential operation impacts

Operation of the proposed airport may have an impact on the biodiversity values of the GBMWHA resulting from changes to surface water quality, noise, the potential for fuel jettisoning, reduced air quality, greenhouse gas emissions, and the potential for aircraft crashes.

Noise

For most of the GBMWHA near the proposed airport, anthropogenic noise would currently be minimal. Most noise would currently be generated from existing roads and residential areas (eg the Great Western Highway and adjacent suburbs). Small amounts of localised noise are generated from smaller roads, such as trails leading to camping grounds (eg Euroka Clearing), lookouts (eg Nepean Lookout) and general fire trails. Some localised noise is also generated by boats operating along the Nepean River. Occasional light aircraft (for example sight-seeing flights) and helicopters also operate above the GBMWHA, and commercial flights operate high above the area. As such, most resident fauna species in the GBMWHA would currently be subject to some low levels of anthropogenic noise, at least on occasion.

Aircraft operations over the GBMWHA following construction of the proposed airport would increase noise levels for resident fauna species that reside under the proposed flight paths. As described in section 6.1.3, aircraft may approach the proposed airport from the south-west and take off to the south-west depending on meteorological conditions. Given the fundamental airspace design for the proposed airport, parts of the GBMWHA would necessarily be subjected to large numbers of aircraft overflights. The aircraft would be at heights generally greater than 5,000 feet. Maximum noise levels may occasionally reach 60 dBA at some points, but levels directly under a flight path would typically be below 55 dBA, and often much lower (Wilkinson Murray 2015b). The number of aircraft movements above the GBMWHA may be over 200 per day. In the locations where these occur, the character of the area could be altered, even though the noise levels associated with the overflights would be low and comparable with other noise heard in the area. The fact that the overflights are concentrated on specific flight paths means that other parts of the GBMWHA will be relatively unaffected (Wilkinson Murray 2015b).

Flights would occur both during the day and the night, impacting both diurnal and nocturnal fauna. In the early stages of operation, this would create a novel impact on fauna species, particularly in the areas of the GBMWHA under the main flight paths. Increased noise levels can substantially reduce the distance and area over which acoustic signals can be sensed by an animal receiver. Noise has been shown to have a variety of impacts on fauna, including

changing foraging behaviour, impacting breeding success and changing species occurrences (refer to section 6.1.3). Low-flying aircraft can cause flight response in some species, causing them to abandon nests, and other species are known to avoid higher elevation areas where noise levels are higher, potentially resulting in fragmentation of habitat (Ellis, Ellis, & Mindell, 1991; Landon et al 2003). Most of these impacts occur when noise levels are high (greater than 65 dB), and given the height at which flights are likely to be, these impacts are unlikely.

While background noise would increase under the flight paths, fauna are likely to become habituated to the elevated noise levels in the long term (Anderson et al 1996; Conomy et al 1998) as aircraft would not be flying at low altitudes over the GBMWHA. Operation of aircraft is highly unlikely to permanently alter foraging or breeding behaviour of any fauna species. Any impacts would be localised, with impacts occurring under the main flight paths. The majority of fauna within the vast GBMWHA would not be impacted by aircraft noise. Noise would not result in a loss of biodiversity and would not interfere with the ecological viability and capacity for ongoing evolution of species within the GBMWHA.

Surface water and hydrology

A portion of the GBMWHA fronts the Nepean River downstream of its confluence with Duncans Creek. Changes to water quality and hydrology have a very low potential to impact water quality in this portion of the GBMWHA given the aiport design and recommended mitigation.

Construction of the proposed airport has the potential to release sediments and pollutants into local waterways. With the appropriate management plans in place, construction is not expected to have any significant impact on existing water quality concentrations in the receiving waters downstream of the site. Any exceedances would likely be localised and short term (GHD 2015c). As such the Stage 1 development is not likely to affect water quality of downstream aquatic habitats including key fish habitat. Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.

Bio-retention basins would be installed to treat surface runoff before it leaves site. The bio-retention basins would not be able to satisfy WSUD targets and ANZECC water quality objectives, however with the implementation of additional mitigation measures, it is expected that the proposed airport would have no adverse impact on downstream water quality (GHD 2015c).

A portion of the airport site draining to Badgerys Creek would be diverted to Duncans Creek. Changes to water quantity and flooding as a result of construction have the potential to affect the physical condition of this water course. Potential impacts would be mitigated through further refinement of the surface water drainage system (GHD 2015b).

Impacts on aquatic habitat and key fish habitat may thus occur as a result of changed hydrology. Given the generally poor quality of aquatic habitats in and downstream of the airport site, the proposed airport is unlikely to have a substantial impact on fish habitat in downstream areas. These impacts are likely to be generally restricted to reaches close to the airport site. Further downstream, inflow from other creeks will dissipate these changes, and any such impacts would be dissipated through distance by the time the water reaches the GBMWHA.

The GBMWHA is located about 10 km downstream of the airport site. Given the above considerations, and the distance of the GBMWHA from the airport site, the construction and operation of the proposed airport would have no adverse impact on downstream key fish habitat and other aquatic habitat located within the GBMWHA.

Fuel jettisoning

The operation of the proposed airport would result in a low risk of fuel jettisoing from aircraft. As described in Section 6.1.9, fuel jettisoning is extremely rare and fuel jettisoning is required to occur at an altitude that ensures all fuel is vaporised before reaching the ground. The effects of fuel jettisoning on local air quality would be limited due to the inability of many aircraft to perform jettison fuel, the rapid vaporisation and wide dispersion of jettisoned fuel, the strict guidelines on fuel jettisoning altitudes and locations, and the anticipated reduction in fuel jettisoning events and volumes in the future. Based on this information, fuel jettisoning over the GBMWHA would be extremely rare, and no fuel would reach the ground. Fuel jettisoning is therefore unlikely to interfere with any ecosystem processes, result in the substantial degradation of habitat, or reduce the viability of any flora or fauna species.

Air quality

Aircraft traffic in particular would increase emissions of NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2, and air toxics, could potentially reduce the air quality of the GBMWHA. The highest off-site concentrations of the air quality metrics evaluated were generally predicted to occur to the north and north-east of the proposed airport due to the prevalence of south-westerly winds (GHD 2015d). As such, these emissions are generally unlikely to affect air quality over the GBMWHA, as it is located to the west of the airport site. Any changes to air quality would be temporary and localised. Occasional changes to air quality as a result of wind changes are not likely to impact biodiversity values in the GBMWHA.

Greenhouse gas emissions

Human activities including energy use, industrial processes, solvent and other product use, agriculture, land use change and forestry, and waste cause greenhouse gas emissions leading to climate change. The distribution of many species, populations and communities is determined by climate. Australia's biodiversity is at risk from even moderate climate change and already under stress, for example from habitat degradation, changed fire regimes and invasive species. Climate change is likely to exacerbate these existing stressors and add additional stresses (Steffen et al 2009). In particular, climate change may result in changes to regional temperatures, rainfall, fire frequency and intensity. These changes in turn can result in changes to the distribution of species and communities, shifts in genetic composition and altered life cycles, among other impacts (Steffen et al 2009).

The construction and operation of the proposed airport will increase the emission of greenhouse gasses. The two main sources of greenhouse gas emissions during construction would be from the operation of construction equipment and from vegetation clearing. The main source of greenhouse gas emissions during operation would be from jet fuel from departing planes (GHD 2015c). The proposed airport is located in western Sydney, a region undergoing substantial urban development. All development in the region would contribute to the increase in greenhouse gas emissions, further increasing the risks associated with climate change. Climate change in general is likely to impact biodiversity values within the GBMWHA, potentially changing the species composition and distribution in the long-term. The emissions from the construction and operation of the proposed airport itself, however, are not likely to have a significant impact on the GBMWHA, as it is only a minor part of a much larger and more wide-spread issue.

Aircraft crashes

Although very unlikely, operation of the proposed airport could result in an aircraft crashing within the GBMWHA. An aircraft crash could result in felling of trees, mortality of plants and animals, potential bush fire, introduction of pollutants (fuel) and debris within the GBMWHA. The

likelihood of aircraft crashes is low, however over the lifespan of the proposed airport are a possibility. An aircraft crash would mainly cause localised damage to a relatively small area of the GBMWHA. A resulting bush fire, however, could potentially impact a much larger area. Similarly, if pollutants enter waterways, a much larger area could be impacted as the pollutants are transported downstream to other areas. Despite these potential impacts, aircraft crashes are unlikely to be of a scale that would cause a substantial change in biodiversity values in the GBMWHA. The GBMWHA is regularly subject to wide-spread wildfires that result in the death of many plants and animals. There is an extremely low risk that an aircraft crash could impact a site for a rare and locally endemic species, such as the Wollemi Pine. The diversity of eucalypts and other flora and fauna, for which the GBMWHA was listed, is unlikely to be reduced.

Significance of impacts on the GBMWHA

An assessment of the likely significance of potential impacts on the GBMWHA focussing on biodiversity values has been prepared with respect to the significant impact guidelines 1.1 (DotE 2013a) and is included in Section Appendix D. Chapter 26 of the EIS provides more detail on impacts on other values, for example cultural heritage. The project is unlikely to have a significant impact on the biodiversity values of the GBMWHA given:

- There would be no direct impact on the GBMWHA
- The construction and operation of the proposed airport is unlikely to result in the loss of biological diversity or biological processes within the GBMWHA.
- Potential impacts on fauna within the GBMWHA as a result of noise are unlikely to result in changes to species breeding or habitat use
- Potential impacts on the GBMWHA as a result of changes to air quality are likely to be negligible given the distance to the GBMWHA and prevailing wind conditions
- The proposed airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site and to avoid substantial alteration of surface water drainage patterns outside of the airport site.
- While greenhouse gas emissions will increase as a result of the construction and operation of the proposed airport, this is unlikely to directly result in the loss of biological diversity or biological processes within the GBMWHA.

8.3 Impacts on Commonwealth land

The significant impact guidelines for actions on or impacting the environment on Commonwealth land are set out in DotE (2013b). Of particular relevance to this report are the potential impacts on plants and animals. These are detailed in Table 65 and Table 66. Impacts on other aspects of the environment are discussed in the EIS.

Table 65 Likely significance of impacts on plants

Significance criteria	Assessment of impacts
Is there a real chance or possibility that the action will:	
• involve medium or large-scale native vegetation clearance	Construction of the Stage 1 development would result in direct impacts within a 1065 hectare disturbance footprint, including 280.8 hectares of native vegetation as shown on Figure 4. The extent of clearing of vegetation and habitats within the Stage 1 construction impact zone is summarised in Table 58. The majority of the Stage 1 construction impact zone is cleared land, cropland or exotic grassland (around 74%). Native vegetation removal at the airport site comprises land clearance as defined under the EPBC Act. The 280.8 hectares of native vegetation clearance would comprise 'large-scale native vegetation clearance'.
• involve any clearance of any vegetation containing a listed threatened species which is likely to result in a long-term decline in a population or which threatens the viability of the species	The Stage 1 construction impact zone includes at least four individuals comprising a local population of *Pultenaea parviflora*. Construction of the proposed airport would remove this local population as well as occupied and potential habitat. The population of *P. parviflora* at the site is not an 'important population' as defined in the significant impact criteria for vulnerable species (DotE 2013a). Therefore the proposed airport would not result in any direct impacts on an important population of *P. parviflora* and is not likely to threaten the recovery of the species or the viability of the western Sydney regional population. The Stage 1 construction impact zone contains at least 93 stems of *Marsdenia viridiflora* subsp. *viridiflora* (see Table 65). These plants comprise part of the *M. viridiflora viridiflora* population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas which is listed as an endangered population under the TSC Act. The proposed airport would result in a significant impact on the local population of *M. viridiflora viridiflora* and given the quantum of impacts may threaten the viability of the endangered population. The species occupies a broad range in northern NSW and southern Queensland (OEH 2015b) and so the proposed airport would not threaten the viability of the species as a whole. Impacts may be partially mitigated by implementation of a translocation program and the retention of some potential habitat in the environmental conservation zone (see Section 8). It should be possible to retain the genetic material of this local population of *M. viridiflora viridiflora* and potentially also to create a viable local population of translocated plants within or in the vicinity of the airport site. No other threatened flora species or populations have been recorded at the airport site.
• introduce potentially invasive species	Construction of the proposed airport would involve a substantial area of vegetation removal and would create some new edges on vegetation and habitat adjoining the site. Construction activities may, in general, increase the degree of weed infestation in adjacent areas through dispersal of weed propagules (seeds, stems and flowers) into areas of native vegetation via erosion (wind and water), workers shoes and clothing or construction vehicles. Recommendations have been made in Section 8 to minimise the potential spread of weeds from the airport site. Measures to manage weeds and to reduce the risk of spreading weeds off site in soil or water would be implemented during construction. The proposed airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site and to avoid substantial alteration of surface water drainage patterns outside of the airport site.

Significance criteria	Assessment of impacts
	The proposed environmental conservation zone would provide a buffer between the proposed airport and adjoining areas of native vegetation along its eastern, southern and western boundaries including the riparian corridors of Badgerys Creek and Duncans Creek. The extent of native vegetation cover would be increased in the environmental conservation zone and weeds would be managed. This reduces the chance that weeds would spread or that other edge effects would penetrate into habitat outside the airport site. The proposed airport would have a minor effect on the extent or seriousness of edge effects in the locality and is unlikely to introduce any new weed species or increase the significance of weed infestations (see Section 5.1.7). Operation of the proposed airport poses a biosecurity risk. There is the potential for the introduction of new species as a result of the transport of goods on aircraft. For example, the one record of Yellow Crazy Ants from New Zealand is likely to have been a transit passenger (on taro in air baggage) (Biosecurity New Zealand, undated). Invasion of Yellow Crazy Ants is listed as a key threatening process under the TSC Act (see section 8.1). Any escaped novel species could potentially establish in nearby vegetated areas, or be transported to other areas of native vegetation with cargo, and impact the local native flora and fauna. As with all international airports, Australian Government border control and biosecurity risk management measures will be applicable at the proposed airport.
• involve the use of chemicals which substantially stunt the growth of native vegetation, or	Construction vehicles and equipment would cause a minor localized increase in the risk of hydrocarbon contamination or other pollutants. Measures to manage harmful substances and to avoid impacts on vegetation, soil or water and specifically to prevent discharge of harmful substances off site would be implemented during the construction and operation of the proposed airport. Any accidental mobilisation of harmful substances during construction would not be 'regular' (if at all) and are unlikely substantially to stunt the growth of native vegetation. The operation of the proposed airport and associated transport and commercial activities would involve bulk fuel storage and is likely to include transport of harmful substances. Open space within the Stage 1 airport would be actively managed, which may include use of fertilisers and herbicides. Any such use, storage or transport of potential pollutants would be conducted under appropriate controls and with reference to relevant environmental legislation including the Airports (Environment Protection) Regulations 1997. Any inappropriate or illegal activities or accidental mobilisation of contaminants would not be 'regular' (if at all) and are unlikely to substantially stunt the growth of native vegetation. The proposed environmental conservation zone would provide a buffer between the proposed airport and adjoining areas of native vegetation along its eastern, southern and western boundaries including the riparian corridors of Badgerys Creek and Duncans Creek. The environmental conservation zone increases the distance between potential sources of contamination such as runways, storage areas and parking areas and these sensitive receptors. The proposed airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site which would further reduce the risk of transfer of contaminants off site. These measures would help to mitigate the risk of any impacts on native vegetation outside of the airport site.

Significance criteria	Assessment of impacts
	Mitigation measures are recommended in section 9.2 to minimise the risk of impact from chemicals.
• involve large-scale controlled burning or any controlled burning in sensitive areas, including areas which contain listed threatened species?	The proposed airport would not result in large-scale controlled burning or any controlled burning in areas containing listed threatened plant species. Burns may occur in areas of listed threatened ecological communities; however as described below fire is a natural part of the ecology of these communities and is unlikely to have Significant adverse effects. It is expected that the airport would implement specific measures to manage the risk of fire at the airport which would also reduce the risk of off-site impacts. This may include controlled burning to manage fuel loads. Any controlled burning would be purposefully undertaken with reference to a bushfire management plan and would be undertaken in cells to limit the extent or frequency of burns. There is no rainforest or other particularly sensitive areas at the site. The majority of native vegetation at the site is grassy woodland or open forest. Fire is accepted as a positive component of the ecology of these vegetation communities (DEC 2005; DEWHA 2010c). The bushfire management plan would consider the presence of threatened plant species (which may include translocated threatened plants in the environmental conservation zone) in planning the layout of cells and/or the timing of controlled burns.

Table 66 Likely significance of impacts on animals

Significance criteria	Assessment of impacts
Is there a real chance or possibility that the action will:	
• cause a long-term decrease in, or threaten the viability of, a native animal population or populations, through death, injury or other harm to individuals	As described in section 5.1, the proposed airport has the potential to cause the long-term decrease or extinction of populations of small, less mobile animals such as frogs, reptiles and the threatened Cumberland Plain Land Snail. The removal of a large area of foraging habitat is likely to have a significant impact on the Grey-headed Flying-fox (see section 8.2.3). The loss of foraging habitat and many hollow-bearing trees may also have a significant impact on threatened microchiropteran bats (see section 8.4.3). Other common fauna such as birds, bats and larger mammals would be more able to move to adjacent areas, or would be part of a larger local population. Some less mobile individuals of these populations (e.g. nestlings, animals denning or roosting in tree hollows) may be subject to death or injury during clearing operations. The loss of these individuals is not likely to threaten the viability of the population.
• displace or substantially limit the movement or dispersal of native animal populations	As described in section 5.1, the proposed airport would cause displacement of fauna and/or mortality of less mobile fauna that are within the proposed airport area at the time of construction activities. Some fauna may be able to seek refuge and persist in alternative habitat outside the proposed airport site. Construction of Stage 1 would create a gap in habitat that is around 1060 hectares in area and about 1.5 km wide from north to south and almost 7 km long from east to west. This area would be mostly inhospitable to fauna and would be a barrier to

Significance criteria	Assessment of impacts
	ecological processes such as dispersal. Mobile, aerial fauna species that comprise part of the ecological community may continue to occur in areas of open space at the airport site and move around or through it. Native species are likely to suffer increased risk or energy costs as a result of moving around an obstacle of this size. The proposed runway, terminals, carpark and other built features would comprise a significant barrier to the majority of fauna species particularly in combination with security fences. Light, noise, aircraft and vehicle movement may further deter fauna species from crossing these gaps in habitat. Many generalist species of open country that currently occur at the airport site would not be able to move over or through the proposed airport. Overall, despite the current patchy and fragmented distribution of vegetation at the airport site and in the locality, construction of Stage 1 would comprise a significant decrease in the degree of available habitat for native species.
• substantially reduce or fragment available habitat for native species	The proposed airport would be located in a highly fragmented, rural landscape. Fragmentation of native vegetation and associated fauna habitats in the locality has previously occurred through clearing for agriculture, residences and farm buildings and construction of linear infrastructure (such as transmission lines and roads). These land uses have created barriers to movement for some fauna species, particularly those that are limited by dispersal abilities and habitat preferences. More mobile species, such as birds and bats, can more readily traverse this landscape. Construction would require the permanent removal of a maximum of 120.6 hectares of woodland and forest habitat, 762.2 hectares of native and exotic grassland, and 25.4 hectares of artificial wetlands. The proposed airport would cause displacement or mortality of less mobile fauna that are within the area to be cleared for the proposed airport at the time of construction activities. Given the size of the airport site, entire populations of some small animals (eg skinks, snails) could be destroyed. The viability of most species would not be threatened, as similar habitat is found in surrounding areas. More mobile fauna, such as birds and bats would be displaced rather than killed. Some mortality of less mobile individuals, such as nestlings, old or sick animals may occur. Displaced individuals would be vulnerable to predation since they would be disturbed in daylight hours and would experience energy costs, increased risk of predation and increased competition for resources (especially for alternative hollows). This may result in impacts beyond the disturbance area by favouring aggressive or generalist species. The viability of these species would not be threatened, as similar habitat is found in surrounding areas, and most species that occur at the airport site have large distributions that cover a range of habitats.
• reduce or fragment available habitat for listed threatened species which is likely to displace a population, result in a long-term decline in a population, or threaten the viability of the	Patches of native vegetation in the airport site are already highly fragmented. Construction of Stage 1 of the proposed airport would contribute to fragmentation at a local and regional scale by removing patches of habitat, severing vegetated corridors and by creating an extensive, permanent footprint that would comprise a significant barrier to movement of some species. Construction of the proposed airport would increase existing fragmentation of foraging habitat for the Grey-headed Flying-fox

Significance criteria	Assessment of impacts
species	in a mainly agricultural landscape by impacting on patches of native vegetation but would not create a barrier to the species' existing ability to move through the area. While the proposed airport represents a risk of aircraft strike of individuals, it would not be an impermeable barrier to their movement. Highly mobile species such as the Grey-headed Flying-fox are expected to be less impacted by fragmentation and this species is well-adapted to accessing widely spaced habitat resources given its mobility and preference for seasonal fruits and blossom. This species' typically exhibits very large home ranges and Grey-headed Flying-foxes are known to travel distances of at least 50 kilometres from roost sites to access seasonal foraging resources (Eby 1996). The Cumberland Plain Land Snail was generally recorded during recent surveys in larger patches of woodland and forest. Given the sedentary nature of the species and limited ability to colonise new areas, fragmentation would further limit the ability of this species to move through the landscape. The removal of good quality occupied patches of vegetation would remove entire local populations/subpopulations, further reduce the species' ability to disperse between patches, and would reduce genetic diversity of the species in the locality of the airport site. The loss of habitat at the airport site would have a significant impact on this species. All other threatened species recorded or likely to occur at the airport site are highly mobile species, or are species that mainly use the Badgerys Creek corridor to move through the area. As such, fragmentation as a result of construction of the proposed airport is unlikely to result in a long-term decline in these populations, or threaten the viability of the species (see section 8.4.3)
• introduce exotic species which will substantially reduce habitat or resources for native species, or	Construction of the proposed airport is unlikely to introduce new exotic species to the airport site or surrounding habitats. The proposed airport has the potential to introduce exotic species imported accidentally via airlines (see 6.1.10). Species such as the Yellow Crazy Ant could substantially reduce habitat or resources for native species if introduced. There would be management controls in place throughout the construction and operation of the proposed airport to mitigate the risk of introduction of exotic species (see Section 0).
• undertake large-scale controlled burning or any controlled burning in areas containing listed threatened species?	The proposed airport would not result in large-scale controlled burning. The final Airport Plan for Stage 1 and then for longer term development at the airport site would include specific measures to manage the risk of uncontrolled wildfire at the proposed airport and to reduce the risk of off-site impacts. This may include controlled burning to manage fuel loads. Any controlled burning would be purposefully undertaken with reference to a bushfire management plan and would be undertaken in cells to limit the extent or frequency of burns. The bushfire management plan would consider the presence of threatened fauna or their habitats in planning the layout of cells and/or the timing of controlled burns.

Based on the above considerations, the proposed airport is likely to have a significant impact on the environment. The proposed airport would result in:

- large-scale vegetation clearing in an area of Commonwealth Land;
- permanent removal of the 90.8 hectares of vegetation within the local occurrence of Cumberland Plain Woodland that is commensurate with the EPBC Act form of the CEEC as described above and an additional 130.5 hectares that comprises the TSC Act-listed form of the CEEC or the closely related endangered ecological community (EEC) Shale-gravel Transition Forest;
- permanent removal of 34.1 hectares of River-flat Eucalypt Forest, which is listed as an EEC under the TSC Act;
- removal of 93 individual *Marsdenia viridiflora* subsp. *viridiflora* that are part of an endangered population listed under the TSC Act as well as up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat;
- the long-term decrease or extinction of populations of small, less mobile animals such as frogs, reptiles and the Cumberland Plain Land Snail (*Meridolum corneovirens*);
- removal of up to 120.6 hectares of suitable potential foraging habitat for the Grey-headed Flying-fox (*Pteropus poliocephalus*);
- removal and fragmentation of known and potential habitat for a range of threatened woodland birds and microchiropteran bat species listed under the TSC Act.

8.4 Impacts on NSW-listed biota

8.4.1 Threatened ecological communities

All of the native woodland and forest vegetation at the airport site, including derived native grasslands, comprise local occurrences of TECs listed under the TSC Act (see Figure 6Impacts on these TECs are summarised in Table 67 and discussed further below.

Table 67 Extent of impacts of Stage 1 on TECs listed under the TSC Act

TEC Name	TSC Act Status	Risk of impact	Extent of good condition vegetation (hectares)	Extent of poor condition vegetation (hectares)	Total (hectares)	Significance of impacts
Cumberland Plain Woodland	CEEC	Known. Construction would reduce the extent of a local occurrence.	90.8	130.5	221.3	Likely
River Flat Eucalypt Forest	EEC	Known. Construction would reduce the extent of a local occurrence.	29.8	4.2	34.0	Likely
Shale-Gravel Transition Forest	EEC	Known. Construction would reduce the extent of a local occurrence.	2.2	0.4	2.6	Likely

Construction of Stage 1 would result in substantial impacts on a local occurrence of Cumberland Plain Woodland. The larger and better condition patches of this vegetation at the airport site comprise the Cumberland Plain Woodland CEEC as defined under the EPBC Act and associated policy. Impacts on the EPBC Act-listed form of Cumberland Plain Woodland are

assessed in detail in Section 8.2.1. The outcome of this assessment is that Stage 1 of the proposed airport is likely to have a significant impact on the local and regional occurrence of Cumberland Plain Woodland through a substantial reduction in the extent of the community and increase in the degree of fragmentation which would in turn result in a substantial negative effect on the potential for recovery of the community. Impacts on the broader TSC Act form of Cumberland Plain Woodland at the airport site include the removal of a further 130.5 hectares of derived grassland or scrub. Construction of Stage 1 of the proposed airport would remove the majority of the local occurrence of Cumberland Plain Woodland and would result in a significant impact on the community as listed under the TSC Act.

Construction of Stage 1 would remove 29.8 hectares of good condition vegetation in riparian corridors and a further 4.2 hectares of derived grassland or scrub on flats within a local occurrence of River Flat Eucalypt Forest EEC. This is around 30% of the extent of the community at the airport site, though the local occurrence extends off site to the north and west in the riparian corridors of Badgerys, Duncans and Oaky creeks. Impacts would be partially mitigated by the retention of the environmental conservation zone. The conservation zone is around 122 hectares in area, including around 44.3 hectares of River Flat Eucalypt Forest. Up to 61 hectares would be revegetated. Operational impacts of the proposed airport such as increased noise, light spill and vehicle traffic may reduce the quality of habitat at the airport site and surrounding areas. These operational impacts may alter the species composition of the community if some more susceptible species cease using this habitat.

Construction of Stage 1 would create a gap in habitat that is around 1065 hectares in area and about 1.5 km wide from north to south and almost 7 km long from east to west. The area affected currently contains patchy and fragmented habitat however this would still comprise a substantial reduction in the overall extent of habitat and a substantial increase in the distance between patches. This area would be mostly inhospitable to fauna and would be a barrier to ecological processes such as dispersal, pollination and seed fall. Connectivity of habitat would be partially retained in the proposed environmental conservation zone, including a continuous riparian corridor along Badgerys Creek and links to the riparian corridor of Duncans Creek. The upper reaches of Oaky Creek would be completely removed and continuity with related communities at higher elevations would be severely reduced. This will reduce the ability of component species in the community to move across the landscape and interrupt ecological processes such as pollination, seed fall and dispersal. Overall, despite the retention of some vegetated corridors and the current patchy and fragmented distribution of vegetation in the locality, construction of Stage 1 would comprise a significant reduction in extent and increase the degree of fragmentation of River Flat Eucalypt Forest. Construction of Stage 1 of the proposed airport would therefore be likely to result in a significant impact on the local occurrence of River Flat Eucalypt Forest.

The local occurrence of Shale-Gravel Transition Forest is restricted to a single patch of 10.6 hectares of woodland and derived scrub in the north-east of the airport site. Construction of the proposed airport would reduce the extent of this local occurrence by 2.6 hectares and significantly reduce connectivity with related Cumberland Plain Woodland communities to the west. The majority of the local occurrence would be maintained in the environmental conservation zone and a small area would be revegetated. Continuity would be maintained with around 100 hectares of vegetation in the riparian corridor of Badgerys Creek. As described for River Flat Eucalypt Forest above, operational impacts of the proposed airport may affect the species composition of the community if some more susceptible species cease using this habitat. Overall given a reduction in extent of around 25% and imposition of operational impacts on a very small, localised occurrence, Stage 1 of the proposed airport is likely to result in a significant impact on Shale-Gravel Transition Forest. This quantum of impacts is also likely to be significant when considered as part of the overarching ecological community ‘Cumberland Plain

Woodland and Shale-Gravel Transition Forest' as defined under the EPBC Act (see Section 8.2.1).

Longer term development at the airport site would further reduce the extent of the Cumberland Plain Woodland and River Flat Eucalypt Forest, fragment habitat and interfere with the recovery of these TECs. Longer term development at the airport site would further increase the significance of impacts of Stage 1 and would comprise a significant impact on these TECS in its own right.

Based on the current Airport Plan, longer term development at the airport site would not result in any direct impacts on Shale-Gravel Transition Forest and would result in relatively minor cumulative indirect impacts on the community in the context of the significant impacts arising from Stage 1. Any changes to the Airport Plan and longer term development that would result in direct impacts on Shale-Gravel Transition Forest would need to be assessed as part of consideration of a major development plan under the Airports Act.

Offsets for threatened ecological communities listed under the TSC Act have been calculated using the BioBanking methodology for a major project as part of the assessment of offsets for impacts on the environment (see section 9.3).

8.4.2 Threatened flora species and populations

The majority of the flora species listed as a threatened under the TSC Act that may occur at the airport site are also listed as threatened species under the EPBC Act. Impacts on these species have been assessed in accordance with the EPBC Act and associated policies (see Section 8.2.2). These species are not considered further in this section.

No other threatened flora species listed under the TSC Act have been recorded at the airport site. There is potential habitat at the airport site for two additional threatened plant species listed under the TSC Act: *Dillwynia tenuifolia* and *Grevillea juniperina* subsp*. juniperina*. The *Dillwynia tenuifolia* population at Kemps Creek is also listed as an endangered population however the plants at the airport site do not comprise part of this population. The quantum of potential impacts on these threatened species is summarised in Table 68.

Table 68 Extent of impacts of Stage 1 on threatened flora species and endangered populations listed under the TSC Act

Species	TSC Act Status	Likelihood of occurrence	Risk of impact	Quantum of impact	Significance of impact
Marsdenia viridiflora subsp. *viridiflora*	Endangered population	Present. 93 individuals were recorded at the airport site.	Certain. All individuals recorded and a large area of potential habitat in shale woodlands would be removed.	93 individuals and up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat.[1]	Likely
Grevillea juniperina subsp*. juniperina*	Vulnerable	Possible. The species has been recorded in the locality and there is potential habitat at the airport site.	Moderate. Construction would remove a large area of potential habitat in shale woodlands and derived grassland and scrub.	Up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat.[1]	Unlikely

Species	TSC Act Status	Likelihood of occurrence	Risk of impact	Quantum of impact	Significance of impact
Dillwynia tenuifolia	Vulnerable	Possible. The species has been recorded in the locality and there is potential habitat at the airport site.	Moderate. Construction would remove a small area of potential habitat in Shale-Gravel Transition Forest and derived scrub.	Up to 2.2 hectares of better quality potential habitat and a further 0.4 hectares of poor quality potential habitat.[2]	Unlikely

Notes: 1) Comprising the areas of Good and poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528), Grey Box - Forest Red Gum grassy woodland on hills (HN529), Forest Red Gum - Rough-barked Apple grassy woodland (HN526)and Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512) as shown in Table 58.

2) Comprising the areas of Good and poor condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512) as shown in Table 58.

There is no evidence of a viable local population of *Grevillea juniperina* subsp. *juniperina* or *Dillwynia tenuifolia* at the airport site or in adjoining vegetation despite many weeks of targeted survey effort in multiple seasons (Biosis 1999; SMEC 2014; OEH 2015a). There is a chance that these species may be present at the airport site in low numbers such as in areas of habitat that were not directly observed or in the soil seed bank. There is also a chance that these species could colonise this habitat at some point in the future. As such there is a moderate risk of impacts on a local population of these threatened plants through the removal, modification or fragmentation of potential habitat at the airport site.

Construction of Stage 1 of the proposed airport would remove up to 221 hectares of potential habitat for *Grevillea juniperina juniperina*. There is no evidence that this habitat is of particular value or significance to the species and there are around 10,014 hectares of similar shale woodland habitat (NPWS 2006; Tozer 2010) and relatively abundant populations in the locality (OEH 2015a). Construction of Stage 1 of the proposed airport would remove up to 2.6 hectares of potential habitat for *Dillwynia tenuifolia* which is likely to have minor value compared to the relatively extensive areas of shale/gravel transition and alluvial habitat supporting thousands of individuals at Kemps Creek, around three kilometres to the east (OEH 2015b). The proposed airport is therefore not likely to result in a significant impact on a local population of these threatened plant species (if present).

One endangered population *M. viridiflora viridiflora* population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local a government area which is listed as an endangered population under the TSC Act was recorded at the airport site. A total of 93 stems of *Marsdenia viridiflora* subsp. *viridiflora* were recorded at the airport site (see Figure 6).).

Construction of Stage 1 of the proposed airport would completely remove the known local population of *M. viridiflora viridiflora* and its occupied and potential habitat. No stems of *M. viridiflora viridiflora* were recorded in the environmental conservation zone or in the longer term development area. The closest known records of the species are each around five kilometres away near Bringelly and Mulgoa (OEH 2015a). The proposed airport would result in a significant impact on the local population of *M. viridiflora viridiflora*. The quantum of potential impacts on this endangered population is summarised in Table 68.

Impacts may be partially mitigated through the implementation of a translocation program and the retention of some potential habitat in the environmental conservation zone (see Section 9.2). It should be possible to retain the genetic material of this local population of *M. viridiflora*

viridiflora and potentially also to create a viable local population of translocated plants within or in the vicinity of the airport site. *M. viridiflora viridiflora* features an underground tuber up to 20 cm in diameter (RBGT 2015). Plants with large underground tubers use them as a store of resources to produce above ground tissue in response to events such as bushfire, dry periods or herbivory. This means that plants with large underground tubers can generally be successfully transplanted and so the proposed translocation program should be able to salvage many of the *M. viridiflora viridiflora* individuals at the airport site.

Changes to water quality or hydrology are unlikely to impact threatened flora habitat that occurs downstream of the airport site. Implementation of additional measures are proposed so that the proposed airport would have no adverse impact on downstream water quality (GHD 2015c). Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts.

Offsets for threatened flora listed under the TSC Act have been calculated using the BioBanking methodology for a major project as part of the assessment of offsets for impacts on the environment (see section 9.3).

8.4.3 Threatened fauna species

The two threatened fauna species discussed in section 8.2.3, the Grey-headed Flying-fox and the Swift Parrot, are also listed under the TSC Act. Potential impacts on these species are not discussed further in this section.

Threatened fauna listed under the TSC Act that were recorded at the airport site included the Cumberland Plain Land Snail, various small woodland bird species, the Black Bittern, the Little Eagle and various microchiropteran bat species. A number of additional bird species are also likely to occur and be impacted by the proposed airport. Impacts on these NSW-listed threatened fauna species are summarised in Table 69 and discussed further below.

Table 69 Extent of impacts of Stage 1 on threatened fauna species listed under the TSC Act

Common Name	TSC Act Status	Likelihood of occurrence	Risk of impact	Habitat to be removed (hectares)	Significance of impacts
Grey-headed Flying-fox	Vulnerable	Present. Would forage throughout the airport site. No roost camps present at the airport site.	Definite. Construction would remove known habitat.	120.6[1]	Likely
Swift Parrot	Endangered	Likely. May forage on occasion in the airport site during winter migration.	Moderate. Construction would remove potential habitat.	120.6[1]	Unlikely
Barking Owl	Vulnerable	Possible. May forage in the airport site. Limited, generally only marginally suitable breeding habitat present. Few local records.	Moderate. Construction would remove potential habitat.	120.6[1]	Unlikely

Common Name	TSC Act Status	Likelihood of occurrence	Risk of impact	Habitat to be removed (hectares)	Significance of impacts
Black Bittern		Present. Observed at the northern end of Badgerys Creek.	Definite. Construction would remove potential habitat. Habitat in the Badgerys Creek riparian corridor would be retained in the environmental conservation zone.	55.3[2]	Unlikely
Black-chinned Honeyeater (eastern subspecies)	Vulnerable	Possible. May occur on occasion in larger patches in the airport site.	Moderate. Construction would remove potential habitat.	120.6[1]	Unlikely
Blue-billed Duck	Vulnerable	Present. May occur at larger dams on occasion.	Definite. Proposal would remove known and potential habitat.	23.5	Unlikely
Diamond Firetail	Vulnerable	Likely. Suitable woodland and grassland habitat present.	Moderate. Construction would remove potential habitat.	120.6[1]	Unlikely
Gang-gang Cockatoo	Vulnerable	Possible. May occur during winter months. Unlikely to breed in the airport site.	Moderate. Construction would remove potential habitat.	120.6[1]	Unlikely
Little Eagle	Vulnerable	Present. Individuals observed, mainly on the western side of the airport site.	Definite. Proposal would remove known habitat.	882.5[4]	Unlikely
Little Lorikeet	Vulnerable	Present. Some suitable potential habitat present.	Definite. Proposal would remove known habitat.	120.6[1]	Unlikely
Masked Owl	Vulnerable	Likely. May forage in the airport site. Limited, generally only marginally suitable breeding habitat present.	Moderate. Construction would remove potential habitat.	120.6[1]	Unlikely
Powerful Owl	Vulnerable	Likely. May forage in the airport site. Limited, generally only marginally suitable breeding habitat present.	Moderate. Construction would remove potential habitat.	120.6[1]	Unlikely
Scarlet Robin	Vulnerable	Present. Recorded in the riparian corridor along Badgerys Creek.	Definite. Construction would remove known habitat.	120.6[1]	Unlikely
Speckled Warbler	Vulnerable	Possible. Some suitable potential habitat present, however may not be of appropriate patch size. No individuals recorded during surveys.	Moderate. Construction would remove potential habitat.	120.6[1]	Unlikely

Common Name	TSC Act Status	Likelihood of occurrence	Risk of impact	Habitat to be removed (hectares)	Significance of impacts
Varied Sittella	Vulnerable	Present. Recorded in the riparian corridor along Badgerys Creek.	Definite. Construction would remove known habitat adjoining the Badgerys Creek riparian corridor.	120.6[1]	Unlikely
Eastern Bentwing-bat	Vulnerable	Possibly recorded (Anabat). May forage throughout the airport site. Could roost under bridges and in buildings.	High. Construction would remove habitat in which this species has possibly been recorded.	909.5[3]	Unlikely
Eastern False Pipistrelle	Vulnerable	Previously recorded. Would forage in woodland habitat. May roost in hollow-bearing trees and bridges, culverts etc at the airport site.	High. Construction would remove habitat in which this species has previously been recorded.	120.6[1]	Likely
Eastern Freetail-bat	Vulnerable	Present. Most common bat species recorded. May roost in hollow-bearing trees and bridges, culverts etc at the airport site.	Definite. Construction would remove known habitat.	120.6[1]	Likely
Greater Broad-nosed Bat	Vulnerable	Likely. Would forage throughout the airport site. May roost in hollow-bearing trees and bridges, culverts etc at the airport site.	High. Construction would remove habitat in which this species has possibly been recorded.	909.5[3]	Likely
Large-footed Myotis	Vulnerable	Probably recorded. Likely to forage along creeks and above dams. May roost under bridges and in tree hollows at the airport site.	Definite. Construction would remove known habitat.	55.3[2]	Possible
Yellow-bellied Sheathtail-bat	Vulnerable	Possible. Suitable foraging and roosting habitat present. Few local records.	Moderate. Construction would remove potential habitat.	909.5[3]	Likely
Cumberland Plain Land Snail	Endangered	Present. Occurs in larger remnant patches of Cumberland Plain Woodland with deep leaf litter.	Definite. Construction would remove known habitat.	120.6[1]	Likely

Notes 1) based on all areas of good quality native vegetation as detailed in Table 58.
2) based on the area of artificial wetlands and good quality riparian vegetation as detailed in Table 58.
3) based on all areas of native vegetation, grassland and artificial wetlands as detailed in Table 58.
4) based on all areas of native vegetation and grassland as detailed in Table 58.

The Cumberland Plain Land Snail was generally recorded during recent surveys in larger patches of woodland and forest that were generally subject to less grazing pressure, however in some locations grazing was occurring. Previous surveys for the earlier 1997-1999 EIS also generally recorded the species in the larger woodland and forest patches, and also within linear vegetation along Longleys Road. Vegetation types included Cumberland Plain Woodland,

Shale-gravel Transition Forest and River Flat Eucalypt Forest, and included good quality and poor quality vegetation as identified by vegetation surveys. Based on a conservative estimate and assuming all woodland and forest vegetation is potential habitat for the species, the proposed airport would remove a total of 120.6 hectares of occupied and potential habitat. Given the sedentary nature of the species and limited ability to colonise new areas, only part of this habitat is likely to be occupied by the species. Some occupied and potential habitat would be retained within the environmental conservation zone along Badgerys Creek and in the western portion of the airport site, although much of the riparian vegetation is not suitable habitat for this species, which is more likely to occur in Cumberland Plain Woodland or at the intergrade of River-flat Eucalypt Forest and Cumberland Plain Woodland. The loss of habitat at the airport site would have a significant impact on this species. The removal of good quality occupied patches of vegetation would remove entire local populations/subpopulations and would reduce genetic diversity of the species in the locality of the airport site.

Small woodland birds recorded in the study area included the Scarlet Robin and the Varied Sittella. The Scarlet Robin and the Varied Sittella were both recorded along the Badgerys Creek riparian corridor, but could occur in any of the woodland and forest patches. A number of additional small woodland birds may also occur, but were not recorded during surveys (Table 28).The proposal would remove about 120.6 hectares of woodland and forest vegetation for threatened woodland birds. 61 hectares of occupied and potential habitat would be retained within the environmental conservation zone along Badgerys Creek and in the western portion of the airport site. The loss of this vegetation would reduce the total area of habitat for these threatened woodland bird species in the locality. Many of these species require large patches of intact vegetation for their survival, and may only occur at the airport site on a transient basis, if at all, and are highly unlikely to breed at the site. Given that these species are likely to mainly occur along the riparian corridor which would be protected as an environmental conservation zone, the impacts of the proposal would be limited, and it is unlikely to result in a significant impact on these species.

The Little Eagle was recorded regularly soaring above the airport site. No nests were observed at the site, however the species may nest in tall trees present in some stands. The airport site may support a number of breeding pairs. Good quality foraging habitat for the Little Eagle is provided by the high numbers of rabbits and hares observed at the site. Similar foraging habitat is likely to be present throughout agricultural areas within the locality. The construction and operation of the proposed airport would remove 882.5 hectares of potential foraging and breeding habitat for the Little Eagle. The species may continue to forage above the southern portion of the site prior to this area being developed. Soaring individuals are at risk of mortality from aircraft strike. The proposed airport would reduce the area of available habitat for the species in the locality. Given the large home ranges, and large area of potential habitat present in the locality, this is unlikely to be a significant impact on the species.

Three Blue-billed Ducks were observed at a large artificial dam in the Stage 1 construction footprint. In NSW this species occurs mainly in the Murray-Darling Basin, and only during summer or in drier years that they occur in coastal areas. The Blue-Billed Duck would be a rare visitor to the airport site, and would not breed at the airport site. The construction and operation of the proposed airport would remove 25.4 hectares of artificial wetlands that would provide only occasional foraging habitat for a few individuals. No breeding habitat would be removed. There is a very low risk of mortality from aircraft strike give the low numbers of individuals that may occur in the area. Changes to water quality or hydrology are unlikely to impact Blue-billed Duck habitat that may occur downstream of the airport site. Implementation of additional measures are proposed so that the proposed airport would have no adverse impact on downstream water quality (GHD 2015c). Further resolution of mitigation measures would be provided in the final EIS having regard to potential impacts on Blue-billed Duck populations and their habitat that

may occur downstream of the site and the potential for impacts. Given these points, the proposed airport is unlikely to have a significant impact on this species.

No threatened owls were recorded at the airport site, however local records exist for the Powerful Owl, Masked Owl and Barking Owl. Most local records of these species are associated with well vegetated areas such as the Blue Mountains National Park, Warragamba area, Bents Basin State Conservation Area and Mulgoa Nature Reserve. A range of prey species, including possums, rabbits and birds were recorded at the site. These owl species could potentially forage at the site on occasion, however given the large areas of cleared land in the area, the airport site is not likely to be core habitat for these species. Large, hollow-bearing trees are present that are theoretically suitable for breeding. As per the previous point, however, given the lack of good quality foraging habitat, breeding is unlikely to occur in the airport site. The proposed airport would remove up to 120.6 hectares of woodland and forest habitat. 61 hectares of potential habitat would be retained within the environmental conservation zone along Badgerys Creek and in the western portion of the airport site. Strike risk for most birds during operation is considered to be low (Avisure 2015). Given the lack of evidence of these species at the site, and the patchy nature of the vegetation to be removed, the proposed airport is unlikely to have a significant impact on these species.

The Gang-gang Cockatoo was not recorded during targeted surveys, but may forage at the airport site during cooler months. Most local records of this species are associated with well vegetated areas such as the Blue Mountains. This species often moves to lower altitudes during autumn and winter, occurring in drier more open eucalypt forests and woodlands, and is often recorded in urban areas. During spring and summer it moves to tall mountain forests and woodlands for breeding. As such, the Gang-gang Cockatoo is unlikely to breed at the airport site. The proposed airport would remove up to 120.6 hectares of woodland and forest, which is potential foraging habitat for the species. 61 hectares of potential habitat would be retained within the environmental conservation zone along Badgerys Creek and in the western portion of the airport site. Strike risk for most birds during operation is considered to be low (Avisure 2015). Given the lack of evidence of this species at the site, the patchy nature of the vegetation to be removed, and that breeding at the site is unlikely, the proposed airport is unlikely to have a significant impact on this species.

The Little Lorikeet was recorded flying over woodland in the airport site. This species tends to occur in large remnants, with most breeding records from west of the Great Dividing Range. The airport site is likely to provide foraging habitat for occasional transient visitors. Given the patchy nature of the vegetation, low density of hollow-bearing trees, and the fact that most breeding occurs west of the Great Dividing Range, this species is unlikely to breed at the site. The proposed airport would remove up to 120.6 hectares of woodland and forest, which is potential foraging habitat for the species. 61 hectares of potential habitat would be retained within the environmental conservation zone along Badgerys Creek and in the western portion of the airport site. Strike risk for most birds during operation is considered to be low (Avisure 2015). Given the lack of evidence of this species at the site, the patchy nature of the vegetation to be removed, and that breeding at the site is unlikely, the proposed airport is unlikely to have a significant impact on this species.

The Black Bittern was recorded within the Badgerys Creek riparian corridor near Elizabeth Drive. Preferred habitat for this species at the airport site is mainly located along this riparian corridor, which will mostly be retained within the environmental conservation zone. It could also occur at wetlands on the airport site where there is suitable cover and the riparian corridors of Duncans Creek and Oaky Creek. A total of about 55.3 hectares of wetland and riparian vegetation would be removed for the Stage 1 development. Not all of this area would be suitable for the species, as it requires dense vegetation for cover. Changes to water quality or hydrology are unlikely to impact Black Bittern habitat that may occur downstream of the airport

site. Implementation of additional measures are proposed so that the proposed airport would have no adverse impact on downstream water quality (GHD 2015c). Further resolution of mitigation measures would be provided in the final EIS having regard to potential impacts on Black Bittern populations and their habitat that may occur downstream of the site and the potential for impacts. Around 61 hectares of potential habitat would be retained within the environmental conservation zone along Badgerys Creek and in the western portion of the airport site. Given the protection of the Badgerys Creek corridor and the large numbers of artificial wetlands present in the locality, the proposed airport is unlikely to have a significant impact on this species.

A number of threatened microchiropteran bat species were recorded at the airport site during recent and previous surveys. Additional threatened bat species may also occur (see Table 69). The Stage 1 development would remove 120.6 hectares of forest and woodland foraging habitat for bats, 762.2 hectares of native and exotic grassland (foraging habitat for open country species such as the Eastern Bentwing Bat), and 25.4 hectares of wetland habitat (foraging habitat for the Large-footed Myotis and other bat species). 61 hectares of potential habitat would be retained within the environmental conservation zone along Badgerys Creek and in the western portion of the airport site. There are relatively extensive areas of similar foraging habitat in the locality including around 17,393 hectares of woody native vegetation interspersed with open country (see Figure 7).

No breeding habitat is present for the cave-breeding species such as the Eastern Bentwing Bat though they may occupy diurnal roosts in bridges or culverts. The Eastern Bentwing Bat will forage in open country and females may travel hundreds of kilometres to the nearest maternity colony (Churchill 2008). The proposed airport is unlikely to have a significant impact on the Eastern Bentwing Bat

The Large-footed Myotis is mainly known to breed in caves and other man-made structures, however there is evidence it may also breed in tree hollows (Campbell 2009). The colony of bats (probably Large-footed Myotis) observed under Badgerys Creek bridge may include breeding individuals. This bridge could be removed as part of road upgrades for the proposed airport and may impact breeding for a small number of individuals. Removal of any remaining buildings could also result in the loss of breeding habitat for bats. The removal of tree hollows may also reduce breeding habitat for this species in the locality. There are large areas of potential breeding habitat in the locality for this species, including around 17,393 hectares of woody native vegetation that would contain tree hollows as well as buildings, bridges and culverts. The Large-footed Myotis would forage along rivers and above dams throughout the locality. Changes to water quality or hydrology are unlikely to impact Large-footed Myotis habitat that occurs downstream of the airport site. Implementation of additional measures are proposed so that the proposed airport would have no adverse impact on downstream water quality (GHD 2015c). Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts. The proposed airport may have a significant impact on this species if it uses tree hollows in the airport site for breeding. Significant impacts on the foraging habitat are unlikely given the wide-ranging nature of this species.

Hollow-bearing trees may provide roosting and breeding habitat for the threatened bat species listed in Table 69 and in particular the Eastern Freetail Bat, which was the most common bat species recorded during the recent surveys. Occasional hollow paddock trees are present, and some larger, more intact patches of native vegetation contain occasional hollow-bearing trees.

The construction of the proposed airport and other associated infrastructure would result in the loss of hollow-bearing trees. Given the historical clearing that has occurred at the airport site and surrounding areas, hollow-bearing trees occur in generally low densities. As such, hollows

present at the airport site are likely to be important for maintaining breeding populations of local populations of bats. A proportion of the hollow-bearing trees at the airport site would be protected along the Badgerys Creek riparian corridor and the rest of the environmental conservation zone.

Given the large scale of the Stage 1 construction impact zone a relatively large number of individual microbats may be harmed and the habitat resources to be removed may be significant to local populations of these threatened bats. Bat populations at the airport site would experience additional risk and energy costs associated with travelling to occupy alternative habitat. There is also likely to be competition with resident bats in these alternative habitats, particularly for comparatively scarce resources such as hollow-bearing trees, which may lead to an overall decline in population sizes. Further development of the locality would follow as a result of construction, resulting in additional clearing of foraging and roosting habitat for microbat species. Based on the considerations above, the construction of the proposed airport is likely to result in a significant impact on the threatened obligate hollow-breeding microbat species Eastern False Pipistrelle, Eastern Freetail-bat, Greater Broad-nosed Bat, and Yellow-bellied Sheathtail-bat through direct impacts on individual bats and removal of a substantial area of foraging and roosting habitat.

As discussed in Section 6.1.1, while individuals of these fauna species may be at risk of mortality from aircraft strike during operation, this is unlikely to substantially impact any populations as a whole. Operation of the proposed airport would increase general traffic in the area surrounding the airport site, and could result in increased risk of fauna mortality on surrounding roads. In the context of the current level of development and volume of traffic in the locality these additional impacts are unlikely to substantially impact any populations as a whole.

Offsets for threatened fauna listed under the TSC Act have been calculated using the BioBanking methodology for a major project (see section 9.3).

9. Recommended management measures

Recommended measures to mitigate biodiversity loss arising from the construction and operation of the proposed WSA are presented in this section according to the hierarchy of avoidance, mitigation and offsetting of impacts.

9.1 Avoidance of impacts

The airport site was selected based on criteria such as site topography, surrounding topography, proximity to infrastructure, and the need to minimise potential environmental and social impacts. Given this range of selection criteria, the size of site required and the constraints associated with the safe operation of an airport it would not have been possible to completely avoid impacts on biodiversity values. The airport site that has been selected is rural and residential land that has been extensively modified by clearing for agriculture, dwellings and industry. Impacts on native flora and fauna, while significant, are substantially less than would be associated with an undisturbed 'green field' site. Construction of the Stage 1 development would result in direct impacts within a 1065 hectare disturbance footprint of which 280.8 hectares is native vegetation.

The portion of the Badgerys Creek corridor within the airport site would be protected as part of the 122 hectares of land in the environmental conservation zone (see Figure 2). The environmental conservation zone includes around 61 hectares of native vegetation and representative areas of each of the vegetation types at the airport site (see Table 58). This report assumes that the 61 hectares of land within the conservation zone that does not currently contain native vegetation would be revegetated. The environmental conservation zone is well placed around the perimeter of the airport site to maintain vegetation connectivity and to provide opportunity for fauna movement and other ecological processes that are necessary to maintain biodiversity values.

The opportunity to further modify the extent or layout of the proposed airport is limited by constraints such as the length and position of the runway, size of terminal and parking required, access, security and the obstacle limitation surface that is required to ensure safe operation of the proposed airport. As such, there is little opportunity to further avoid impacts on biodiversity values at the airport site.

It is expected that the longer term development area outside the Stage 1 construction impact zone would not be cleared and grubbed until required for construction of the second runway or other developments that would be the subject of separate approvals. This approach means that longer term impacts on biodiversity values outside the Stage 1 construction impact zone would be avoided for as long as is practicable. As such, it is expected that native vegetation and habitat in the areas outside the Stage 1 construction impact zone would help to maintain biodiversity values in the locality for up to 20 years or more after the Stage 1 construction impacts. Biodiversity values would be maintained in the longer term development area through:

- retention of native vegetation and flora and fauna populations in areas not subject to development for up to 20 years. This would help maintain the viability of populations outside the airport site by providing source populations for ecological processes such as pollination, reproduction and recruitment as well as helping to maintain genetic variability;
- retention of habitat resources, including potential refuge habitat and resources such as tree-hollows, in areas not subject to development for up to 20 years for fauna displaced by clearing for Stage 1; and

- maintenance of habitat connectivity, including locally important vegetated corridors linking larger patches of Cumberland Plain Woodland at the airport site with riparian corridors extending away from the site.

A staged vegetation clearing process would be implemented during construction of Stage 1. This would provide opportunity for fauna that are resident in the Stage 1 construction impact zone to seek refuge in alternative habitat in the environmental conservation zone, longer term development impact zone or outside the airport site. Clearing would commence in the north east of the site and proceed south and west. The clearing will be undertaken before the construction of the Southern perimeter fence to allow fauna to relocate towards the environmental conservation zone and off site. This approach will be taken to maximise the opportunity for resident fauna to vacate the clearing footprint via vegetated remnants and move toward alternative habitat.

9.2 Recommended mitigation of impacts

In order to address the potential impacts of the proposed airport on biodiversity values as discussed in Sections 5, 6 and 8 the recommended mitigation and management measures outlined in Table 70 should be implemented.

The recommended mitigation and management measures have been presented according to the specific environmental issue which they are intended to address and split into ‘Design’, ‘Pre-construction’ ‘Construction’ and ‘Operation’ stages of the proposed airport.

A Construction and Environmental Management Plan (CEMP) would be prepared that would identify the specific measures for the ‘Pre-construction’ and ‘Construction’ stages and would include work methods, contingencies, roles and responsibilities. The CEMP would specify, as a minimum, industry-standard measures for the management of environmental hazards and risks prepared with reference to the outline in Table 70. Sub-plans would be prepared with additional detail relating to specific environmental factors.

It should be noted that a precautionary approach has been adopted in the biodiversity assessment and that the assessment of residual impacts on biodiversity values at the airport site does not rely on the effectiveness of mitigation measures. For instance residual impacts and biodiversity offsets have been calculated based on the removal of all threatened plants in the Stage 1 construction impact zone whereas it is likely that a proportion of the resident populations would survive the proposed translocation program.

Additional design measures would need to be assessed and designed for implementation during the detailed design phase to ensure that downstream impacts could be fully mitigated. Additional mitigation and management measures, including water quality monitoring, should also be implemented during the construction and operational phases of the project (GHD 2015c). Further resolution of mitigation measures would be provided in the final EIS having regard to identified downstream threatened species and potential for impacts. Residual impacts on downstream environments would be reassessed once the effectiveness of the final suite of mitigation measures have been designed and assessed.

Table 70 Recommended mitigation measures

Issue	Mitigation/management measure	Recommended timing of implementation
Pre-construction stage		
Fauna hazard	Develop a Wildlife Hazard Management Plan to include: • conduct of additional surveys to confirm the findings of the preliminary risk study and monitor for changes in species and movement patterns; • review of detailed design documentation to identify potential to identify potential bird and bat attractants; and • review of plans for proposed developments within 13 km of the airport site that are likely to increase the bird and bat strike risk. Design of the proposed airport to minimise its attractiveness to fauna and thus minimise bird and bat strike risk and terrestrial fauna strike risk. Measures to include: • design and build drains, water basins and the airfield to reduce the availability of water; • the design should have an appropriate fence to restrict terrestrial animal access to the airfield; and • the design should have airside access roads to facilitate active wildlife management.	Design
Hydrology	Design of the surface water management system at the airport site to minimise the potential for adverse impacts on downstream environments, where feasible, involving measures to: • separate 'clean' and 'dirty' water and retain and treat any surface water generated on hard stand areas on site before discharge from the airport site; and • avoid substantial alteration of surface water drainage patterns and the volume of downstream flows.	Design
Waterway-crossings	Location and design of new waterway crossings or upgrades of existing crossing (if required on the airport site) to minimise impacts on riparian and aquatic habitats. Crossings should be designed to minimise potential impacts on watercourse functionality, in particular impacts on aquatic and riparian habitats and fish passage, in accordance with DPI (2013).	Design

Issue	Mitigation/management measure	Recommended timing of implementation
Lighting	Design of airport lighting to avoid unnecessary light spill into adjoining areas of retained vegetation (such as in the conservation areas) as far as practicable given operational and security requirements.	Design
Environmental management	A Construction and Environmental Management Plan (CEMP) will be prepared, including the specific mitigation/management measures and sub plans listed below along with work methods, contingencies, roles and responsibilities. The mitigation/management measures included in the CEMP and sub-plans would be implemented during pre-construction and construction stages.	Pre-construction
Worker inductions	All workers are to be provided with an environmental induction prior to starting construction activities on site. This would include information on the ecological values of the airport site and protection measures to be implemented to protect biodiversity during construction.	Pre-construction
Erosion and sediment	Erosion and sediment control plans will be prepared in accordance with Volume 2D of Managing Urban Stormwater: Soils and Construction (DECC 2008f). The erosion and sediment control plans would be established prior to the commencement of construction and be updated and managed throughout as relevant to the activities during the construction phase to minimise the potential for adverse impacts on adjoining conservation areas, watercourses and downstream environments.	Pre-construction
Dust	Specific measures will be incorporated into the CEMP to minimise the generation of dust and associated impacts on natural environments adjacent and downstream of the airport site. These should include: • rapid stabilisation of disturbed soil surfaces following clearing and earthworks; • setting maximum speed limits for construction and operational traffic within the airport site to limit dust generation; • use of a water tanker or similar to spray unpaved roads during construction where required; • application of dust suppressants or covers on soil stockpiles; and • immediate removal off site of excavated fill materials not required for backfilling or other onsite uses.	Construction

Issue	Mitigation/management measure	Recommended timing of implementation
Contaminants	Specific measures should be incorporated into the CEMP to minimise the potential for chemical spills and associated impacts on natural environments adjacent to and downstream of the airport site. These should include: • storage of chemicals in clearly marked and bunded areas; • management of sewage storage tanks, including regular emptying and disposal off site; • regular inspection of vehicles and mechanical plant for leakage of fuel or oil; • no refuelling of vehicles, vehicle maintenance or washing of vehicles within 20m of waterways; and • an emergency plan for spills, to minimise the risk of impacts on retained vegetation and downstream habitats.	Pre-construction
Vegetation clearance and habitat loss	Disturbance and removal of some areas of native vegetation and habitat will be unavoidable during the construction phase. To reduce the potential for adverse impacts on ecologically sensitive areas the following measures should be implemented: • deferral of vegetation removal until necessary; • locating site offices and stockpiles in already cleared and disturbed areas where possible to avoid further unnecessary removal or disturbance of native vegetation and hollow-bearing trees; • provision of maps to construction staff clearly showing vegetation clearing boundaries and exclusion/no-go zones; and • a suitably qualified ecologist or environmental officer would be engaged prior to any clearing works to clearly demarcate vegetation protection areas.	Pre-construction
Disease management	Management of plant and animal disease (such as Phytophthora, Myrtle Rust and Chytrid fungus) would be a principal consideration in the development of the construction environmental management plan, with particular regard to protection of environmental conservation zones.	Pre-construction

Issue	Mitigation/management measure	Recommended timing of implementation
Threatened fauna management plans	Threatened fauna species management plans should be prepared to reduce the potential for impacts on relevant species. These should include: • maps identifying locations of threatened species; • scope and requirements for targeted surveys, pre-clearing surveys; • unexpected finds protocol; • salvage and translocation of threatened species as per the measures recommended below; • clearing protocols; and • reporting and adaptive management measures.	Pre-construction
Threatened flora translocation plan	A threatened flora salvage and/or translocation sub plan to the CEMP should be prepared in consultation with the Australian Botanic Garden, Mount Annan. It is recommended that this include consideration of the salvage and propagation or transplanting of the known local populations of *Pultenaea parviflora* and *Marsdenia viridiflora* subsp. *viridiflora* and any other threatened plants detected at the airport site. The plan should consider the suitability of sites within the environmental conservation zone and any biodiversity offset sites that are within the vicinity of the airport site in order to maintain populations of these species as close to their original location as is possible.	Pre-construction

Issue	Mitigation/management measure	Recommended timing of implementation
Pre-clearance surveys for threatened species	Pre-clearance surveys should be undertaken by a qualified ecologist and the required methodology will be developed for target species as part of the CEMP. Specific management plans should be prepared as sub-plans to the CEMP to manage impacts on threatened flora and fauna species as outlined above. Surveys should include: • additional targeted searches of the airport site for the Green and Golden Bell Frog in optimal conditions to confirm that they are no present at the site (surveys for the species were conducted at the end of the survey season and were subject to access constraints as discussed in Section 3.4.3). A management plan should be prepared as a sub plan to the CEMP to provide more detail on Green and Golden Bell Frog relocation and habitat management should this species be located during targeted surveys. Frog collection and relocation would need to be conducted by appropriately experienced ecologists; • targeted searches of the airport site for the Cumberland Plain Land Snail (in suitable conditions) and salvage and relocation of any snails and/or suitable shelter sites that are detected. A management plan should be prepared as a sub plan to the CEMP to provide more detail on Cumberland Plain Land Snail relocation and habitat management. Snails and/or suitable shelter sites would be relocated to appropriate habitat near the airport site. Snail collection and relocation would need to be conducted by appropriately experienced ecologists. Discussion would occur with OEH about the location of the receiver sites. • survey of any bridges or culverts that need removal to search for roosting bats; • pre-clearing surveys for larger birds' nests, particularly the White-bellied Sea-Eagle and Little Eagle; and • targeted searches for threatened flora species in areas of appropriate habitat.	Pre-construction

Issue	Mitigation/management measure	Recommended timing of implementation
Habitat clearing and fauna management protocol	Measures for the management of impacts on fauna species during clearing activities should be developed and incorporated into the CEMP, including the following measures: • preparation of a nest box strategy including provisions for: – installation of nest-boxes within conservation areas prior to clearing areas of native vegetation on the airport site to provide a safe location for hollow-dwelling fauna to be transferred to during clearing operations; and – salvage of native fauna from existing nest boxes on the airport site prior to their removal and translocation of fauna to newly established nest box sites. • pre-clearing surveys undertaken by a suitably qualified ecologist to mark and map hollow-bearing trees, logs and existing nest boxes that would require fauna management during removal; • establishing protocols for the staged clearing vegetation and safe tree felling and log remove to reduce the risk of fauna mortality; • protocols for the capture and relocation of less mobile fauna (such as nestling birds and nocturnal fauna) by a trained fauna handler; and • protocols for the appropriate management of injured or deceased individuals.	Pre-construction
Weeds	A weed management plan should be prepared as part of the CEMP and should include: • implementing soil erosion and sediment control measures; • mapping of weed infestations; • removal and control of noxious weed species. In particular, the Alligator Weed infestation on the dam at the quarry should be eradicated prior to any works in the vicinity; • appropriate disposal of weeds and weed-infested soils; • stabilisation of disturbed areas following clearing to prevent weed spread; • monitoring and adaptive management of weeds; and • reporting on the extent, composition and severity of weed infestations and adaptive management measures.	Pre-construction

Issue	Mitigation/management measure	Recommended timing of implementation
Unexpected finds	An unexpected finds protocol should be prepared to detail measures to be undertaken if threatened flora and fauna not previously recorded on site are detected during clearing or construction activities.	Pre-construction
Dam decommissioning	A protocol for the decommissioning of dams should be developed in consultation with relevant agencies, and should include, but not be restricted to, the actions described below: • dam removal should follow any requirements of a Green and Golden Bell Frog management plan if one has been prepared (see above); • the Alligator Weed infestation on the dam at the quarry should be eradicated prior to any works in the vicinity; • existing dams within the footprint should be progressively emptied over a number of days to allow fauna to relocate as the water is removed as far as possible. Smaller dams should be emptied by water carts directly pumping the water into their tanks, larger dams will have a standpipe installed; • dam removal should not be conducted during the nesting season of waterbirds where possible. A pre-removal survey should be conducted to ensure no birds are breeding; • salvage and relocation of aquatic vertebrate fauna, including frogs, turtles and eels, to areas of suitable habitat retained on the airport site or adjoining habitats should be undertaken where practicable with regard to numbers and identification of suitable release sites; • Eastern Gambusia (*Gambusia holbrooki*) and other noxious fish should not be released into local waterways as a result of draining of farm dams. Eastern Gambusia should be eradicated from dams using humane methods; and • protocols for the humane euthanasia of aquatic fauna, including fish, should be specified and implemented.	Pre-construction

Issue	Mitigation/management measure	Recommended timing of implementation
Fire	A Bushfire Management Plan should be prepared to minimise the risk of bushfire and associated impacts on adjoining areas of native vegetation, including the proposed conservation areas. This should include the following: • a requirement for relevant permits to be obtained for all activities likely to generate sparks. Restrictions contained within these permits should be based on the forecast fire danger; • preparation of pre-planned fire response action plans in accordance with the nationally endorsed 'Prepare, Act, Survive' format. The action plans should be issued as part of the site induction for all site personnel; • development of limitations on relevant construction procedures which should be applied during the fire season based on specific fire danger ratings. An example of such restrictions would include the halting of all construction works during extreme or catastrophic fire danger days; • management of the airport site to maintain a low overall fuel hazard. Measures to achieve this should include a combination of herbicide application (applied according to relevant State Catchment Authority (SCA) and label standards), slashing/ trittering, low intensity prescribed burning and hand removal; and • fuel-reduction measures should be appropriate to biodiversity values in each area (e.g. low intensity prescribed burns rather than slashing should be used in native woodland and forest).	Pre-construction
Construction stage		
Water quality	All water discharge into creeks should be guided by the ANZECC Water Quality Guidelines (2000). Measures to manage erosion and sediments and contaminants as detailed in GHD (2015a, b) should be implemented to avoid impacts on surface water quality, where practicable.	Construction
Groundwater	Any groundwater seepage in excavations should be characterised and treated as appropriate for any observed water quality issues prior to discharge off site. Measures to manage erosion and sediments and contaminants as detailed in GHD (2015a, b) should be implemented to avoid impacts on groundwater quality where practicable.	Construction
Lighting	Steps should be taken to avoid unnecessary light spill into adjoining areas of retained vegetation (such as in the conservation areas) as far as possible.	Construction

Issue	Mitigation/management measure	Recommended timing of implementation
Erosion and sediment	Erosion and sediment control measures should be implemented in accordance with plans. Environmental controls should be inspected and maintained and should be adapted as required in response to weather conditions.	Construction
Contaminants	Specific measures in the CEMP to minimise the potential for chemical spills and associated impacts should be implemented.	Construction
Weeds	Specific measures to minimise the potential for the spread of weeds contained in the weed management sub plan of the CEMP should be implemented.	Construction
Fauna management	Subject to safety and security, measures for the management of impacts on fauna species during clearing activities should be implemented, including in particular the matters outlined below: • A plan for a progressive vegetation clearing process should be implemented. This should provide opportunity for fauna that are resident in the Stage 1 construction impact zone to seek refuge in alternative habitat in the environmental conservation zone, longer term development impact zone or outside the airport site. Clearing should commence in the northeast of the site and proceed south and west. The clearing should be undertaken before the construction of the southern perimeter fence to allow fauna to relocate offsite and towards the environmental conservation zone. This approach has been identified to maximise the opportunity for resident fauna to vacate the clearing footprint via vegetated remnants and move toward alternative habitat. • Prior to the commencement of clearing a fauna spotter should undertake an assessment to identify potential habitat trees and logs. These should be clearly identified with spray paint. A dozer should then clear the undergrowth and trees not identified as potential habitat trees. An excavator should follow several days behind the dozer to give resident fauna the opportunity to vacate habitat trees. The excavator should drop trees in a manner to increase the likelihood of survival of any fauna present. • An experienced fauna spotter-catcher, licensed wildlife carer or ecologist should be present to supervise native vegetation clearing or removal/disturbance of other habitat features (e.g. culverts), and to capture and relocate fauna if required. Any injured native fauna should be transferred to the care of a licenced wildlife carer.	Construction
Threatened species management	Measures contained within the threatened species management plans should be implemented (as relevant) to minimise potential impacts on threatened flora and fauna species at the airport site.	Construction

Issue	Mitigation/management measure	Recommended timing of implementation
Dam decommissioning	Specific dam decommissioning protocols contained in the CEMP should be implemented.	Construction
Operation stage		
Bird and bat strike	Initiate active management of birds and bats at the site six months prior to the commencement of runway operations.	Pre-operation
Airport management	Sub-plans should be prepared, including the specific environmental management measures listed below.	Pre-operation
Vegetation	Engage an ecologist to prepare a vegetation management plan (VMP). The VMP should apply to open space within the airport site and the environmental conservation zone and should include: • retention of native vegetation and/or supplementary replanting with indigenous native species of local provenance; • slashing of grassland to manage fuel loads and bushfire risk; • identification of threatened flora populations and measures to avoid impacts from activities such as weed control or bushfire hazard reduction; • measures for the management of weeds; • planting schedules; • monitoring of the success of revegetation, weed control and adaptive management; and • reporting.	Operation
Biosecurity	Due to existing requirements for airlines and airports to comply with biosecurity requirements under the Quarantine Act 1908 (Cth) and other relevant legislation, no specific mitigation measures are proposed	Operation
Fauna strike	Due to existing requirements for airports to comply with wildlife strike management requirements under the Civil Aviation Safety Regulations 1998 (Cth) and other relevant legislation, no specific management measures are proposed	Operation

Issue	Mitigation/management measure	Recommended timing of implementation
Fire	The Bushfire Management Plan should be implemented. Fire-fighting vehicles and staff should be located at the proposed airport to minimise the risk of impact of fire on adjacent native vegetation.	Operation
Contaminants	Implementation of measures to manage the risk of contaminants polluting surface water and other sensitive receptors adjoining the airport site, including: • maintenance of sewerage systems; • appropriate fencing, bunding and management of chemicals and fuel storage areas to prevent spills; • appropriate storage and management of pesticides and herbicides to prevent entry into local waterways; and • emergency response protocols to contain and clean-up accidental spills.	Operation
Water quality	Appropriate management of stormwater to maintain aquatic habitat values downstream, having regard to relevant regulatory standards and guidelines.	Operation

9.3 Offsetting of impacts

9.3.1 Overview

The EIS guidelines state that the proposed airport will require biodiversity offsets for residual significant impacts associated with the airport, calculated in accordance with the *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* (the offset policy) (DSEWPaC 2012a). The key considerations included in the policy are that:

- offsets are required for significant residual impacts on matters that are protected under the EPBC Act including listed threatened species and communities and the environment, where Commonwealth agencies are proposing to take an action;
- the amount of offset required for threatened species and communities listed under the EPBC Act must be calculated using the 'offset assessment guide' spreadsheet. The offset assessment guide uses a balance sheet approach to calculate the percentage of the proposal's impacts that would be directly offset;
- at least 90 per cent of the proposed airport's impacts must be directly offset and the offset site must be identified, assessed and securely conserved under a covenant and management plan, preferably prior to the impact occurring; and
- up to 10% of the proposed airport's impacts may be indirectly offset through contribution to a research fund or a conservation program.

Further consultation with the DotE has revealed that the estimate of offsets for residual impacts on the environment, including threatened biota and their habitats listed under the New South Wales (NSW) *Threatened Species Conservation Act 1995* (TSC Act), should be calculated using the NSW Biodiversity Banking and Offsets Scheme (BioBanking) assessment methodology.

The EPBC Act Offsets Policy requires biodiversity offset sites to be securely titled under a legally binding conservation covenant and actively managed under a fully funded plan. There are a variety of mechanisms for achieving this, including BioBanking, Voluntary Conservation Agreements or dedication of land to the National Parks estate.

At this stage of the planning and assessment for the proposed airport, the intent is to deliver biodiversity offsets through conservation of suitable offset sites. The offset sites will be secured by registration of a BioBanking agreement on title to the sites. A BioBanking agreement is recognised as a practical and secure way of delivering biodiversity offsets and is endorsed by the Department as well as OEH and DPE for this purpose. This approach would require the purchase of the number and type of biodiversity credits that match the offset area which is required to offset proposal's impacts as calculated in accordance with the EPBC Act offsets policy.

Biodiversity offsets for the proposed airport would be provided via a staged approach.

1. development of a biodiversity offset package that accompanies the EIS, comprising:
    - a summary of the biodiversity impact assessment for the airport;
    - an estimate of the quantum of biodiversity offsets required;
    - the preferred approach for delivering biodiversity offsets, including a description of potential offset sites or other environmental contributions; and
    - concluding statements demonstrating compliance with the assessment requirements for the EIS and that the offsets proposed for the airport, when implemented would improve or maintain the viability of the protected matters and comply with the offset policy.

2. Delivery of biodiversity offsets in accordance with the conditions for the proposal, comprising:
   - confirmation of the quantum of impacts and biodiversity offsets required;
   - confirmation of the actual biodiversity offset that would be delivered such as a detailed description of specific offset sites or alternative environmental contributions;
   - description of the funding and management arrangements for delivering the biodiversity offset and the timing of delivery; and
   - concluding statements demonstrating compliance with the conditions for the proposal and the offset policy (DSEWPaC 2012a).

The biodiversity offset package report has been prepared using the EPBC Act offset policy, the offsets assessment guide and BioBanking assessment methodology (GHD 2015a) and summarised below. The offset package comprises the first stages in the delivery of biodiversity offsets for the airport.

The offset package would build upon biodiversity offsets that would be delivered for the North West and South West growth centres strategic assessment, which include the conservation of a minimum of 998 hectares of Cumberland Plain Woodland within the growth centres (DoP 2010). The offset package has been developed with reference to the strategic assessment for the North West and South West growth centres (DoP 2010) and the Cumberland Plain Recovery Plan (DECCW 2010). The offset package will complement regional conservation strategies including by securing offset sites within identified priority conservation lands that are intended to maintain the biodiversity values of the Cumberland Plain (DECCW 2010).

9.3.2 Summary of impacts requiring offsets

According to the EPBC Act offset policy biodiversity offsets are required for significant residual impacts on matters protected by the EPBC Act, including (as relevant for this report) threatened species and communities listed under the EPBC Act and other biodiversity aspects of the environment, after any proposed avoidance and mitigation measures have been taken into account. The desktop assessment, field surveys and impact assessment included above have been used to identify MNES and other biodiversity matters that are known or may occur at the airport site and that have the potential to incur a significant impact. Assessments of significance have been prepared in accordance with the Significant impact guidelines 1.1 (DotE 2013a) for impacts on threatened biota listed under the EPBC Act with the potential to be affected by the airport and Significant impact guidelines 1.2 (Dote 2013b) for impacts on the environment as a result of actions being undertaken by the Commonwealth. The outcome of these assessments is that the airport is likely to have a significant impact on:

- Cumberland Plain Woodland which is listed as a CEEC under the EPBC Act and occurs at the airport site. Offsets are required for the removal of 90 hectares of vegetation within the local occurrence of the community (see Appendix D);
- the Grey-headed Flying-fox, which is listed as a vulnerable species under the EPBC Act and which has been observed at the airport site. Offsets are required for the removal of 120 hectares of foraging habitat (see Appendix D); and
- features of the natural environment including plant populations, fauna populations and several species and communities listed under NSW legislation (see Sections 8.3 and 8.4).

Impacts on EPBC Act-listed biota have been entered in the EPBC Act offset assessment guide (see Section 9.3.4). The offset assessment guide can only be used to calculate offsets for threatened biota listed under the EPBC Act and so an alternative approach is required for impacts on other protected matters. The EPBC Act offsets policy requires that the approach to calculating offsets must be in proportion to the level of statutory protection that applies to the

protected matter, be of a size and scale proportionate to the residual impacts on the protected matter and be scientifically robust and reasonable (DSEWPaC 2013a). The BioBanking assessment methodology meets each of these criteria and is supported by DotE for this purpose.

BioBanking credit calculations using the assessment methodology for a major project in NSW have been used to estimate offsets for impacts on the environment, including species and communities listed under NSW legislation. The outcome of the BioBanking credit calculations is that the species credits summarised in Table 71 and the ecosystem credits summarised in Table 72 would be required to offset significant residual impacts of the proposed airport on the natural environment.

Table 71 Species credits required to offset impacts of the proposed airport

Common name	Scientific name	Threatened species multiplier	Species credits required
Black Bittern	*Ixobrychus flavicollis*	1.3	719
Cumberland Plain Land Snail	*Meridolum corneovirens*	1.3	1568
Marsdenia viridiflora subsp. *viridiflora* in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas	*Marsdenia viridiflora* subsp. *viridiflora* - endangered population	4.0	3720
Pultenaea parviflora	*Pultenaea parviflora*	1.5	60
Southern Myotis	*Myotis macropus*	2.2	656

Table 72 Ecosystem credits required to offset impacts of the proposed airport

Plant community type name	Condition	TSC Act Status	EPBC Act Status	Management zone area	Ecosystem credit requirement	Offset options – Plant community types
Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	Moderate/ Good	CEEC	CEEC	71.27	3,555	HN528, HH526[1]
Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	Moderate/ Good_Poor	CEEC		107.79	3,208	HN528, HH526
Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	Moderate/ Good	CEEC	CEEC	17.32	751	HN529, HN528, HN526[1]
Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	Moderate/ Good_Poor	CEEC		22.29	647	HN529, HN528, HN526
Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	Moderate/ Good	EEC		29.83	1,530	HN526, HN528
Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	Moderate/ Good_Poor	EEC		4.22	127	HN526, HN528
Good condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	Moderate/ Good	EEC	CEEC	2.19	161	HN512, HN513, HN604, HN556[1]
Poor condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)	Moderate/ Good_Poor	EEC		0.39	20	HN512, HN513, HN604, HN556
Good condition artificial freshwater wetland on floodplain (HN630)	Moderate/ Good			25.44	700	HN630, HN520

Notes: 1) Ecosystem credits that are used to offset impacts on EPBC Act Cumberland Plain Woodland would need to be plant community types HN528, HN529 or HN512 and associated with better quality vegetation in order to comply with the EPBC Act offset policy (DSEWPaC 2012).

9.3.3 Proposed offsets

Proposed offset strategy

The biodiversity offset strategy for the proposed airport is to conserve habitat for the affected protected matters by sourcing credits from offset sites which are subject to a BioBanking agreement registered on the title of offset sites, as this would ensure they would be securely titled and managed for conservation as a biobank in perpetuity. The number and type of biodiversity credits required to offset the proposed airport's impacts as calculated by the offset assessment guide would be purchased and retired from offset sites. Additional biodiversity credits would be purchased to offset impacts on the natural environment.

The EPBC Act offset policy requires that a minimum of 90 per cent of the proposed airport's impacts must be directly offset as calculated with the offset assessment guide for listed threatened species and communities or as calculated with BioBanking or an alternative metric for other protected matters. The remaining offset requirement is able to be met by alternative contributions such as a financial contribution to research or conservation.

The specific components of this strategy that are included in the offset package are described below.

Potential offset sites

A desktop assessment was performed to identify and describe potential offset sites for the airport. Candidate sites would be secured by under a BioBanking agreement that would ensure that the offset sites would be securely titled for conservation as a biobank in perpetuity.

The sources that were considered in the desktop assessment include BioBanking online registers administered by OEH, BioBanking assessment reports for existing and potential biobank sites and consultation with private landowners and agencies

The desktop assessment has revealed suitable offset sites that contain Cumberland Plain Woodland and/or Grey-headed Flying-fox habitat. Potential offset sites that contain habitat for the affected threatened biota and that could be included in this offset package are detailed in Table 73. Portions of four of these potential offset sites (Williamswood, Montpelier Stages 1 and 2 and Durham biobanks) are located in Cumberland Plain Priority Conservation Lands identified in the recovery plan for Cumberland Plain Woodland (DECCW 2010, 2011).

Table 73 Potential offset sites

Potential Offset Site	Location	Total area (ha)	Status and ownership	Source
Williamswood biobank	Mount Hunter	104.4	Established biobank, private owner.	Williamswood Biobank BioBanking Assessment (GHD 2014a).
Durham biobank	Oxley Park (Ropes Creek riparian corridor)	46.85	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015d).
Mamre biobank	Mamre Park (South Creek riparian corridor)	98.1	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015d).
Luddenham biobank	Mamre Park (South Creek riparian corridor)	42	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015d).
Roper biobank	Minchinbury (Ropes Creek riparian corridor)	14.05	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015d).
Caddens biobank	Claremont Meadows (South Creek riparian corridor)	36.08	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015d)
Dunheved biobank	Werrington County (South Creek riparian corridor)	90.17	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015d).
Forrester biobank	Tregear (Ropes Creek riparian corridor)	9.16	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015d).
Stage 1 Montpelier biobank	The Oaks	76.24	Potential biobank, private owner.	Stage 1 Montpelier Biobank BioBanking Assessment (GHD 2015d).
Stage 2 Montpelier biobank	The Oaks	79.5	Potential biobank, private owner	Stage 2 Montpelier Biobank BioBanking Assessment (GHD in prep).
Menangle Road biobank	The Oaks	57.07	Potential biobank, private owner	Menangle Road Biobank BioBanking Assessment (GHD 2015e).
Bruelle biobank	Mulgoa	27.5	Potential biobank, private owner	Bruelle biobank site Draft Biobank agreement assessment (GHD 2015f).
The Oaks	Mowbray Park	40	Established biobank, private owner	The Oaks Biobank BioBanking Assessment (GHD 2015g).
Western Sydney Parklands ID 120	Cecil Park	19.4	Established biobank, Western Sydney Parklands Trust	The biodiversity credits register (OEH 2015b).
Western Sydney Parklands ID 70	Cecil Park and Chandos West	40.5	Established biobank, Western Sydney Parklands Trust	The biodiversity credits register (OEH 2015b).

There are local occurrences of each of the TECs that would be removed for construction of the airport and known or potential habitat for many of the threatened species that would be affected at the offset sites (see Table 74 and GHD 2015a).

Table 74 Threatened species recorded at the potential offset sites

Common name	Scientific name	TSC Act Status	EPBC Act Status	Sites recorded
Brown Treecreeper (eastern subspecies)	*Climacteris picumnus* subsp. *victoriae*	V		Dunheved[1]
Eastern Freetail-bat	*Mormopterus norfolkensis*	V		Mamre[2]
Little Eagle	*Hieraaetus morphnoides*	V		Roper, Luddenham, Montpelier Stage 1, Montpelier Stage 2, Williamswood[3]
Powerful Owl	*Ninox strenua*	V		Mamre[2]
Swift Parrot	*Lathamus discolor*	E	E	Dunheved[1]
Turquoise Parrot	*Neophema pulchella*	V		Luddenham[1]
Varied Sittella	*Daphoenositta chrysoptera*	V		Dunheved[1], Mamre[2]
Cumberland Plain Land Snail	*Meridolum corneovirens*	E		Forrester[1], Caddens[2]
Juniper-leaved Grevillea	*Grevillea juniperina* subsp. *juniperina*	V		Durham[3], Roper[3]
Dillwynia tenuifolia	*Dillwynia tenuifolia*	V		Roper[4]
Grey-headed Flying-fox	*Pteropus poliocephalus*	V	V	Caddens[2] and roost camp within 500 metres[4],
Large-footed Myotis	*Myotis macropus*	V		Mamre[2]
Pultenaea parviflora	*Pultenaea parviflora*	V	V	Dunheved[3]
Spiked Rice-flower	*Pimelea spicata*	E	E	Williamswood[3]

1 = Toolijooa (various dates); 2 = OEH (2015a); 3 = GHD (2014a,b; 2015a,b,c,d,e; in prep.); 4 = PB (2013).

The potential offset sites described above contain some areas of native vegetation and habitat that is not an appropriate 'like for like' match for impacts on the EPBC Act-listed affected threatened biota or is associated with biodiversity credits that have already been sold. Only appropriate 'like for like' vegetation and habitat would be included in the offset package. A subset of the habitat available at the potential offset sites has been selected on the basis that it would directly offset impacts on the affected threatened biota, and the biodiversity credits which are generated to represent the offsets for that area are available for purchase. DotE will require these specific areas to be clearly documented and mapped in the final offset package.

The criteria for selecting the proposed offset areas are:

- areas that are linked to biodiversity credits that area available for sale at established biobanks or that would be available for sale at proposed biobanks;
- presence of EPBC Act Cumberland Plain Woodland;
- presence of habitat for the Grey-headed Flying-fox;

The ‘proposed offset areas’ (i.e. the specific areas of habitat at potential offset sites that would be included in the offset package to offset impacts on the affected threatened biota) are summarised in Table 74.

The area of Grey-headed Flying-fox habitat available in the proposed offset areas (around 401 hectares) is substantially greater than the estimated area required to meet this species’ offset requirement. This area would also contribute offsets for impacts on the environment and so the full area has been included in the Offset assessment guide calculations.

Table 75 Proposed offset areas

Potential Offset Site	Total area (ha)	Extent of available EPBC Act Cumberland Plain Woodland (ha)[1]	Extent of available poorer quality Cumberland Plain Woodland (ha)[2]	Grey-headed Flying fox habitat (ha) [3]	Notes
Williamswood biobank	104.5	31.9	28.0	50.4	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland.
The Oaks	40.0	10.0	3.0	10.4	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland.
Durham biobank	42.7	2.9	0.0	24.1	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional Grey-headed Flying-fox habitat associated with River Flat Eucalypt Forest and close to a known roost camp.
Mamre Biobank	98.1	0.0	0.0	52.5	Grey-headed Flying-fox habitat associated with River Flat Eucalypt Forest and linked to biodiversity credits that area available for sale.
Luddenham biobank	40.0	4.1	0.7	34.6	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional Grey-headed Flying-fox habitat associated with River Flat Eucalypt Forest. Additional poorer quality Cumberland Plain Woodland.
Roper biobank	13.3	3.0	1.7	6.7	EPBC Act Cumberland Plain Woodland and poorer quality Cumberland Plain Woodland linked to credits that are available for sale.

Potential Offset Site	Total area (ha)	Extent of available EPBC Act Cumberland Plain Woodland (ha)[1]	Extent of available poorer quality Cumberland Plain Woodland (ha)[2]	Grey-headed Flying fox habitat (ha) [3]	Notes
Caddens biobank	33.3	4.8	1.2	17.3	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland. Biodiversity credits for other impacts on the environment.
Dunheved biobank	65.0	3.8	8.7	23.0	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland. Biodiversity credits for other impacts on the environment.
Forrester biobank	9.2	0.0	0.0	5.9	Grey-headed Flying-fox habitat associated with River Flat Eucalypt Forest and linked to biodiversity credits that area available for sale.
Stage 1 Montpelier biobank	76.2	34.1	11.4	40.9	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland. Biodiversity credits for other impacts on the environment.
Stage 2 Montpelier biobank	79.5	20.9	9.2	48.5	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland. Biodiversity credits for other impacts on the environment.
Menangle Road biobank	57.1	27.0	21.1	36.0	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland. Biodiversity credits for other impacts on the environment.
Bruelle biobank	26.8	14.4	0.0	27.5	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Biodiversity credits for other impacts on the environment.

Potential Offset Site	Total area (ha)	Extent of available EPBC Act Cumberland Plain Woodland (ha)[1]	Extent of available poorer quality Cumberland Plain Woodland (ha)[2]	Grey-headed Flying fox habitat (ha) [3]	Notes
Western Sydney Parklands ID 120	19.4	18.2	0.0	18.2	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Biodiversity credits for other impacts on the environment.
Western Sydney Parklands ID 70	40.5	5.2	0.0	5.2	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Biodiversity credits for other impacts on the environment.
	786.2	**180.3**	**78.6**	**401.2**	

9.3.4 Preliminary offset assessment guide calculations

Overview

The EPBC Act Offset Policy requires a formal assessment of impacts and offset contributions for EPBC Act-listed species and communities using the 'offsets assessment guide'. The offsets assessment guide utilises a balance sheet approach to measure impacts and offsets. According to the EPBC Act Offsets Policy, controlled actions requiring offsets must achieve a minimum 90 per cent 'direct offset'. Direct offsets are defined as 'those actions that provide a measurable conservation gain for an impacted protected matter'. A conservation gain for the protected matter may be achieved by measures such as:

- improving existing habitat ;
- creating new habitat;
- reducing threats; and/or
- averting the loss of a protected matter or its habitat that is under threat.

Offset assessment guide calculations have been performed based on the significant residual impacts documented in this report and the EIS and likely conservation and management of the potential offset sites. A detailed description of calculations is provided in the Biodiversity Offsets Package (GHD 2015a). The output of this preliminary assessment is an estimate of the percentage of the airport impacts that would be 'directly offset' by the potential offset sites. The area of the offset site was treated as a variable in these calculations and adjusted until 100% of the proposal's offsets would be directly offset.

Once the final offset sites have been identified a 90 per cent direct offset may be acceptable under EPBC Act Offset Policy with up to 10 per cent of the offset able to be achieved through 'other compensatory measures', which are 'those actions that … are anticipated to lead to benefits for the impacted protected matter, for example funding for research or educational programs'.

Separate data are entered in the offsets assessment guide for each of the biodiversity-related protected matters that may be impacted by the airport however offset contributions for separate protected matters may be grouped when it is appropriate to do so. Circumstances where this may be appropriate include where the protected matters have similar ecology or habitat requirements and where these requirements can be demonstrated to be met by a single offset. In these instances, the protected matters with the greatest offset requirement determines the quantum of offset required for the project.

Preliminary Offset assessment guide calculations

Preliminary offset assessment guide calculations were performed for the affected threatened biota based on the following:

- removal of approximately 88.9 hectares of EPBC Act Cumberland Plain Woodland with a site quality score of 6/10 (as described in GHD 2015a);
- removal of approximately 120.4 hectares of habitat for the Grey-headed Flying-fox with a site quality score of 7/10 (as described in GHD 2015a); and
- the conservation and management of offset sites to achieve increased site quality, containing:
  - EPBC Act Cumberland Plain Woodland (as described in GHD 2015a);
  - poorer quality Cumberland Plain Woodland (as described in GHD 2015a); and
  - Grey-headed Flying-fox habitat (as described in GHD 2015a).

The outcome of these preliminary offset assessment guide calculations is that:

- the proposed offset areas containing around 180 hectares of EPBC Act Cumberland Plain Woodland would offset 59 per cent of the proposed airport's impacts on the ecological community;
- the proposed offset areas containing around 79 hectares of poorer condition Cumberland Plain Woodland would offset around 15 per cent of the proposed airport's impacts on the ecological community, resulting in a total offset contribution of 74 per cent of the proposed airport's impacts.
- The proposed offset areas containing up to 401 hectares of habitat for the Grey-headed Flying-fox would offset around 136 per cent of the proposed airport's impacts on this vulnerable species.

Based on these preliminary calculations, the proposed offset sites could not meet all of the proposed airport's EPBC Act offsetting requirements as direct offsets. Additional offset sites containing Cumberland Plain Woodland will be identified throughout the environmental assessment and approval process for the proposed airport and will be included in the final offset package. (see Section 9.3.5).

9.3.5 Delivery of offsets

Biodiversity credits

Biodiversity credits would be purchased to secure the proposed offset areas for EPBC Act-listed biota. Subject to confirmation of the overall offset requirement for the proposed airport, additional biodiversity credits would be purchased to offset the proposal's impacts on the environment.

The EPBC Act offset policy and the BioBanking assessment methodology include different rules that govern the biodiversity offsets that can be delivered for a development's impacts. The EPBC Act offset policy requires 'like for like' biodiversity offsets and the offset site must be able to reach the same site quality score as the development site. Therefore only EPBC Act Cumberland Plain Woodland, poorer quality Cumberland Plain Woodland that could reach this standard and Grey-headed Flying Fox habitat have been included in the proposed offset areas. The suite of biodiversity credits that are associated with the proposed offset areas would be purchased and retired in order to secure the offsets for EPBC Act-listed biota. The BioBanking assessment methodology includes greater flexibility with respect to some criteria. This flexibility allows trading of ecosystem credits for closely related vegetation types if they are in the same vegetation class and are at least as extensively cleared (i.e. have the same or greater conservation significance). BioBanking also allows trading of ecosystem credits associated with low condition vegetation at a biobank site, including vegetation that could not meet the standard of EPBC Act Cumberland Plain Woodland. This flexibility should be considered along with the fact that BioBanking requires the calculation of biodiversity offsets for poorer condition vegetation. A substantial area of poor condition vegetation at the airport site has contributed to the amount of offset required for residual significant impacts on the environment. Species credits should be traded on a like for like basis.

The number and type of biodiversity credits that would be required to offset the proposed airport's impacts on the environment are specified in the BioBanking credit report (see GHD 2015a). Both species credits and ecosystem credits would be required to offset the proposed airport's impacts on the environment.

No species credits have been calculated at any of the existing or proposed biobank sites included in the offset package. Species credits may be generated once targeted surveys have been undertaken to confirm the presence of threatened species and the numbers of individuals

of plants and area of habitat for fauna. Based on the assessments undertaken to date, the proposed offset sites contain known or potential habitat for each of the species credit-type threatened species affected by the proposed airport. Table 76 summarises the species credits required to offset the impacts of the proposed airport, the equivalent area of fauna habitat or number of plants required to generate these credits at an offset site and a summary of the potential habitat available at offset sites.

Sufficient *Pultenaea parviflora* has already been recorded at the Dunheved biobank site to generate the required number of species credits. Based on the site surveys and habitat assessments undertaken it is likely that supplementary surveys would confirm the presence of the fauna species at these offset sites and allow the calculation of species credits. *Marsdenia viridiflora* subsp. *viridiflora* is very sparsely and sporadically distributed within its range and so it is likely to be difficult to locate a population of the required size at offset sites. The proposed translocation program will be important in avoiding or minimising impacts on this endangered population and should be coordinated with the offset package.

Once appropriate species credits have been calculated and generated at the biobank sites these species credits would be purchased and retired to offset impacts on the individual threatened species listed in Table 76.

Table 76 Species credits potentially available at offset sites

Common name	Scientific name	Species credits required	Individuals / area required in offset site	Individuals / area available in offset site(s
Black Bittern	*Ixobrychus flavicollis*	719	101	Up to around 314 hectares of potential habitat in Forest Red Gum - Rough-barked Apple grassy woodland (HN526) and Coastal freshwater wetland (HN630) at proposed off set sites.
Cumberland Plain Land Snail	*Meridolum corneovirens*	1568	221	Up to around 414 hectares of potential habitat in Grey Box - Forest Red Gum grassy woodland on shale (HN529) and Grey Box - Forest Red Gum grassy woodland on plains (HN528). The species has been recorded at the Forrester and Caddens biobank sites.
Marsdenia viridiflora subsp. *viridiflora* - endangered population	*Marsdenia viridiflora* subsp. *viridiflora* -	3720	524	Up to around 476 hectares of potential habitat in Grey Box - Forest Red Gum grassy woodland on shale (HN529), Grey Box - Forest Red Gum grassy woodland on plains (HN528) and Grey Box - Forest Red Gum shrubby woodland (HN524).
Pultenaea parviflora	*Pultenaea parviflora*	60	8	100 individuals recorded at the Dunheved biobank site.
Southern Myotis	*Myotis macropus*	656	92	Up to around 313 hectares of potential habitat in Forest Red Gum - Rough-barked Apple grassy woodland (HN526) at proposed off set sites. The species has been recorded at the Mamre biobank site.

Table 77 includes a comparison of the ecosystem credits available at the proposed offset sites and the ecosystem credit requirement to offset the proposed airport's impacts on the natural environment as estimated with BioBanking credit calculations. There would be sufficient ecosystem credits available to offset impacts on Grey Box - Forest Red Gum grassy woodland on shale (HN529) and Forest Red Gum - Rough-barked Apple grassy woodland (HN526). The 'Credit balance' in Table 77 shows that additional ecosystem credits would be required to offset impacts on other vegetation types and associated predicted threatened species. The credit shortfall for Grey Box - Forest Red Gum grassy woodland on flats (HN528) can be partially met by trading surplus HN526 credits, which is permitted by the BioBanking credit trading rules.

Table 77 Ecosystem credits for impacts on the natural environment

Potential Offset Site	Total area (hectares)	Available HN528 credits	Available HN529 credits	Available HN526 credits	Available HN512 credits	Available HN630 credits	Available HN524 credits
Williamswood biobank	104.5	0	694	280	0	0	38
Durham biobank	42.7	31	0	246	0	0	0
Mamre biobank	98.1	0	0	680	0	7	0
Luddenham biobank	40.0	34	0	246	0	0	0
Roper biobank	13.3	48	0	20	25	0	0
Caddens biobank	33.3	47	0	181	0	5	0
Dunheved biobank	65.0	93	0	362	0	0	0
Forrester biobank	9.2	0	0	56	0	0	0
Stage 1 Montpelier biobank	76.2	119	442	0	0	0	153
Stage 2 Montpelier biobank	79.5	0	363	0	0	0	118
Menangle Road biobank	57.1	0	454	36	0	0	29
Bruelle biobank	26.8	0	141	0	0	0	0
The Oaks	40.0	0	261	11	0	0	69
Western Sydney Parklands ID 120	19.4	120	0	61	0	0	0
Western Sydney Parklands ID 70	40.5	49	0	10	0	0	0
Total	**892.8**	**542**	**2355**	**2188**	**25**	**12**	**407**
Ecosystem credit requirement		**6763**	**1398**	**1657**	**181**	**700**	**0**
Credit balance		**-6221**	**957**	**531**	**-156**	**-688**	**407**
Total including trading of matching credits		**1074**[1]		**1657**			
Credit balance including trading of matching credits		**-5689**	**957**	**0**	**-156**	**-688**	**407**

Notes: 1) includes 531 HN526 credits which may be traded with HN528.

Identification of additional offsets

Based on the preliminary offset assessment guide calculations and BioBanking calculations, the proposed offset sites could not meet all of the proposed airport's EPBC Act offsetting requirements as direct offsets. Additional offset sites containing Cumberland Plain Woodland and other additional offset contributions will be identified throughout the environmental assessment process for the proposed airport and will be included in the final offset package. Any additional offset sites would be identified according to the approach specified in GHD 2015a to ensure that they are an appropriate 'like for like' match for the airport's impacts and meet the other requirements of the EPBC Act offset policy.

A similar approach would be taken in the event that any credits which have been identified for purchase from biobank sites identified in this EIS are sold to third parties before they can be secured as offsets for the proposed airport.

Finalisation of the offset package

The Minister for the Environment would advise the final quantum of biodiversity offsets required for the proposed airport as part of the process of obtaining the Minister's advice that the airport plan may be determined. This may include the requirement for additional site specific information such as proposed management, current risk of development and the security of titling proposed for individual offset sites. These additional data would be considered by specialists within DotE and the final calculations and details regarding data and assumptions underlying the results would be compiled and collectively comprise the EPBC Act offset package for the proposed airport.

10. Conclusion

This Biodiversity Assessment has been prepared to describe the biodiversity values present at the airport site, assess impacts of the proposed airport, and recommend appropriate management measures and offset requirements for the proposed airport.

The airport site comprises gently undulating, low hills on shale and broad flats on alluvium on the Cumberland Plain. It features remnant patches of grassy woodland and narrow corridors of riparian forest within extensive areas of derived grassland, cropland and cleared, developed land. The main land uses are agriculture and low density rural residential development.

The condition of native vegetation and habitat across the airport site varies as a result of previous land uses and grazing intensity. Areas that have been historically cleared and/or heavily grazed now contain regrowth vegetation in poorer condition. There is moderate to severe weed infestation throughout, with linear remnants along roads and isolated patches in agricultural land the most severely affected. Notwithstanding the generally poor condition of the airport site it has high conservation significance as a result of the presence of threatened species and ecological communities and the generally limited extent and quality of similar environments in the Western Sydney region.

Construction of the Stage 1 development at the airport site would result in direct impacts within a 1065 hectare disturbance footprint, including 280 hectares of native vegetation. The majority of impacts for the Stage 1 development would be in areas that have previously been cleared for agricultural purposes. The Stage 1 construction impact zone would be completely developed and converted to airport infrastructure or managed open space with minimal native vegetation cover. Native vegetation removal in the Stage 1 construction impact zone would comprise land clearance as defined under the EPBC Act and would constitute a substantial increase in the operation of this Key Threatening Process in the locality and region.

Construction and operation of Stage 1 of the proposed airport would create a gap in habitat that is around 1060 hectares in area and about 1.5 km wide from north to south and almost 7 km long from east to west. This area would be mostly inhospitable to native species given the presence of cleared areas, fences, infrastructure, lights and aviation-related activities. The gap would create a barrier to ecological processes such as dispersal, pollination and seed fall. The proposed airport would result in a substantial increase in the degree of habitat fragmentation in the locality and region.

Other direct and indirect impacts arising from the proposed construction and operation of the airport would include harm to plants and animals during construction, substantial alteration of the land surface and hydrology, the risk of bird and bat strike by aircraft and the potential for alteration of flows and water quality downstream.

The Stage 1 development would result in the following impacts on threatened biota and other biodiversity matters listed under the EPBC Act:

- permanent removal of 90.8 hectares of vegetation within the local occurrence of Cumberland Plain Woodland that is commensurate with the EPBC Act form of the critically endangered ecological community (CEEC);
- removal of a local population of *Pultenaea parviflora*, comprising four individuals and up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat;

- removal of a maximum of 120.6 hectares of better quality potential habitat and a up to a further 134.7 hectares of poor quality potential habitat for the threatened flora species White-flowered Wax Plant (*Cynanchum elegans)*, Spiked Rice-flower (*Pimelea spicata)* and Downy Wattle (*Acacia pubescens*), which are listed as endangered species and Small-flower Grevillea (*Grevillea parviflora* subsp. *parviflora*) and Austral Toadflax (*Thesium australe*), which are listed as vulnerable species under the EPBC Act. The scale of impacts on these threatened plants varies depending on their specific habitat requirements;
- removal of up to 120.6 hectares of suitable potential foraging habitat for the Grey-headed Flying-fox (*Pteropus poliocephalus*), which is listed as a vulnerable species under the EPBC Act and which has been observed flying over the airport site;
- removal of up to 120.6 hectares of potential winter foraging habitat for the Swift Parrot (*Lathamus discolor*), which is listed as an endangered species under the EPBC Act and which may occur at the airport site during annual migrations on an opportunistic basis;
- removal and fragmentation of habitat for migratory bird species;
- large-scale vegetation clearing and other impacts on plants in an area of Commonwealth Land;
- the long-term decrease or extinction of populations of small, less mobile animals such as frogs, reptiles and the Cumberland Plain Land Snail (*Meridolum corneovirens*) and other impacts on fauna in an area of Commonwealth Land;
- operational impacts on the matters listed above such as increased noise, light or traffic and the potential for bird and bat strike by aircraft; and
- substantial cumulative and facilitated impacts on the matters listed above such as additional removal of native vegetation and habitat resources as a result of other planned and potential infrastructure developments linked to the proposed airport. Construction of the proposed airport is also likely to provide a stimulus to economic activity in the locality and result in commercial developments in the surrounding area.

The Stage 1 development would result in impacts on threatened biota listed under the NSW TSC Act, comprising:

- permanent removal of the 90.8 hectares of vegetation within the local occurrence of Cumberland Plain Woodland that is commensurate with the EPBC Act form of the CEEC as described above and an additional 130.5 hectares that comprises the TSC Act-listed form of the CEEC or the closely related endangered ecological community (EEC) Shale-gravel Transition Forest;
- permanent removal of 34.1 hectares of River-flat Eucalypt Forest, which is listed as an EEC under the TSC Act;
- removal of 93 individual *Marsdenia viridiflora* subsp. *viridiflora* that are part of an endangered population listed under the TSC Act as well as up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat;
- the impacts on threatened plants listed under the EPBC Act described above, as each of these species are also listed as threatened species under the TSC Act. Removal of up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat for two additional plant species, *Dillwynia tenuifolia* and *Grevillea juniperina* subsp*. juniperina*, which are listed as vulnerable species under the TSC Act*;*
- the impacts on threatened fauna listed under the EPBC Act described above, as each of these species are also listed as threatened species under the TSC Act;

- removal of 120.6 hectares of known and potential habitat for the Cumberland Plain Land Snail, which is listed as an endangered species under the TSC Act; and
- removal and fragmentation of known and potential habitat for a range of threatened woodland birds and microchiropteran bat species listed under the TSC Act.

Assessments of significance have been prepared in accordance with the *Matters of National Environmental Significance Significant Impact Guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999* (DotE 2013a) for impacts on threatened biota and other MNES and the *Significant Impact Guidelines 1.2 - Actions on, or impacting upon, Commonwealth land and Actions by Commonwealth Agencies* (DotE 2013b) for impacts on the natural environment.

The outcome of these assessments is that the proposal is likely to have a significant impact on the following MNES:

- Cumberland Plain Woodland;
- the Grey-headed Flying-fox; and
- plants and animals, including a number of species and populations listed as threatened under the TSC Act, in an area of Commonwealth Land.

Operation of the proposed airport has the potential to impact the biodiversity values of the Greater Blue Mountains World Heritage Area (GBMWHA) through increased levels of aircraft noise, reduced air quality, the potential for fuel jettisoning, the potential for aircraft crashes and contribution to the impacts of climate change through generation of greenhouse gases or increased risk of wildfire. An assessment of the likely significance of impacts on the GBMWHA has been prepared with respect to the significant impact guidelines 1.1 (DotE 2013a). The project would be unlikely to have a significant impact on the biodiversity values of the GBMWHA given:

- There would be no direct impact on the GBMWHA
- Indirect impacts associated with the proposed construction and operation of the airport would be unlikely to result in the loss or significant modification of biological diversity or biological processes within the GBMWHA, given:
  - Potential impacts on fauna within the GBMWHA as a result of noise are unlikely to result in changes to species behaviour or habitat use
  - Potential impacts on the GBMWHA as a result of changes to air quality are likely to be negligible given the distance to the GBMWHA and prevailing wind conditions
  - The draft airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site and to avoid substantial alteration of surface water drainage patterns and water quality outside of the airport site.
  - While greenhouse gas emissions will increase as a result of the proposed construction and operation of the airport, this is unlikely to directly result in the loss of biological diversity or biological processes within the GBMWHA.

The airport site was selected based on criteria such as site topography, surrounding topography, proximity to infrastructure and the need to minimise potential environmental and social impacts. Given this range of selection criteria, the size of site required and the constraints associated with the safe operation of an airport it would not have been possible to completely avoid impacts on biodiversity values. The longer term development area would not be cleared and grubbed until required for construction of the second runway and other longer term

infrastructure. This approach means that impacts on biodiversity values would be avoided for as long as is practicable.

Specific mitigation and management measures are recommended to address the potential impacts on biodiversity values described above. Recommended measures that are likely to substantially reduce the risk or consequence of impacts include:

- protection of the portion of the Badgerys Creek corridor within the airport site along with around 122 hectares of land in an environmental conservation zone that includes around 61 hectares of native vegetation and 61 hectares of land that would be revegetated;
- designing the surface water management system in order to retain any potentially contaminated surface water generated on site and maintain the volume and potentially improve the quality of downstream flows;
- staged vegetation removal during construction, pre-clearing surveys and measures for the salvage of resident fauna and habitat resources;
- translocation programs for the Cumberland Land Snail and for threatened plant species and populations; and
- designing the proposed airport to minimise its attractiveness to fauna and thus minimise bird and bat strike and terrestrial fauna strike.

Biodiversity offsets would be required to compensate for significant residual impacts arising from the proposed airport in accordance with the *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* (DSEWPaC 2012 An offset package has been prepared to compensate for the following significant impacts on threatened species listed under the EPBC Act:

- removal of 90 hectares of vegetation within the local occurrence of Cumberland Plain Woodland;
- removal of 120 hectares of foraging habitat for the Grey-headed Flying-fox; and
- on features of the natural environment including plant populations, fauna populations and several species and communities listed under NSW legislation.

The quantum of biodiversity offsets required has been calculated in accordance with the EPBC Act Offset Policy (DSEWPaC 2012) and includes offset assessment guide calculations for impacts on EPBC Act-listed species and communities and BioBanking credit calculations for impacts on the environment. The offset package would conserve habitat for the affected threatened biota in suitable offset sites in the locality and surrounding region using BioBanking. The offset sites would be secured by the relevant site owners obtaining a BioBanking agreement that would ensure that they would be securely titled and managed for conservation as a Biobank in perpetuity.

Longer term development at the airport site would require separate assessment of impacts and calculation of additional biodiversity offsets. Other major developments in the locality subject to State approval processes would need to deliver biodiversity offsets in accordance with the NSW Framework for Biodiversity Assessment and/or the EPBC Act offset policy. The cumulative benefits of biodiversity offsets should help to compensate for the cumulative impacts of the various developments.

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Appendices

Appendix A – Assessment of likelihood of occurrence of threatened and migratory species at the airport site

Marine/pelagic/estuarine species, including seabirds, shorebirds, sandpipers, turtles, whales, sharks, appearing in database search results are not considered in the assessment given the inland location of the site. All habitat information in this table is taken from NSW OEH and Commonwealth DotE Threatened Species profiles (OEH 2015, DotE 2015) unless otherwise stated.

The codes used in this table are: CE – Critically Endangered; E – Endangered; V – Vulnerable; EP – Endangered Population; C - CAMBA, J-JAMBA-R-ROKAMBA ;CEEC – Critically Endangered Ecological Community; EEC – Endangered Ecological Community; VEEC -Vulnerable Endangered Ecological Community M - Migratory.

A description of likelihood of occurrence classes is used in tables below

Likelihood of occurence	Definition
Present	Biota confirmed as present within the study area either from previous records or field survey results.
Likely	Species previously recorded within the locality and/or; suitable habitat occurs within the study area. These species are likely to occur in the study area and the airport may result in direct or indirect impacts on these species, including through the removal of habitat resources that may be relied upon by local populations of these species.
Possible	Species known or predicted to occur within the locality and potentially suitable habitat occurs within the study area. These species may occur in the study area on a transitory, seasonal or opportunistic basis. The project may result in direct or indirect impacts on these species, but would not remove any habitat resources that are relied upon by local populations of these species for their ongoing survival in the locality.
Unlikely	Species not previously recorded within the locality; study area is outside of the biota's known distribution and/or; suitable habitat not present within the study area. The project would not result in any direct or indirect impacts on these species or their habitats.

Appendix Table 1 Threatened flora recorded within 10km of the study area

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact
Acacia bynoeana	Bynoe's Wattle	E	V	Endemic to central eastern NSW, currently known from only 34 locations, many of only 1-5 plants. Grows mainly in heath/ dry sclerophyll forest on sandy soils, prefers open, sometimes slightly disturbed sites such as trail margins, road edges, and in recently burnt open patches. Flowers September to March, and fruit matures in November.	Species or species' habitat likely to occur within 10km (DotE 2015a)	No sandy soils present at the site.	Unlikely	Low
Acacia pubescens	Downy Wattle	V	V	Occurs mainly in Bankstown-Fairfield-Rookwood and Pitt Town areas, with outliers at Barden Ridge, Oakdale and Mountain Lagoon. Grows on alluviums, shales and shale/sandstone intergrades. Soils characteristically gravely, often with ironstone. Occurs in open woodland and forest, in communities including Cooks River/ Castlereagh Ironbark Forest, Shale/ Gravel Transition Forest and Cumberland Plain Woodland. Flowers August to October.	16 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Potential habitat present in shale woodlands and Shale-Gravel Transition Forest.	Possible	Moderate risk of removal of potential habitat.
Allocasuarina glareicola		E	E	Primarily restricted to small populations in and around Castlereagh NR (NW Cumberland Plain), but with an outlier population at Voyager Point, Liverpool. Also reported from Holsworthy Military Area. Grows on tertiary alluvial gravels, with yellow clayey subsoil and lateritic soil. Occurs in Castlereagh open woodland.	Species or species' habitat likely to occur within 10km (DotE 2015a)	No tertiary alluvial gravels or Castlereagh woodland at the site.	Unlikely	Low
Asterolasia elegans		E	E	Occurs north of Sydney, in the Baulkham Hills, Hawkesbury and Hornsby LGAs, may also occur in the western part of Gosford LGA. 7 known populations. Occurs on Hawkesbury sandstone, commonly amongst rocky outcrops and boulders in sheltered forests on mid- to lower slopes and valleys.	Species or species' habitat may occur within 10km (DotE 2015a)	No sandstone habitat present. Outside of species' known range.	Nil	Nil

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact
Cryptostylis hunteriana	Leafless Tongue-orchid	V	V	Occurs in coastal areas from East Gippsland to southern Queensland. Habitat preferences not well defined. Grows mostly in coastal heathlands, margins of coastal swamps and sedgelands, coastal forest, dry woodland, and lowland forest. Prefers open areas in the understorey and is often found in association with Cryptostylis subulata and the Cryptostylis erecta. Soils include moist sands, moist to dry clay loam and occasionally in accumulated eucalypt leaves. Flowers November-February.	Species or species' habitat may occur within 10km (DotE 2015a)	Marginal habitat present. Not previously recorded in the locality.	Unlikely	Nil
Cynanchum elegans	White-flowered Wax Plant	E	E	Occurs from Gerroa (Illawarra) to Brunswick Heads and west to Merriwa in the upper Hunter. Most common near Kempsey. Usually occurs on the edge of dry rainforest or littoral rainforest, but also occurs in Coastal Banksia Scrub, open forest and woodland, and Melaleuca scrub. Soil and geology types are not limiting.	5 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Potential habitat present in forest and woodland.	Possible	Moderate risk of removal of potential habitat.
Dillwynia tenuifolia	*Dillwynia tenuifolia,* Kemps Creek	EP		Bounded by Western Road, Elizabeth Drive, Devonshire Road and Cross Street, Kemps Creek in the Liverpool Local Government Area.This population occurs on a small outlier of the Berkshire Park Soil Landscape; the site supports a transition from Castlereagh	26 records within 10km (OEH 2015a)	The Kemps Creek endangered population is located around three kilometres to the east of the airport site (OEH, 2015b). Any *Dillwynia tenuifolia* individuals or habitat at the airport site would not be part of this endangered population.	Nil	Nil

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact
Dillwynia tenuifolia		V		Occurs in western Sydney, predominately the Cumberland Plain as well as the Lower Blue Mountains and north to Yengo. Grows in scrubby/dry heath areas of Castlereagh Ironbark Forest and Shale Gravel Transition Forest on tertiary alluvium or laterised clays, and associated transitional communities including Castlereagh Scribbly Gum Woodland.	41 records within 10km (OEH 2015a)	Potential habitat present in Shale-Gravel Transition Forest.	Possible	Moderate risk of removal of potential habitat.
Eucalyptus benthamii	Camden White Gum	V	V	Occurs on the alluvial flats of the Nepean River and its tributaries. Known distribution from The Oaks (south) to Grose Wold (north) and Kedumba Valley (west). 2 major subpopulations: in Kedumba Valley and Bents Basin State Recreation Area. Occurs in wet open forest on alluvial flats, in well drained alluvial sands and gravels to 1 m deep.	24 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Broadly suitable habitat present but not recorded despite targetted survey for this large, conspicuous species.	Unlikely	Minor risk of removal of potential habitat.
Eucalyptus scoparia	Wallangarra White Gum	E	V	Occurs mostly in Queensland with only three known occurrences in NSW near Tenterfield. In NSW it is found on well-drained granitic hilltops, slopes and outcrops, often as scattered trees in open forest and woodland.	1 record within 10km (OEH 2015a)	No suitable habitat. Outside of species' known distribution.	Nil	Nil
Genoplesium baueri	Yellow Gnat-orchid	E	E	Occurs from Ulladulla to Port Stephens, with only 13 known extant populations. Grows in sparse sclerophyll forest and moss gardens over sandstone	Species or species' habitat may occur within 10km (DotE 2015a)	No suitable sandstone habitat.	Unlikely	Nil
Grevillea juniperina subsp. juniperina	Juniper-leaved Grevillea	V		Occurs only within western Sydney in an area bounded by Blacktown, Erskine Park, Londonderry and Windsor. Outlier populations also at Kemps Creek and Pitt Town. Grows on reddish clay to sandy soils derived from Wianamatta Shale and Tertiary alluvium, typically containing lateritic gravels. Occurs in association with Cumberland Plain Woodland, Castlereagh Ironbark Woodland, Castlereagh Scribbly Gum Woodland and Shale-Gravel Transition Forests.	87 records within 10km (OEH 2015a)	Potential habitat present in shale woodlands and Shale-Gravel Transition Forest.	Possible	Moderate risk of removal of potential habitat.

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	V	V	Occurs between Moss Vale/Bargo and lower Hunter Valley, with most occurrences in Appin, Wedderburn, Picton and Bargo. Broad habitat range including heath, shrubby woodland and open forest on light clay or sandy soils, and often in disturbed areas such as on the fringes of tracks.	11 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	Potential habitat present in Shale-Gravel Transition Forest.	Possible	Moderate risk of removal of potential habitat.
Haloragis exalata subsp. exalata	Wingless Raspwort	V	V	Occurs in 4 widely scattered localities in eastern NSW, in the central coast, south coast and north-western slopes. Requires protected and shaded damp situations in riparian habitats.	Species or species' habitat may occur within 10km (DotE 2015a)	Marginal habitat. Outside of species' known distribution.	Nil	Nil
Hypsela sessiliflora syn. Isotoma sessiliflora		E	X	Currently known from a single location less than 10x15m on the Cumberland Plain in western Sydney. Known to grow in damp places, on the Cumberland Plain, including freshwater wetland, grassland/alluvial woodland and an alluvial woodland/shale plains woodland (Cumberland Plain Woodland) ecotone. May be an early successional species that benefits from some disturbance. Possibly out competed when overgrown by some species such as *Cynodon dactylon*.	7 records within 10km (OEH 2015a)	Potential habitat present in wetlands and adjoining moist grassland.	Unlikely	Low. Outside of the species known, limited distribution. Considered extinct under the EPBC Act and may not be a valid taxon (Leonard, G. pers. comm.).

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact
Marsdenia viridiflora subsp. viridiflora	Marsdenia viridiflora R. Br. subsp. viridiflora population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas	EP		Recent records are from Prospect, Bankstown, Smithfield, Cabramatta Creek and St Marys. Previously known north from Razorback Range. A climber that grows in vine thickets and open shale woodland.	22 records within 10km (OEH 2015a)	Occupied habitat present in shale woodlands and Shale-Gravel Transition Forest.	Present	Removal of around 93 stems and of occupied habitat.
Melaleuca deanei	Deane's Melaleuca	V	V	Occurs from Nowra- St Albans and west to the Blue Mountains, with most records in Ku-ring-gai / Berowra and Holsworthy/Wedderburn areas. Mostly grows on broad flat ridgetops, dry ridges and slopes and strongly associated with low nutrient sandy loam soils, sometimes with ironstone. Grows in heath- open forest, often in sandstone ridgetop woodland communities.	Species or species' habitat may occur within 10km (DotE 2015a)	No suitable sandy soils.	Unlikely	Nil
Pelargonium sp. Striatellum	Omeo Stork's-bill	E	E	Omeo Storksbill Pelargonium sp. (G.W. Carr 10345), syn. P. striatellum, is a tufted perennial forb known from only 3 locations in NSW, with two on lake-beds on the basalt plains of the Monaro and one at Lake Bathurst. It has a narrow habitat that is usually just above the high-water level of irregularly inundated or ephemeral lakes, in the transition zone between surrounding grasslands or pasture and the wetland or aquatic communities.	Species or species' habitat likely to occur within 10km (DotE 2015a)	No suitable habitat. Outside of species' known distribution.	Nil	Nil
Persoonia acerosa	Needle Geebung	V	V	Recorded on central coast and in Blue Mountains, from Mt Tomah to Hill Top (though now believed extinct in Hill Top). Mainly in Katoomba, Wentworth Falls and Springwood areas. Inhabits dry sclerophyll forest, scrubby low woodland and heath on sandstone. Occurs in well-drained soils including sands, laterite and gravels between 550- 1000m asl. May occur in disturbed areas eg roadsides.	Species or species' habitat likely to occur within 10km (DotE 2015a)	No suitable habitat. Outside of species' known distribution.	Nil	Nil

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact
Persoonia nutans	Nodding Geebung	E	E	Occurs from Richmond to Macquarie Fields on the Cumberland Plain. Grows only on aeolian and alluvial sediments in sclerophyll forest and woodland vegetation communities. Largest populations occur in Agnes Banks Woodland or Castlereagh Scribbly Gum Woodland.	8 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Marginal habitat present in Shale-gravel Transition Forest.	Unlikely	Low
Pimelea curviflora var. curviflora		V	V	Confined to area between north Sydney in the south and Maroota in the north-west. Former range extended to Parramatta River including Five Dock, Bellevue Hill and Manly. Grows on shaley/lateritic soils over sandstone and shale/sandstone transition soils on ridgetops and upper slopes amongst woodlands. Often grows amongst dense grasses and sedges. Flowers October to May.	Species or species' habitat may occur within 10km (DotE 2015a)	No sandstone-transition habitat present. No records in the locality.	Unlikely	Low
Pimelea spicata	Spiked Rice-flower	E	E	Disjunct populations within the Cumberland Plain (from Mount Annan and Narellan Vale to Freemans Reach and Penrith to Georges Hall) and Illawarra (from Mt Warrigal to Gerroa) (DEC 2005). In the Cumberland Plain region, restricted to areas which support or historically supported Cumberland Plain Woodland. Grows on well-structured clay soils derived from Wianamatta Shale. In the Illawarra, grows on variable soils in close proximity to the coast on hills or coastal headlands. Inhabits coastal woodland or grassland with emergent shrubs (DEC 2005).	8 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	Potential habitat present in shale woodland and forest.	Possible	Moderate risk of removal of potential habitat.
Pomaderris brunnea	Rufous Pomaderris	V	V	Mainly occurs in SW Sydney (Wollondilly and Camden LGAs), with other populations in the Hawkesbury-Wollemi region, near Walcha in the New England tablelands and Gippsland in VIC. In NSW, grows in moist woodland or open forest on clay and alluvial soils on flood plains and creek lines. Near Sydney occurs in open woodland dominated by E. amplifolia with Allocasuarina sp. and Bursaria sp. understorey, or on alluvial flats with eucalypts including E. elata, E. piperita and E. punctata (Sutter 2011).	Species or species' habitat likely to occur within 10km (DotE 2015a)	Potential habitat present in alluvial woodland and forest. Outside of species' known distribution.	Unlikely	Moderate risk of removal of potential habitat.

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact
Pterostylis gibbosa	Illawarra Greenhood	E	E	Known from a small number of populations in the Illawarra, Nowra and Hunter regions. First collected in western Sydney. Only visible above the ground between late summer and spring, and only when soil moisture levels can sustain its growth. Grows in open forest or woodland, on flat or gently sloping land with poor drainage. In the Illawarra region, the species grows in woodland dominated by Eucalyptus tereticornis, E. longifolia and Melaleuca decora. Near Nowra, the species grows in an open forest of Corymbia maculata, E.tereticornis and E. paniculata. In the Hunter region, the species grows in open woodland dominated by E. crebra, E.tereticornis and Callitris endlicheri.	Species or species' habitat may occur within 10km (DotE 2015a)	Marginal habitat present. Not previously recorded in the locality.	Unlikely	Low
Pterostylis saxicola	Sydney Plains Greenhood	E	E	Occurs in western Sydney between Picton and Freemans Reach. Grows in small pockets of shallow soil in depressions on sandstone rock shelves above cliff lines. Associated vegetation above these rock shelves is sclerophyll forest or woodland on shale or shale/sandstone transition soils.	Species or species' habitat likely to occur within 10km (DotE 2015a)	Marginal habitat present. Not previously recorded in the locality.	Unlikely	Low
Pultenaea glabra	Smooth Bush-pea	V	V	In NSW restricted to higher Blue Mountains in the Katoomba-Hazelbrook and Mt Victoria areas. Unconfirmed sightings in Mt Wilson and Mt Irvine areas. Grows in swamp margins, hillslopes, gullies and creekbanks and occurs within dry sclerophyll forest and tall damp heath on sandstone.	Species or species' habitat likely to occur within 10km (DotE 2015a)	No sandstone habitat present. Outside of species' known range.	Nil	Nil
Pultenaea parviflora		E	V	Occurs on the Cumberland Plain, with core distribution from Windsor to Penrith and east to Dean Park, and outliers in Kemps Creek and Wilberforce. Grows in dry sclerophyll woodlands, forest or in grasslands on Wianamatta Shale, laterite or Tertiary alluvium, on infertile sandy to clay soils. Associated communities include Castlereagh Ironbark Forest, Shale Gravel transition Forest and intergrade with Castlereagh Scribbly Gum Woodland.	89 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Occupied habitat present in shale woodland.	Present	Removal of four individuals and of occupied habitat.

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact
Streblus pendulinus	Siah's Backbone		E	Siah's Backbone occurs from Cape York Peninsula to Milton, south-east New South Wales (NSW), as well as Norfolk Island (ATRP 2010; Jessup 2003; The Royal Botanic Gardens and Domain Trust 2011). Siah's Backbone is found in warmer rainforests, chiefly along watercourses. The species grows in well developed rainforest, gallery forest and drier, more seasonal rainforest (ATRP 2010).	Species or species' habitat known to occur within 10km (DotE 2015a)	Marginal habitat in sheltered pockets of shale woodland. No moist woodland or dry rainforest.	Unlikely	Low.
Thelymitra kangaloonica	Kangaloon Sun Orchid	CE	CE	Only known from three locations near Robertson in the Southern Highlands. Grows in seasonally swampy sedgeland on grey silty clay loam at 600–700 m above sea level. Flowers in late October and early November.	Species or species' habitat may occur within 10km (DotE 2015a)	No suitable habitat. Outside of species' known distribution.	Nil	Nil
Thesium australe	Austral Toadflax	V	V	Found in small, scattered populations along the east coast, northern and southern tablelands. Occurs in grassland or grassy woodland, and is often found in association with Kangaroo Grass (*Themeda australis*).	Species or species' habitat may occur within 10km (DotE 2015a)	Potential habitat presentin woodland and derived grassland.	Possible	Moderate risk of removal of potential habitat.

Appendix Table 2 Threatened fauna recorded within 10km of the study area

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Frogs										
Heleioporus australiacus	Giant Burrowing Frog	V	V	Occurs along the coast and eastern slopes of the Great Dividing Range south from Wollemi National Park. Appears to exist as 2 populations with a 100km gap in records between Jervis Bay and Eden. Northern population occurs on sandy soils supporting heath, woodland or open forest. Has a strong geological association with Hawkesbury Sandstone and occupies upper topographic areas with ephemeral watercourses of gentle gradients. Breeds in ephemeral to intermittent streams with persistent pools. Only infrequently moves to breeding sites, most commonly found on ridges away from creeks, several hundred metres from water.	4 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	No sandstone habitat present.	Nil.	Nil.	Known to occur in the GBMWHA (OEH 2015b).	Low
Litoria aurea	Green and Golden Bell Frog	E	V	Formerly occurred from Brunswick Heads to Victoria, but >80% populations now extinct. Inhabits marshes, natural and artificial freshwater to brackish wetlands, dams and in stream wetlands. Prefers sites containing Cumbungi (*Typha spp*.) or spike rushes (*Eleocharis spp*.), which are unshaded and have a grassy area and/or rubble as shelter/refuge habitat nearby. Gambusia holbrooki is a key threat as they feed on green and Golden Bell Frog eggs and tadpoles.	1 record within 10km (OEH 2015a); Species or species' habitat may occur within 10km (DotE 2015a)	Numerous dams with emergent vegetation present. Mosquitofish common.	Unlikely. Appropriate habitat present, however no individuals recorded despite targeted surveys during March 2015 and October 1998. No previous records at the airport site.	Low.	Unlikely. Suitable habitat not likely to be present.	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Litoria littlejohni	Littlejohn's Tree Frog	V	V	Occurs on plateaus and eastern slopes of the Great Dividing Range south from Watagan State Forest. Occurs along permanent rocky streams with thick fringing vegetation associated with eucalypt woodlands and heaths among sandstone outcrops, hunting either in shrubs or on the ground.	Species or species' habitat may occur within 10km (DotE 2015a)	No appropriate rocky stream habitat present.	Nil.	Nil.	Known to occur in the GBMWHA (OEH 2015b).	Low
Pseudophryne australis	Red-crowned Toadlet	V		Restricted to Sydney Basin, from Nowra to Pokolbin and west to Mt Victoria. Inhabits heathland and open woodland on Hawkesbury and Narrabeen Sandstones, within 100m of ridgelines. Breeds in ephemeral feeder creeks or flooded depressions, requiring unpolluted water between 5.5 and 6.5 pH. Shelters under rocks, amongst masses of dense vegetation or leaf litter. Populations restricted to immediate vicinity of breeding areas.	2 records within 10km (OEH 2015a)	No sandstone habitat present.	Nil.	Nil.	Known to occur in the GBMWHA (OEH 2015b).	Low.
Birds										
Anthochaera phrygia	Regent Honeyeater	CE	E	In NSW confined to two known breeding areas: the Capertee Valley and Bundarra-Barraba region. Non-breeding flocks occasionally seen in coastal areas foraging in flowering Spotted Gum and Swamp Mahogany forests, presumably in response to drought. Inhabits dry open forest and woodlands, particularly Box-Ironbark woodland and riparian forests of River Sheoak, with an abundance of mature trees, high canopy cover and abundance of mistletoes.	3 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	No Spotted Gum or Swamp Mahogany forest present.	Unlikely. No suitable foraging habitat present. Not known to breed in the area.	Low.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Botaurus poiciloptilus	Australasian Bittern	E	E	Widespread but uncommon over most NSW except the northwest. Favours permanent freshwater wetlands with tall dense reedbeds particularly Typha spp. and Eleocharis spp., with adjacent shallow, open water for foraging. Roosts during the day amongst dense reeds or rushes and feeds mainly at night on frogs, fish, yabbies, spiders, insects and snails.	Species or species' habitat known to occur within 10km (DotE 2015a)	Farm dams and creeks with emergent vegetation present.	Possible. May occur at farm dams and creeks. No local records. Not recorded during surveys.	Low.	May occur in the GBMWHA. No records in the area to the west of the airport site (OEH 2015b).	Low
Burhinus grallarius	Bush Stone-curlew	E		Scattered distribution across NSW. Inhabits lowland grassy woodland and open forest and, in coastal areas, Casuarina and Melaleuca woodlands, saltmarsh and mangroves. Requires a low, sparse groundcover, some fallen timber and leaf litter, and a general lack of a shrubby understory (DEC 2006b).	2 records within 10km (OEH 2015a)	Small patches of grassy woodland present. Some fallen timber. Mainly grazed.	Unlikely. Limited suitable habitat present.	Low.	Not known or predicted to occur in the GMBWHA (OEH 2015b)	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Callocephalon fimbriatum	Gang-gang Cockatoo	V		Restricted to the south-eastern coast and highlands, from the lower Hunter and northern Blue Mountains to the Southwestern Slopes, south to and contiguous with the Victorian population. Inhabits eucalypt open forests and woodlands with an acacia understorey. In summer it lives in moist highland forest types, and in winter it moves to more open types at lower elevations. The Gang-Gang Cockatoo nests in hollows in the trunks, limbs or dead spouts of tall living trees, especially eucalypts, often near water. The Gang-gang Cockatoo feeds on seeds obtained in trees and shrubs, mostly from eucalypts and wattles.	7 records within 10km (OEH 2015a)	Open woodland, including riparian woodland present.	Possible. May occur during winter months. Unlikely to breed in the airport site.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low
Calyptorhynchus lathami	Glossy Black-Cockatoo	V		Widespread but uncommon from coast to southern tablelands and central western plains. Feeds almost exclusively on the seeds of Allocasuarina species. Prefers woodland and open forests, rarely away from Allocasuarina. Roost in leafy canopy trees, preferably eucalypts, usually <1km from feeding site. Nests in large (approx. 20cm) hollows in trees, stumps or limbs, usually in Eucalypts (Higgins 1999).	18 records within 10km (OEH 2015a)	Small patches of woodland with Allocasuarina species present. Some hollows-bearing trees along present.	Possible. No large expanses of Allocasuarina-dominated woodland present. May forage on occasion in the airport site.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Chthonicola sagittata	Speckled Warbler	V		Within NSW most frequently reported from the hills and tablelands of the Great Dividing Range, rarely from the coast. Inhabits a wide range of Eucalyptus-dominated communities with a grassy understorey, a sparse shrub layer, often on rocky ridges or in gullies. Sedentary and requires large, relatively undisturbed remnants to persist in an area. Forages on the ground for seeds and insects, and nests in a slight hollow in the ground or at the base of a low dense plant.	16 records within 10km (OEH 2015a)	Grassy and shrubby woodland patches present. Few large, undisturbed patches present.	Possible. Some suitable potential habitat present, however may not be of appropriate patch size. No individuals recorded during surveys.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low
Daphoenositta chrysoptera	Varied Sittella	V		Sedentary, occurs across NSW from the coast to the far west. Inhabits eucalypt forests and woodlands, especially rough-barked species and mature smooth-barked gums with dead branches, mallee and Acacia woodland. Sensitive to habitat isolation and loss of structural complexity, and adversely affected by dominance of Noisy Miners. Cleared agricultural land is potentially a barrier to movement. Builds a cup-shaped nest of plant fibres and cobwebs in an upright tree fork high in the living tree canopy, and often re-uses the same fork or tree in successive years.	36 records within 10km (OEH 2015a)	Eucalypt woodland present.	Present. A small group recorded foraging in Badgerys Creek riparian corridor. May breed at the airport site.	Definite. Proposal would remove known habitat.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Dasyornis brachypterus	Eastern Bristlebird	E	E	Occurs in three disjunct areas of south-eastern Australia: southern Queensland/northern NSW, the Illawarra Region and in the vicinity of the NSW/Victorian border. Illawarra population comprises an estimated 1600 birds, mainly from Barren Grounds Nature Reserve, Budderoo National Park and the Jervis Bay area. Habitat characterised by dense, low vegetation including heath and open woodland with a heathy understorey. The fire history of habitat is important, and the Illawarra and southern populations reach maximum densities in habitat that have not been burnt for over 15 years.	Species or species' habitat may occur within 10km (DotE 2015a)	No heathy habitat present.	Nil.	Nil.	Not known or predicted to occur in the GMBWHA (OEH 2015b)	Nil.
Ephippiorhynchus asiaticus	Black-necked Stork	E		In NSW, becomes increasingly uncommon south of the Northern Rivers region, and rarely occurs south of Sydney. Breeding recorded as far south as Buladelah, though most breeding in NSW occurs in the north-east. Primarily inhabits permanent freshwater wetlands and surrounding vegetation including swamps, floodplains, watercourses and billabongs, freshwater meadows, wet heathland, farm dams and shallow floodwaters. Will also forage in inter-tidal shorelines, mangrove margins and estuaries. Feeds in shallow, still water. Breeds during summer, nesting in or near a freshwater swamp.	1 record within 10km, last recorded 1994 (OEH 2015a)	Farm dams present.	Unlikely. Outside usual range.	Low.	Known to occur in the northern portion of the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Glossopsitta pusilla	Little Lorikeet	V		Occurs from coast to western slopes of the Great Dividing Range. Inhabits dry, open eucalypt forests and woodlands. Occurrence is positively associated with patch size, and with components of habitat complexity including canopy cover, shrub cover, ground cover, logs, fallen branches and litter. Feed primarily on profusely-flowering eucalypts and a variety of other species including melaleucas and mistletoes. Mostly nests in small (opening approx. 3cm) hollows in living, smooth-barked eucalypts. Most breeding records are from the western slopes.	3 records within 10km (OEH 2015a)	Eucalypt woodland with areas of shrubs and logs present. Few large patches.	Present. Some suitable potential habitat present, however may not be of appropriate patch size. Few local records.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low
Hieraaetus morphnoides	Little Eagle	V		Occurs throughout NSW except most densely forested parts of the Dividing Range escarpment. Occupies habitats rich in prey within open eucalypt forest, woodland or open woodland. Also occurs in open country. For nest sites it requires a tall living tree within a remnant patch, where pairs build a large stick nest in winter and lay in early spring.	6 records within 10km (OEH 2015a)	Woodland and open country present. Abundance of prey (rabbits etc).	Present. Individuals observed across most of the airport site. Likely to part of the home range for a breeding pair.	Definite. Proposal would remove known habitat.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Ixobrychus flavicollis	Black Bittern	V		Occurs from southern NSW to Cape York and the Kimberley, and southwest WA. Inhabits terrestrial and estuarine wetlands, generally in areas of permanent water and dense vegetation. May occur in flooded grassland, forest, woodland, rainforest and mangroves as long as there is permanent water. Roosts by day in trees or within reeds on the ground. Nests in branches overhanging water and breeds from December to March.	1 record within 10km (OEH 2015a)	Vegetated creeks and dams with emergent vegetation present.	Present. Observed at the northern end of Badgerys Creek.	Definite. Proposal would remove known habitat.	Known to occur in the GBMWHA (OEH 2015b).	Low
Lathamus discolor	Swift Parrot	E	E	Migratory, travelling to the mainland from March to October. Breeds in Tasmania from September to January. On the mainland, it mostly occurs in the southeast foraging on winter flowering eucalypts and lerps, with records of the species between Adelaide and Brisbane. Principal over-winter habitat is box-ironbark communities on the inland slopes and plains. Eucalyptus robusta, Corymbia maculata, C. gummifera and E. tereticornisdominated coastal forests are also important habitat.	8 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Eucalyptus tereticornis dominates much of the native vegetation in the study area.	Likely. May forage on occasion in the airport site.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Limosa limosa	Black-tailed Godwit	V	C,J,K	The Black-tailed Godwit is a migratory wading bird that breeds in Mongolia and Eastern Siberia and flies to Australia for the southern summer, arriving in August and leaving in March. In NSW, it is most frequently recorded at Kooragang Island (Hunter River estuary), with occasional records elsewhere along the north and south coast, and inland. Records in western NSW indicate that a regular inland passage is used by the species, as it may occur around any of the large lakes in the western areas during summer, when the muddy shores are exposed. It is usually found in sheltered bays, estuaries and lagoons with large intertidal mudflats and/or sandflats. It has also been found around muddy lakes and swamps, wet fields and sewerage treatment works.	1 record within 10km, last recorded 1982 (OEH 2015a)	No preferred habitat present. May occur at farm dams on occasion.	Unlikely. Limited suitable habitat present.	Low.	Not known or predicted to occur in the GMBWHA (OEH 2015b)	Nil.

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Lophoictinia isura	Square-tailed Kite	V		Occurs across NSW, resident in North, northeast and along west-flowing rivers. Summer breeding migrant to southeast of state. Inhabits a variety of habitats including woodlands and open forests, with preference for timbered watercourses. Favours productive forests on the coastal plain, box-ironbark-gum woodlands on the inland slopes, and Coolibah/River Red Gum on the inland plains. In Sydney area nests in mature living trees within 100m of ephemeral/permanent watercourse. Large home range > 100 km2.	3 records within 10km (OEH 2015a)	Woodland and timbered water courses present.	Possible. Suitable potential habitat present.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low
Melanodryas cucullata cucullata	Hooded Robin (south-eastern form)	V		Considered a sedentary species, but local seasonal movements are possible. Prefers lightly wooded country, usually open eucalypt woodland, acacia scrub and mallee, often in or near clearings or open areas. Occurrence is positively associated with patch size, and with components of habitat complexity including canopy cover, shrub cover, ground cover, logs, fallen branches and litter. Nests on low, live or dead forks or branches of trees or stumps, or occasionally on fallen trees or limbs.	3 records within 10km (OEH 2015a)	Lighly wooded and open areas present. Few large patches present.	Possible. Some suitable potential habitat present, however may not be of appropriate patch size. Few local records. Not recorded during surveys.	Low.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	V		Widespread in NSW, but rarely recorded east of Great Dividing Range except in Richmond and Clarence River areas and scattered sites in the Hunter, Central Coast and Illawarra regions. Mostly in upper levels of drier open forests /woodlands dominated by box and ironbark eucalypts, or less commonly smooth-barked gums, stringybarks and tea-treas. Forage over home range of >5 hectares. Tend to occur within largest woodland patches in the landscape. They forage for insects, nectar and honeydew. The nest is hidden by foliage high in the crown of a tree.	1 record within 10km (OEH 2015a)	Dry open woodland, including woodland dominated by Grey Box present. Few large patches present.	Possible. May occur on occasion in larger patches in the airport site. Not recorded during surveys.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low
Ninox connivens	Barking Owl	V		Occurs from coast to inland slopes and plains, though is rare in dense, wet forests east of the Great Dividing Range and sparse in higher parts of the tablelands and in the arid zone. Inhabits eucalypt woodlands, open forest, swamp woodlands, and, especially in inland areas, timber along watercourses. Roosts along creek lines in dense, tall understorey foliage (e.g. in Acacia and Casuarina), or dense eucalypt canopy. Nests in hollows of large, old eucalypts including *Eucalyptus camaldulensis*, *Eucalyptus albens*, *Eucalyptus polyanthemos* and *Eucalyptus blakelyi*. Birds and mammals important prey during breeding. Territories range from 30 to 200 hectares.	1 record within 10km (OEH 2015a)	Eucalypt woodland present.	Possible. May forage and breed in the airport site. Few local records. Not recorded during surveys.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Ninox strenua	Powerful Owl	V		Occurs from the coast to the western slopes. Solitary and sedentary species. Inhabits a range of habitats from woodland and open sclerophyll forest to tall open wet forest and rainforest. Prefers large tracts of vegetation. Nests in large tree hollows (> 0.5 m deep), in large eucalypts (dbh 80-240 cm) that are at least 150 years old. Pairs have high fidelity to a small number of hollow-bearing nest trees and defend a large home range of 400 - 1,450 hectares. Forages within open and closed woodlands as well as open areas.	17 records within 10km (OEH 2015a)	Woodland and open country present.	Likely. Suitable foraging and breeding habitat present. Not recorded during surveys.	High.	Known to occur in the GBMWHA (OEH 2015b).	Low
Oxyura australis	Blue-billed Duck	V	-	Partly migratory, travels short distances between breeding swamps and over-wintering lakes. Young birds disperse in April-May from breeding swamps in inland NSW to Murray River system and coastal lakes. Prefers deep water in large permanent wetlands and swamps with dense aquatic vegetation. Nests in Cumbungi over deep water or in trampled Lignum, sedges or spike-rushes. Completely aquatic, swimming along the edge of dense cover.		Freshwater wetland habitat present.	Present. Recorded in a wetland at the site.	Definite. Proposal would remove known habitat.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Petroica boodang	Scarlet Robin	V		In NSW occurs from coast to inland slopes. Breeds in drier eucalypt forests and temperate woodlands, often on ridges and slopes, within open understorey of shrubs and grasses and sometimes in open areas. In autumn and winter it migrates to more open habitats such as grassy open woodland or paddocks with scattered trees. Abundant logs and coarse woody debris are important habitat components.	3 records within 10km (OEH 2015a)	Woodland with woody debris present.	Present. Recorded in woodland alongside Badgerys Creek. Likely to be a non-breeding winter migrant to the airport site.	Definite. Proposal would remove known habitat.	Known to occur in the GBMWHA (OEH 2015b).	Low
Petroica phoenicea	Flame Robin	V		Breeds in upland moist eucalypt forests and woodlands, often on ridges and slopes, in areas of open understorey. Migrates in winter to more open lowland habitats such as grassland with scattered trees and open woodland on the inland slopes and plains. Forages from low perches, feeding on invertebrates taken from the ground, tree trunks, logs and other coarse woody debris. Fallen logs and coarse woody debris are important habitat components. Open cup nest of plant fibres and cobweb is often built near the ground in a sheltered niche, ledge or shallow cavity in a tree, stump or bank.	4 records within 10km (OEH 2015a)	Woodland with woody debris present.	Likely. Areas of suitable habitat present. Likely to be a non-breeding winter migrant to the airport site.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Rostratula australis	Australian Painted Snipe	E	E	Normally found in permanent or ephemeral shallow inland wetlands, either freshwater or brackish. Nests on the ground amongst tall reed-like vegetation near water. Feeds on mudflats and the water's edge taking insects, worm and seeds. Prefers fringes of swamps, dams and nearby marshy areas with cover of grasses, lignum, low scrub or open timber.	Species or species' habitat likely to occur within 10km (DotE 2015a)	Farm dams with tall reeds present.	Possible. May occur at farm dams. No local records. Not recorded during surveys.	Moderate.	Not known or predicted to occur in the GMBWHA (OEH 2015b)	Low
Stagonopleura guttata	Diamond Firetail	V		Typically found west of the Great Dividing Range, but populations also occur in drier coastal areas including W Sydney, Hunter, Clarence and Snowy River valleys. Occurs in grassy eucalypt woodlands including Box Gum and Snow Gum communities, as well as open forest, mallee and natural and derived grasslands. Often found in riparian areas and occasionally in lightly wooded farmland. Nests in shrubby understorey or higher up under nests of other species.	4 records within 10km (OEH 2015a)	Patches of grassy woodland present, as well as riparian areas and lightly wooded farmland.	Likely. Areas of suitable habitat present.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low
Stictonetta naevosa	Freckled Duck	V		Breeds in large, ephemeral swamps in the Murray-Darling, particularly along the Paroo and Lachlan Rivers and other Riverina rivers. In drier times moves to more permanent waters. Disperses during extensive inland droughts and may be found in coastal areas during such times. Prefers freshwater swamps/creeks with dense Cumbungi, Lignum or tea-tree. Nests in dense vegetation at or near water level.	1 record within 10km (OEH 2015a)	Farm dams and creeks with emergent vegetation present.	Possible. May occur on occasion during drought.	Low.	Not known or predicted to occur in the GMBWHA (OEH 2015b)	Nil.

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Tyto novaehollandiae	Masked Owl	V		Inhabits dry eucalypt woodlands from sea level to 1100 m. Roosts and breeds in large (>40cm) hollows and sometime caves in moist eucalypt forested gullies. Hunts along the edges of forests and roadsides. Home range between 500 hectares and 1000 hectares. Prey mostly terrestrial mammals but arboreal species may also be taken.	9 records within 10km (OEH 2015a)	Woodland and open country present.	Likely. Suitable foraging and breeding habitat present. Not recorded during surveys.	High.	Known to occur in the GBMWHA (OEH 2015b).	Low
Fish										
Prototroctes maraena	Australian Grayling		V	Occurs in coastal rivers and streams south from the Shoalhaven River. Inhabits estuarine waters and coastal seas as larvae/juveniles, and freshwater rivers and streams as adults. Most of their lives are spent in freshwater rivers and streams in cool, clear waters with a gravel substrate and alternating pool and riffle zones, however can also occur in turbid water. The species can penetrate well inland, being recorded over 100 km inland from the sea. (Backhouse et al 2008).	Species or species' habitat likely to occur within 10km (DotE 2015a)	No appropriate river habitat present.	Nil.	Nil.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Macquaria australasica	Macquarie Perch	E (FM Act)	E	Occurs in the upper reaches of the Lachlan, Murrumbidgee and Murray Rivers, and in parts of the Hawkesbury and Shoalhaven catchment areas. Inhabits river and lake habitats, especially the upper reaches of rivers and their tributaries. Requires clear water with deep, rocky holes and abundant cover (including aquatic vegetation, woody debris, large boulders and overhanging banks). Spawning occurs in spring and summer in shallow upland streams or flowing sections of river systems.	Species or species' habitat may occur within 10km (DotE 2015a)	No appropriate river habitat present.	Nil.	Nil.	Known to occur in the GBMWHA (OEH 2015b).	Low
Gastropods										
Meridolum corneovirens	Cumberland Plain Land Snail	E		Occurs within a small area of the Cumberland Plain, from Richmond and Windsor to Picton.Found primarily under litter of bark, leaves and logs, or in loose soil around grass clumps within Cumberland Plain Woodland. Has also been found under rubbish. Feeds on fungus. During periods of drought can burrow into the soil to escape the dry conditions.	237 records within 10km (OEH 2015a)	Cumberland Plain woodland present.	Present. Occurs in larger remnant patches of Cumberland Plain Woodland with deep leaf litter.	Definite. Proposal would remove known habitat.	Does not occur in the GBMWHA.	Nil.
Insects										
Archaeophya adamsi	Adam's emerald dragonfly	E (FM Act)		Known from the greater Sydney region. Only five adults have ever been collected. Larvae is found in small creeks with gravel or sandy bottoms, in narrow shaded riffle zones with moss and rich riparian vegetation..	Listed as found within the Sydney Metro CMA (DPI 2015a)	Some small creek habitat with sandy bottoms present.	Unlikely. Riffle zone habitat is limited and not present with other habitat features.	Low.	May occur in the GBMWHA.	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Austrocordulia leonardi	Sydney hawk dragonfly	E (FM Act)		Known from three locations in a small area south of Sydney, from Audley to Picton. The species is known from the Hawkesbury-Nepean, Georges River, Port Hacking and Karuah drainages. Occurs in deep and shady riverine pools with cooler water.	Listed as found within the Sydney Metro CMA (DPI 2015a)	No appropriate riverine pool present.	Nil.	Nil.	May occur in the GBMWHA.	Low
Mammals										
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	Occurs from the coast to the western slopes of the divide. Largest numbers of records from sandstone escarpment country in the Sydney Basin and Hunter Valley (Van Dyck. and Strahan 2008). Roosts in caves and mines and most commonly recorded from dry sclerophyll forests and woodlands. An insectivorous species that flies over the canopy or along creek beds (Churchill 2008). In southern Sydney appears to be largely restricted to the interface between sandstone escarpments and fertile valleys.	9 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	No sandstone habitat present.	Unlikely. No preferred habitat present. Large cleared areas present between the airport site and the Blue Mountains where preferred habitat is located. May forage on occasion in the western portion of the airport site closest to Blue Mountains National Park closer to where suitable habitat is present	Low.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Dasyurus maculatus	Spotted-tailed Quoll	V	E	Inhabits a range of environments including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline. Has a preference for mature wet forest habitats, particularly in areas of 600 mm rainfall per annum. Den sites are in hollow-bearing trees, fallen logs, small caves, rock crevices, boulder fields and rocky-cliff faces. Females occupy home ranges of up to 750 hectares and males up to 3,500 hectares, usually traversed along densely vegetated creek lines. Radio-tracking studies have shown that the species uses gullies and riparian flats for hunting and movement.	Species or species' habitat known to occur within 10km (DotE 2015a)	Patchy woodland including riparian woodland present. Large areas of agricultural land present. Limited connectivity with larger tracts of native vegetation.	Unlikely. Narrow riparian corridor and large cleared areas present. Limited connectivity. No evidence of the species from camera surveys.	Low.	Known to occur in the GBMWHA (OEH 2015b).	Low
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V		Occurs on southeast coast and ranges. Prefers tall (>20m) and wet forest with dense understorey. Absent from small remnants, preferring continuous forest but can move through cleared landscapes and may forage in open areas. Roosts in hollow trunks of Eucalypts, underneath bark or in buildings. Forages in gaps and spaces within forest, with large foraging range (12km foraging movements recorded) (Churchill 2008, Law et al 2008).	5 records within 10km (OEH 2015a)	No tall wet forest present. Few large remnants present.	Possibly recorded. Preferred foraging habitat not present. May forage on ocacsion in larger woodland patches. Could roost in the airport site.	High.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Miniopterus australis	Little Bentwing-bat	V		Occurs from Cape York to Sydney. Inhabits rainforests, wet and dry sclerophyll forests, paperbark swamps and vine thickets. Only one maternity cave known in NSW, shared with Eastern Bentwing-bats at Willi Willi, near Kempsey. Outside breeding season roosts in caves, tunnels and mines and has been recorded in a tree hollow on one occasion. Forages for insects beneath the canopy of well-timbered habitats (Churchill 2008, Van Dyck and Strahan 2008).	2 records within 10km (OEH 2015a)	No moist woodland or rainforest present. Tree hollows and empty buildings and sheds and bridges present.	Unlikely. No preferred habitat present.	Low.	Known to occur in the GBMWHA (OEH 2015b).	Low
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat	V		Generally occurs east of the Great Dividing Range along NSW coast (Churchill 2008). Inhabits various habitats from open grasslands to woodlands, wet and dry sclerophyll forests and rainforest. Essentially a cave bat but may also roost in road culverts, stormwater tunnels and other man-made structures. Only 4 known maternity caves in NSW, near Wee Jasper, Bungonia, Kempsey and Texas. Females may travel hundreds of kilometres to the nearest maternal colony (Churchill 2008).	34 records within 10km (OEH 2015a)	Woodland and open areas present. Bridges, empty buildings and sheds present.	Possibly recorded (Anabat). May forage throughout the airport site. Could roost under bridges and in buidlings.	High.	Known to occur in the GBMWHA (OEH 2015b).	Low
Mormopterus norfolkensis	Eastern Freetail-bat	V		Occurs in dry sclerophyll forest and woodland east of the Great Dividing Range. Forages in natural and artificial openings in vegetation, typically within a few kilometres of its roost. Roosts primarily in tree hollows but also recorded from man-made structures or under bark (Churchill 2008).	38 records within 10km (OEH 2015a)	Woodland present. Tree hollows and empty buildings and sheds present.	Present. Most common bat species recorded. Likely to breed at the airport site.	Definite. Proposal would remove known habitat.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Myotis macropus	Large-footed Myotis	V		Mainly coastal but may occur inland along large river systems. Usually associated with permanent waterways at low elevations in flat/undulating country, usually in vegetated areas. Forages over streams and watercourses feeding on fish and insects from the water surface. Roosts in a variety of habitats including caves, mine shafts, hollow-bearing trees, stormwater channels, buildings, under bridges and in dense foliage, typically in close proximity to water (Campbell 2011). Breeds November or December (Churchill 2008)	24 records within 10km (OEH 2015a)	Creeks and dams present. Tree hollows and empty buildings and sheds and bridges present.	Probably recorded. Would forage along creeks and above dams. May roost under bridges and in tree hollows.	High.	Known to occur in the GBMWHA (OEH 2015b).	Low
Petrogale penicillata	Brush-tailed Rock-wallaby	E	V	Occurs from the Shoalhaven north to the Queensland border. Now mostly extinct west of the Great Dividing Range, except in the Warrumbungles and Mt Kaputar. Occurs on rocky escarpments, outcrops and cliffs with a preference for complex structures with fissures, caves and ledges facing north. Diet consists of vegetation in adjacent to rocky areas eating grasses and forbs as well as the foliage and fruits of shrubs and trees.	1 record within 10km, last recorded 1994 (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	No sandstone habitat present.	Nil.	Nil.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Phascolarctos cinereus	Koala	V	V	Occurs from coast to inland slopes and plains. Restricted to areas of preferred feed trees in eucalypt woodlands and forests. Home range varies depending on habitat quality, from < 2 to several hundred hectares.	3 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	*Eucalyptus tereticornis* (primary feed tree) and *Eucalyptus mollucana* (secondary feed tree) dominate much of the native vegetation in the study area. Woodland is patchy with large cleared areas present. No direct connectivity with other local records.	Unlikely. Patchy vegetation. Local records associated with either the Blue Mountains National Park or the Western Sydney Parklands. No direct connectivity with these areas. No scats recorded.	Low.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Pseudomys novaehollandiae	New Holland Mouse		V	Occurs in disjunct, coastal populations from Tasmania to Queensland. In NSW inhabits a variety of coastal habitats including heathland, woodland, dry sclerophyll forest with a dense shrub layer and vegetated sand dunes (Wilson and Bradtke 1999). Populations may recolonise/ increase in size in regenerating native vegetation after wildfire, clearing and sandmining. Presence strongly correlated with understorey vegetation density, and high floristic diversity in regenerating heath (Lock and Wilson 1999).	Species or species' habitat likely to occur within 10km (DotE 2015a)	No heathy habitat present.	Nil.	Nil.	Known to occur in the GBMWHA (OEH 2015b).	Low
Pteropus poliocephalus	Grey-headed Flying-fox	V	V	Roosts in camps within 20 km of a regular food source, typically in gullies, close to water and in vegetation with a dense canopy. Forages in subtropical and temperate rainforests, tall sclerophyll forests and woodlands, heaths, swamps and street trees, particularly in eucalypts, melaleucas and banksias. Highly mobile with movements largely determined by food availability (Eby and Law 2008). Will also forage in urban gardens and cultivated fruit crops.	38 records within 10km (OEH 2015a); Foraging, feeding and related behaviour known to occur within 10km (DotE 2015a)	Eucalypt woodland present.	Present. Would forage throughout the airport site when trees are in flower. No roost camps present in the airport site.	High.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	V		Migrates from tropics to SE Aus in summer. Forages across a range of habitats including those with and without trees, from wet and dry sclerophyll forest, open woodland, Acacia shrubland, mallee, grasslands and desert. Roosts communally in large tree hollows and buildings (Churchill 2008).	1 record within 10km (OEH 2015a)	Woodland and open areas present. Tree hollows and empty buildings and sheds present.	Possible. Suitable foraging and roosting habitat present. Few local records.	Moderate.	Known to occur in the GBMWHA (OEH 2015b).	Low
Scoteanax rueppellii	Greater Broad-nosed Bat	V		Occurs on the east coast and Great Dividing Range. Inhabits a variety of habitats from woodland to wet and dry sclerophyll forests and rainforest, also remnant paddock trees and timber-lined creeks, typically below 500m asl. Forages in relatively uncluttered areas, using natural or man-made openings in denser habitats. Usually roosts in tree hollows or fissures but also under exfoliating bark or in the roofs of old buildings. Females congregate in maternal roosts in suitable hollow trees (Van Dyck and Strahan 2008), Churchill 2008).	15 records within 10km (OEH 2015a)	Woodland and open areas present. Tree hollows and empty buildings and sheds present.	Possibly recorded Would forage throughout the airport site. May roost in the airport site.	High.	Known to occur in the GBMWHA (OEH 2015b).	Low

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact	Likelihood of occurrence in the GBMWHA	Risk of impact
Vespadelus troughtoni	Eastern Cave Bat	V	-	Occurs in NE NSW south to Kempsey and west to the Warrumbungles. Inhabits rainforest margins, wet and dry sclerophyll forests through to drier forests and woodlands in semi-arid environments. All records are within close proximity to sandstone or volcanic escarpments. Roosts in overhangs and caves, mines, boulder piles, abandoned Fairy Martin nests and occasionally in buildings, and regularly switches between alternate roost colonies. Forages over a small area, but are capable of flying 500 m over clear paddocks (Churchill 2008, Parnaby et al 2008).	0	Woodland and forest areas present. Bridges, culverts and empty buildings and sheds present.	Possibly recorded Would forage throughout the airport site. May roost in the airport site.	High.	Known to occur in the GBMWHA (OEH 2015b).	Low
Reptiles										
Hoplocephalus bungaroides	Broad-headed Snake	E	V	Nocturnal, sheltering in rock crevices and under flat sandstone rocks on exposed cliff edges during autumn, winter, and spring, moving to shelters in hollows of large trees within 200m of escarpments in summer. Feeds mostly on geckos and small skinks, and occasionally on frogs and small mammals.	Species or species' habitat likely to occur within 10km (DotE 2015a)	No sandstone habitat present.	Nil.	Nil.	Known to occur in the GBMWHA (OEH 2015b).	Low

Appendix Table 3 Migratory species recorded within 10km of the study area

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence
Apus pacificus	Fork-tailed Swift		C,J,K	Recorded in all regions of NSW. Non- breeding, and almost exclusively aerial while in Australia. Occurs over urban and rural areas as well as areas of native vegetation.	3 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Rural area with patches of native vegetation.	Likely. May forage in the area on occasion.
Ardea alba	Great Egret		C,J	Occurs across NSW. Within NSW there are breeding colonies within the Darling Riverine Plains and Riverina regions, and minor colonies across its range including the north and north-east of the state. Reported from a wide range of wetland habitats (for example inland and coastal, freshwater and saline, permanent and ephemeral, open and vegetated, large and small, natural and artificial).	8 records within 10km (OEH 2015a); Breeding known to occur within 10km (DotE 2015a)	Variety of farm dams present.	Present. Occasional individuals recorded in the study area.
Ardea ibis	Cattle Egret		C,J	Occurs across NSW. Principal breeding sites are the central east coast from Newcastle to Bundaberg. Also breeds in major inland wetlands in north NSW (notably the Macquarie Marshes). Occurs in tropical and temperate grasslands, wooded lands and terrestrial wetlands. Uses predominately shallow, open and fresh wetlands with low emergent vegetation and abundant aquatic flora. Sometimes observed in swamps with tall emergent vegetation and commonly use areas of tall pasture in moist, low-lying areas.	31 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Variety of farm dams and grassland present.	Present. Flocks of about 40 recorded.
Gallinago hardwickii	Latham's Snipe		C,J,K	Occurs along the coast and west of the great dividing range. Non breeding visitor to Australia. Inhabit permanent and ephemeral wetlands up to 2000 m asl. Typically in open, freshwater wetlands with low, dense vegetation (incl. swamps, flooded grasslands and heathlands). Can also occur in saline/brackish habitats and in modified or artificial habitats close to human activity.	5 records within 10km (OEH 2015a); Species or species' habitat may occur within 10km (DotE 2015a)	Farm dams with low vegetation and adjacent grassland present.	Present. One individual flushed from beside a dam surrounded by grassland.
Haliaeetus leucogaster	White-bellied Sea-Eagle		C	Primarily coastal but may extend inland over major river systems. Breeds close to water, mainly in tall open forest/woodland but also in dense forest, rainforest, closed scrub or remnant trees. Usually forages over large expanses of open water, but also over open terrestrial habitats (e.g. grasslands).	12 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	Various large dams and grassland present.	Present. One or two individuals recorded in the study area.

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Source	Habitat present in the study area	Likelihood of occurrence
Hirundapus caudacutus	White-throated Needletail		C,J,K	Recorded along NSW coast to the western slopes and occasionally from the inland plains. Breeds in northern hemisphere. Almost exclusively aerial while in Australia. Occur above most habitat types, but are more frequently recorded above more densely vegetated habitats (rainforest, open forest and heathland) than over woodland or treeless areas.	1 record within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	Rural area with patches of native vegetation.	Present.
Rhipidura rufifrons	Rufous Fantail			Found along NSW coast and ranges. Inhabits rainforest, dense wet forests, swamp woodlands and mangroves. During migration, it may be found in more open habitats or urban areas (Birds Australia 2008).	4 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	Eucalypt woodland present.	Present. A number of individuals recorded in various patches in the study area.

Notes: 1. Conservation status: M- Migratory species; C = China-Australia Migratory Bird Agreement (CAMBA), J = Japan-Australian Migratory Bird Agreement (JAMBA) and K = Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)

Appendix B – Survey guidelines and methodology

Appendix Table 4 Survey guidelines and methodology for threatened ecological communities known to occur at the airport site*

Scientific name	TSC Status	EPBC Status	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest	CEEC	CEEC	Much of the native vegetation at the airport site is Cumberland Plain Woodland.	The key diagnostic attributes for the Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest are detailed in the listing advice (TSSC 2008). In addition, condition thresholds were also established for the national ecological community (TSSC 2008, DEWHA 2010d). Diagnostic attributes of the community as listed under the TSC Act are provided in the NSW vegetation types database (OEH 2014) and threatened community profile (OEH 2015b). Vegetation mapping can be conducted using a combination of transects or traverses, plot-based surveys and random meanders (DEC 2004). The BioBanking Assessment Methodology details methods for determining the appropriate number of pliot-transects required for a site, and for identifying condition of each plot surveyed (DECC 2009a). The Vegetation types database provides information on each vegetation type in NSW (OEH 2014).	Vegetation survey and assessment for the community listed under both the EPBC Act and TSC Act was carried out in accordance with the BioBanking Assessment Methodology BBAM in order to assess vegetation type and condition and to calculate the quantum of offsets required for the proposed airport. Diagnositic species of each plot-transect were compared with key diagnositic attributes and condition classes for the threatened ecological community detailed in the listing advice (TSSC 2008).	Surveys carried out for Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest at the aiport site are consistent with the various relevant guidelines.

Appendix Table 5 Survey guidelines and methodology for flora species known or considered to have a possibility of occurring at the airport site*

Scientific name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended (DEC 2004)	Survey method and timing implemented	Consistency with guidelines
Acacia pubescens	V	V	16 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Potential habitat present in shale woodlands and Shale-Gravel Transition Forest.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004). Survey may be conducted at any time of the year (NPWS 2003).	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines. The species was assumed to be present and impacted based on the presence of suitable habitat.
Cynanchum elegans	E	E	5 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a).	Potential habitat present in forest and woodland.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004). Survey may be conducted at any time of the year (NPWS 2002a).	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines. The species was assumed to be present and impacted based on the presence of suitable habitat.
Dillwynia tenuifolia	V		41 records within 10km (OEH 2015a).	Potential habitat present in shale woodlands and Shale-Gravel Transition Forest.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004). Best surveyed during the flowering period (August to March, but especially September) (NPWS 2002) , however the species can be identified outside the flowering season.	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines. The species was assumed to be present and impacted based on the presence of suitable habitat.

Scientific name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended (DEC 2004)	Survey method and timing implemented	Consistency with guidelines
Grevillea juniperina subsp. *juniperina*	V		87 records within 10km (OEH 2015a)	Potential habitat present in shale woodlands and Shale-Gravel Transition Forest.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004). Survey may be conducted at any time of the year (NPWS 2003).	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines. The species was assumed to be present and impacted based on the presence of suitable habitat.
Grevillea parviflora subsp. *parviflora*	V	V	11 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	Potential habitat present in Shale-Gravel Transition Forest.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004). Best surveyed during the main flowering period (July to December) (NPWS 2002), however the species can be identified outside the flowering season.	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines. The species was assumed to be present and impacted based on the presence of suitable habitat.
Hypsela sessiliflora	E	X	7 records within 10km (OEH 2015a).	Potential habitat present in wetlands and adjoining moist grassland.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004). Flowers in spring, or if conditions are suitable throughout the year (OEH 2015b).	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders. Targeted searches carried out around dam margins.	Surveys carried out for this species at the aiport site are broadly consistent with the relevant guidelines (other than timing of surveys) The species was not assumed to be present because the aiport site is outside of its highly limited distribution.

Scientific name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended (DEC 2004)	Survey method and timing implemented	Consistency with guidelines
Marsdenia viridiflora subsp. *viridiflora*	EP		22 records within 10km (OEH 2015a).	Occupied habitat present in shale woodlands and Shale-Gravel Transition Forest.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004). Flowers in spring (RBGT 2015), however the species can be identified outside the flowering season.	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders. Targeted searches carried out near known records.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines. The species was recorded at the airport site.
Pimelea spicata	E	E	8 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	Potential habitat present in shale woodland and forest.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004). Surveys should be undertaken when flowering, which is sporadic during the year. A nearby reference population should be used as an indicator of flowering time (NPWS 2004).	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders.	Surveys carried out for this species at the aiport site are broadly consistent with the relevant guidelines (other than confirmation of timing of surveys by checking reference populations). The species was assumed to be present and impacted based on the presence of suitable habitat.
Pomaderris brunnea	V	V	Species or species' habitat likely to occur within 10km (DotE 2015a)	Potential habitat present in alluvial woodland and forest.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004).	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.

Scientific name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended (DEC 2004)	Survey method and timing implemented	Consistency with guidelines
Pultenaea parviflora	E	V	89 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a).	Occupied habitat present in shale woodland.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004). Best surveyed during the flowering period (September) (NPWS 2002), however the species can be identified outside the flowering season.	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders. Targeted searches carried out near known records.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines. This species was recorded at the airport site.
Streblus pendulinus		E	Species or species' habitat known to occur within 10km (DotE 2015a)	Marginal habitat in sheltered pockets of shale woodland. No moist woodland or dry rainforest.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004).	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Thesium australe	V	V	Species or species' habitat may occur within 10km (DotE 2015a)	Potential habitat present in woodland and derived grassland.	Combination of transect or plot surveys, opportunistic observations (eg when walking between sites), random meanders. Recommended effort for random meanders is 30 minutes for each quadrat sampled within the same stratification unit as the quadrat (DEC 2004). Flowers and fruits throughout the year (DotE 2015b).	Flora surveys conducted over 18 days between February and June 2015. Included a combination of plot/transects, opportunistic surveys and random meanders.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. The species was assumed to be present and impacted based on the presence of suitable habitat.

* no targeted surveys were conducted for species that have no habitat present or are unlikely to occur based on the assessment provided in Appendix A however the survey effort summarised above would be consistent with the survey guidelines for many of these species.

Appendix Table 6 Survey guidelines and methodology for fauna species known or considered to have a possibility of occurring at the airport site*

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Birds							
Australasian Bittern	E	E	Species or species' habitat known to occur within 10km (DotE 2015a)	Farm dams and creeks with emergent vegetation present.	A 20 minute dawn or dusk census for each identified watercourse and a 1 hour dawn or dusk survey for each wetland (DEC 2004). Observation of targeted foraging habitat within wetlands in the early morning or early evening. Detection by sightings and unsolicited calls (DEWHA 2010b).	Early morning bird surveys specifically targeting riparian areas were conducted on 4 mornings and specifically targeting wetlands on 4 mornings between March and June 2015. These surveys tended to include a number of riparian and wetland areas. Wetlands often occurred adjacent to woodland patches, and were thus also surveyed during early morning bird surveys in woodland areas on other days. Opportunistic surveys carried out throughout the day at many wetlands and riparian areas over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. Given the large area of the airport, not every farm dam was surveyed. Surveys focussed on those farm dams with suitable potential habitat present.
Australian Painted Snipe	E	E	Species or species' habitat likely to occur within 10km (DotE 2015a)	Farm dams with tall reeds present.	A 20 minute dawn or dusk census for each identified watercourse and a 1 hour dawn or dusk survey for each wetland (DEC 2004). Diurnal area search in appropriate habitat in and around the study area, including flushing surveys (DEWHA 2010b)	Early morning bird surveys specifically targeting riparian areas were conducted on 4 mornings and specifically targeting wetlands on 4 mornings between March and June 2015. These surveys tended to include a number of riparian and wetland areas. Wetlands often occurred adjacent to woodland patches, and were thus also surveyed during early morning bird surveys in woodland areas on other days. Opportunistic surveys carried out throughout the day at many wetlands and riparian areas over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. Given the large area of the airport, not every farm dam was surveyed. Surveys focussed on those farm dams with suitable potential habitat present.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Barking Owl	V		1 record within 10km (OEH 2015a)	Eucalypt woodland present with large hollow-bearing trees present.	Call playback (at least 5 visits per site which should be at least 800m apart). Daytime habitat search for pellets/ likely hollows. Stagwatching at sunset also an option. Surveys can be carried out all year (DEC 2004).	Call playback conducted on 9 nights between March and May 2015. Spotlighting conducted on 12 nights between March and May 2015. Daytime habitat searches carried out over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. Given the size of the site and access restrictions, no stag watching was carried out. Similarly, only one site was surveyed via call playback each night, and most sites were surveyed once or twice.
Black Bittern	V		Recorded during surveys. 1 record within 10km (OEH 2015a).	Vegetated creeks and dams with emergent vegetation present.	A 20 minute dawn or dusk census for each identified watercourse and a 1 hour dawn or dusk survey for each wetland (DEC 2004).	Early morning bird surveys specifically targeting riparian areas were conducted on 4 mornings and specifically targeting wetlands on 4 mornings between March and June 2015. These surveys tended to include a number of riparian and wetland areas. Wetlands often occurred adjacent to woodland patches, and were thus also surveyed during early morning bird surveys in woodland areas on other days. Opportunistic surveys carried out throughout the day at many wetlands and riparian areas over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. Given the large area of the airport, not every farm dam was surveyed. Surveys focussed on those farm dams with suitable potential habitat present.
Black-chinned Honeyeater (eastern subspecies)	V		1 record within 10km (OEH 2015a)	Dry open woodland, including woodland dominated by Grey Box present. Few large patches present.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Diamond Firetail	V		4 records within 10km (OEH 2015a)	Patches of grassy woodland present, as well as riparian areas and lightly wooded farmland.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Flame Robin	V		4 records within 10km (OEH 2015a)	Woodland with woody debris present.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Freckled Duck	V		1 record within 10km (OEH 2015a)	Farm dams and creeks with emergent vegetation present.	A 20 minute dawn or dusk census for each identified watercourse and a 1 hour dawn or dusk survey for each wetland (DEC 2004).	Early morning bird surveys specifically targeting riparian areas were conducted on 4 mornings and specifically targeting wetlands on 4 mornings between March and June 2015. These surveys tended to include a number of riparian and wetland areas. Wetlands often occurred adjacent to woodland patches, and were thus also surveyed during early morning bird surveys in woodland areas on other days. Opportunistic surveys carried out throughout the day at many wetlands and riparian areas over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. Given the large area of the airport, not every farm dam was surveyed. Surveys focussed on those farm dams with suitable potential habitat present.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Gang-gang Cockatoo	V		7 records within 10km (OEH 2015a)	Open woodland, including Riparian forest present.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings and near dams on 4 mornings between May and June 2015 by two ecologists. Opportunistic surveys carried out throughout the day over 3 days in early May 2015. Dedicated driven transects and walked transects carried out on one day in late May and one day in June 2015 by two ecologists.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Glossy Black-Cockatoo	V		18 records within 10km (OEH 2015a)	Small patches of woodland with Allocasuarina species present. Some hollows-bearing trees along present.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Hooded Robin (south-eastern form)	V		3 records within 10km (OEH 2015a)	Lighly wooded and open areas present. Few large patches present.	At least 1 hour dawn or dusk survey (DEC 2004) per 100 hectares stratification unit.	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Little Eagle	V		Recorded during surveys. 6 records within 10km (OEH 2015a)	Woodland and open country present. Abundance of prey (rabbits etc).	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Little Lorikeet	V		Recorded during surveys. 3 records within 10km (OEH 2015a)	Eucalypt woodland with areas of shrubs and logs present. Few large patches.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Masked Owl	V		9 records within 10km (OEH 2015a)	Woodland and open country present. Large, hollow-bearing trees present.	Call playback (at least 8 visits per site which should be at least 800m apart). Daytime habitat search for pellets/ likely hollows. Stagwatching at sunset also an option (DEC 2004).	Call playback conducted on 9 nights between March and May 2015. Spotlighting conducted on 12 nights between March and May 2015. Daytime habitat searches carried out over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. Given the size of the site and access restrictions, no stag watching was carried out. Similarly, only one site was surveyed via call playback each night, and most sites were surveyed once or twice.
Powerful Owl	V		17 records within 10km (OEH 2015a)	Woodland and open country present. Large, hollow-bearing trees present.	Call playback (at least 5 visits per site which should be at least 800m apart). Daytime habitat search for pellets/ likely hollows. Stagwatching at sunset also an option (DEC 2004).	Call playback conducted on 9 nights between March and May 2015. Spotlighting conducted on 12 nights between March and May 2015. Daytime habitat searches carried out over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. Given the size of the site and access restrictions, no stag watching was carried out. Similarly, only one site was surveyed via call playback each night, and most sites were surveyed once or twice.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Scarlet Robin	V		Recorded during surveys. 3 records within 10km (OEH 2015a)	Woodland with woody debris present.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Speckled Warbler	V		16 records within 10km (OEH 2015a)	Grassy and shrubby woodland patches present. Few large, undisturbed patches present.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Square-tailed Kite	V		3 records within 10km (OEH 2015a)	Woodland and timbered water courses present.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Swift Parrot	E	E	8 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Eucalyptus tereticornis dominates much of the native vegetation in the study area.	Surveys on the mainland should be conducted between March and July. Area searches of suitable habitat, in the early morning and afternoon when birds are most active and vocal. Slow-moving vehicle transects also effective in expansive areas. Targeted surveys of patches of heavily flowering eucalypts may be useful (DEWHA 2010b).	Early morning bird surveys carried out in woodland areas on 10 mornings and near dams on 4 mornings between May and June 2015 by two ecologists. Opportunistic surveys carried out throughout the day over 3 days in May 2015. Dedicated driven transects and walked transects carried out on one day in late May and one day in June 2015 by two ecologists. All surveys carried out once Swift Parrots were confirmed within NSW (Birdline NSW). General bird surveys were carried out in March and April however these were prior to the species being recorded in NSW.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Varied Sittella	V		Recorded during surveys. 36 records within 10km (OEH 2015a)	Eucalypt woodland present.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Mammals							
Grey-headed Flying-fox	V	V	Recorded during surveys. 38 records within 10km (OEH 2015a); Foraging, feeding and related behaviour known to occur within 10km (DotE 2015a)	Eucalypt woodland present.	Spotlight observations and roost surveys (1 hour of spotlighting on two separate nights). Surveys can be conducted all year (DEC 2004). A review of known flying fox camps for the airport site and the wider general area. Surveys of vegetation communities and food plants. Night time surveys including walked transects for feeding and flying bats. Daytime field surveys for camps to record presence of unrecorded day roosts. Timing of surveys are dependent on availability of food resources (DEWHA 2010c).	Flying fox camps reviewed. Vegetation surveys included identification of food plants. 12 nights of nocturnal surveys by 2-3 people between March and May 2015. Diurnal surveys of riparian areas included searches for camps.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Eastern Bentwing-bat	V		34 records within 10km (OEH 2015a)	Woodland and open areas present. Bridges, empty buildings and sheds present.	Two Anabat units left recording for the entire night for two nights. Harp trapping (4 trap nights over 2 consecutive nights). Survey recommended to occur between October to March. Additional methods include searching rocks, overhangs and caves/mines (DEC 2004).	Two Anabat units per night for 9 nights in March and early April 2015. Additional 3 nights in May 2015. Inspection of bridges for roosting bats.	Surveys generally consistent with relvant guidelines. Good calls of this species can be distinguished by anabat analysis, although there can also be some overlaps with other species (Pennay et al 2004). Given small patches of vegetation present at the airport

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
							site and generally open nature of habitat present, harp trapping was not considered an efficient survey method.
Eastern False Pipistrelle	V		5 records within 10km (OEH 2015a)	No tall wet forest present. Few large remnants present.	Two Anabat units left recording for the entire night for two nights. Harp trapping (4 trap nights over 2 consecutive nights). Survey recommended to occur between October to March (DEC 2004).	Two Anabat units per night for 9 nights in March and early April 2015. Additional 3 nights in May 2015. No harp nets set as few flyways present in the airport site.	Surveys generally consistent with relvant guidelines. Good calls of this species can be distinguished by anabat analysis, although there can also be some overlaps with other species (Pennay et al 2004). Given small patches of vegetation present at the airport site and generally open nature of habitat present, harp trapping was not considered an efficient survey method.
Eastern Freetail-bat	V		Recorded during surveys. 38 records within 10km (OEH 2015a)	Woodland present. Tree hollows and empty buildings and sheds present.	Two Anabat units left recording for the entire night for two nights. Harp trapping (4 trap nights over 2 consecutive nights). Survey recommended to occur between October to March (DEC 2004).	Two Anabat units per night for 9 nights in March and early April 2015. Additional 3 nights in May 2015. No harp nets set as few flyways present in the airport site.	Surveys generally consistent with relvant guidelines. Calls of this species can be easily distinguished by anabat analysis (Pennay et al 2004). Given small patches of vegetation present at the airport site and generally open nature of habitat present, harp trapping was not considered an efficient survey method.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Greater Broad-nosed Bat	V		15 records within 10km (OEH 2015a)	Woodland and open areas present. Tree hollows and empty buildings and sheds present.	Two Anabat units left recording for the entire night for two nights. Harp trapping (4 trap nights over 2 consecutive nights). Survey recommended to occur between October to March (DEC 2004).	Two Anabat units per night for 9 nights in March and early April 2015. Additional 3 nights in May 2015.	Surveys generally consistent with relvant guidelines. Good calls of this species can be distinguished by anabat analysis, although there can also be some overlaps with other species (Pennay et al 2004). Given small patches of vegetation present at the airport site and generally open nature of habitat present, harp trapping was not considered an efficient survey method.
Southern Myotis	V		Recorded during surveys. 24 records within 10km (OEH 2015a)	Creeks and dams present. Tree hollows and empty buildings and sheds and bridges present.	Two Anabat units left recording for the entire night for two nights. Harp trapping (4 trap nights over 2 consecutive nights). Spotlighting around waterbodies. Survey recommended to occur between October to March (DEC 2004).	Two Anabat units per night for X nights in March and early April 2015. Additional 3 nights in May 2015. Inspection of bridges for roosting bats. No harp nets set as few flyways present in the airport site.	Surveys generally consistent with relvant guidelines. Good calls of this species can be distinguished by anabat analysis, although there can also be some overlaps with other species (Pennay et al 2004). Given small patches of vegetation present at the airport site and generally open nature of habitat present, harp trapping was not considered an efficient survey method.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Yellow-bellied Sheathtail-bat	V		1 record within 10km (OEH 2015a)	Woodland and open areas present. Tree hollows and empty buildings and sheds present.	Two Anabat units left recording for the entire night for two nights. Harp trapping (4 trap nights over 2 consecutive nights). Survey recommended to occur between October to March (DEC 2004).	Two Anabat units per night for 9 nights in March and early April 2015. Additional 3 nights in May 2015. No harp nets set as few flyways present in the airport site.	Surveys generally consistent with relvant guidelines. Calls of this species can be easily distinguished by anabat analysis (Pennay et al 2004). Given small patches of vegetation present at the airport site and generally open nature of habitat present, harp trapping was not considered an efficient survey method.
Invertebrates							
Cumberland Plain Land Snail	E		Recorded during surveys. 237 records within 10km (OEH 2015a)	Cumberland Plain woodland present.	Searches to be conducted at any time of the year in appropriate habitat. Survey effort to be determined by size of potential habitat present (NPWS 2000).	Targeted searches in woodland patches over 11 days between March and May 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Migratory species							
Cattle Egret		C,J	Recorded during surveys. 31 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Variety of farm dams and grassland present.	A 20 minute dawn or dusk census for each identified watercourse and a 1 hour dawn or dusk survey for each wetland (DEC 2004).	Early morning bird surveys specifically targeting riparian areas were conducted on 4 mornings and specifically targeting wetlands on 4 mornings between March and June 2015. These surveys tended to include a number of riparian and wetland areas. Wetlands often occurred adjacent to woodland patches, and were thus also surveyed during early morning bird surveys in woodland areas on other days. Opportunistic surveys carried out throughout the day at many wetlands and riparian areas over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. Given the large area of the airport, not every farm dam was surveyed. Surveys focussed on those farm dams with suitable potential habitat present.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Fork-tailed Swift		C,J,K	3 records within 10km (OEH 2015a); Species or species' habitat likely to occur within 10km (DotE 2015a)	Rural area with patches of native vegetation.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Great Egret		C,J	Recorded during surveys. 8 records within 10km (OEH 2015a); Breeding known to occur within 10km (DotE 2015a)	Variety of farm dams present.	A 20 minute dawn or dusk census for each identified watercourse and a 1 hour dawn or dusk survey for each wetland (DEC 2004).	Early morning bird surveys specifically targeting riparian areas were conducted on 4 mornings and specifically targeting wetlands on 4 mornings between March and June 2015. These surveys tended to include a number of riparian and wetland areas. Wetlands often occurred adjacent to woodland patches, and were thus also surveyed during early morning bird surveys in woodland areas on other days. Opportunistic surveys carried out throughout the day at many wetlands and riparian areas over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. Given the large area of the airport, not every farm dam was surveyed. Surveys focussed on those farm dams with suitable potential habitat present.
Latham's Snipe		C,J,K	Recorded during surveys. 5 records within 10km (OEH 2015a); Species or species' habitat may occur within 10km (DotE 2015a)	Farm dams with low vegetation and adjacent grassland present.	A 20 minute dawn or dusk census for each identified watercourse and a 1 hour dawn or dusk survey for each wetland (DEC 2004). Diurnal area search in appropriate habitat in and around the study area, including flushing surveys (DEWHA 2010b)	Early morning bird surveys specifically targeting riparian areas were conducted on 4 mornings and specifically targeting wetlands on 4 mornings between March and June 2015. These surveys tended to include a number of riparian and wetland areas. Wetlands often occurred adjacent to woodland patches, and were thus also surveyed during early morning bird surveys in woodland areas on other days. Opportunistic surveys carried out throughout the day at many wetlands and riparian areas over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the various relevant guidelines. Given the large area of the airport, not every farm dam was surveyed. Surveys focussed on those farm dams with suitable potential habitat present.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Rufous Fantail			Recorded during surveys. 4 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	Eucalypt woodland present.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
White-bellied Sea-Eagle		C	Recorded during surveys. 12 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	Various large dams and grassland present.	Area search method using the species-time curve approach is recommended (DEC 2004). Various methods recommended, including area searches, transect surveys, and observations from vantage points (DEWHA 2010b).	Early morning bird surveys specifically targeting riparian areas were conducted on 4 mornings and specifically targeting wetlands on 4 mornings between March and June 2015. These surveys tended to include a number of riparian and wetland areas. Wetlands often occurred adjacent to woodland patches, and were thus also surveyed during early morning bird surveys in woodland areas on other days. Opportunistic surveys carried out throughout the day at many wetlands and riparian areas over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
White-throated Needletail		C,J,K	Recorded during surveys. 1 record within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	Rural area with patches of native vegetation.	Area search method using the species-time curve approach is recommended (DEC 2004).	Early morning bird surveys carried out in woodland areas on 10 mornings between March and June 2015. Opportunistic surveys carried out throughout the day over 18 days between February and June 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.

* no surveys were conducted for species that have no habitat present or are unlikely to occur based on the assessment provided in Appendix A.

Appendix Table 7 Survey guidelines and methodology for EPBC Act–listed fauna species unlikely to occur at the airport site*

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Green and Golden Bell Frog	E	V	1 record within 10km (OEH 2015a); Species or species' habitat may occur within 10km (DotE 2015a)	No previous records at the airport site. Numerous dams with emergent vegetation present. Mosquitofish common. Appropriate habitat present, however no individuals recorded despite targeted surveys during March 2015 and October 1998.	The referral guidelines (DEWHA 2009a) recommend an initial habitat assessment followed by at least four nights of surveys between September and March, during warm and windless weather conditions following rainfall. Surveys of about an hour are recommended for wetlands up to 50 metres in width. Where possible, surveys should include use of a nearby reference site (DEWHA 2009a). The survey guidelines for threatened frogs (DEWHA 2010a) further recommend surveys be under taken within one week of heavy rainfall (i.e. greater than 50 mm in seven days) between October and February. Recommended survey methods include visual searches for basking frogs and call playback.	Habitat assessment and four nights of targeted survey conducted in March with heavy rain falling on one night. Surveys could not be conducted prior to this due to timing of project commencement and access constraints.	Surveys carried out for this species at the aiport site are generally consistent with the relevant guidelines. Surveys were conducted over 4 nights in March (consistent with DEWHA (2009a)). Surveys were conducted following a wet summer with many large storms, however only one large rainfall event occurred during surveys. Given the timing of commencement of the project, surveys could not be conducted earlier in the season. Surveys conducted in October 1998 did not record any evidence of the species and Lemckert (1999) considered it likely that the Green and Golden Bell Frog does not occur at the airport site.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Regent Honeyeater	CE	E	3 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	No Spotted Gum or Swamp Mahogany forest present.	Area search method using the species-time curve approach is recommended (DEC 2004). Area searches in suitable habitat, preferable in the morning (DEWHA 2010b).	No preferred foraging habitat present. Early morning bird surveys carried out in woodland areas on 10 mornings and near dams on 4 mornings between May and June 2015 by two ecologists. Opportunistic surveys carried out throughout the day over 3 days in May 2015. Dedicated driven transects and walked transects carried out on one day in late May and one day in June 2015 by two ecologists. All surveys carried out once Swift Parrots were confirmed within NSW (Birdline NSW). General bird surveys were carried out in March and April however these were prior to the species being recorded in NSW.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Koala	V	V	3 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	*Eucalyptus tereticornis* (primary feed tree) and *Eucalyptus mollucana* (secondary feed tree) dominate much of the native vegetation in the study area. Woodland is patchy with large cleared areas present. Local records associated with either the Blue Mountains National Park or the Western Sydney Parklands. No direct connectivity with other local records.	Methods include a combination of desktop assessment of local recodds, vegetation composition, habitat connectivity and assessment of existing threats and recovery value. Various field survey methods can be used, including a combination of strip transects, spotlighting, call playback, remote cameras, and scat searches. Survey methods used depend on area of habitat and considerations of connectivity etc (DotE 2014). The recovery for the Koala details feed trees in various management areas (DECC 2008c).	Habitat assessments between between March and June 2015, with regards to feed trees detailed in DECC (2008c). Scat searches in areas of potential habitat over 11 days (35 sites, about 25 person hours). 12 nights of nocturnal surveys by 2-3 people between March and May 2015.	Surveys carried out for this species at the aiport site are consistent with the relevant guidelines.
Large-eared Pied Bat	V	V	9 records within 10km (OEH 2015a); Species or species' habitat known to occur within 10km (DotE 2015a)	No preferred sandstone habitat present. No breeding habitat present. Large cleared areas present between the airport site and the Blue Mountains where preferred foraging habitat is located. May forage on occasion in the western portion of the airport site closest to Blue Mountains National Park closer to where suitable habitat is present	Two Anabat units left recording for the entire night for two nights. Harp trapping (4 trap nights over 2 consecutive nights). Survey recommended to occur between October to March (DEC 2004). The use of electronic bat detectors is the best means of non-invasive survey, and the most efficient in terms of data collection and area coverage. Trapping with harp traps and mistnets, and roost searches in caves, mines, rock overhangs, culverts and crevices could be undertaken to confirm presence or roosting (DEWHA 2010c).	Two Anabat units per night for 9 nights in March and early April 2015. Additional 3 nights in May 2015. No harp nets set as few flyways present in the airport site.	Surveys for this species at the airport site are consistent with relevant guidelines. The Large-eared Pied Bat can be surveyed using anabat anaylis (DEWHA 2010a). Calls can easily be distinguished from other species by the combination of the low frequencies and distinct pattern of alternation present in search phase calls (Pennay et al 2004). Given the lack of roosting and breeding habitat, no harp netting was considered necessary.

Common name	TSC Status	EPBC Status	Existing records	Habitat present in the study area	Survey method and timing recommended	Survey method and timing implemented	Consistency with guidelines
Spotted-tailed Quoll	V	E	Species or species' habitat known to occur within 10km (DotE 2015a)	Limited marginal habitat present. No local records. Narrow riparian corridor and large cleared areas present. Limited connectivity.	Recommened techniques include searches for habitat resources, scats and latrines, hair sampline and remote cameras (left on site for three weeks). Cage trapping surveys are not considered necessary at the first stage of detection, provided hair funnel surveys or remote cameras are employed, as they are an appropriate and effective alternative. The optimal survey time is during the breeding season, with peak activity occurring between May and August. Surveys conducted during April to August may detect males in areas where they may not usually occur, either as they move in search of females to mate with or move away from other more competitive males (DEWHA 2010e).	Habitat assessment and searches for evidence (scats/latrines) between between March and June 2015. Two infra-red cameras were placed at four separate locations in woodland or near dams (ie each camera recorded at two locations). Cameras were set for 3-4 weeks at each location. Cameras recorded between March and June.	Surveys for this species at the airport site are consistent with relevant guidelines.

Appendix C – Field survey results

Appendix Table 8 Plant species recorded in Good condition Grey Box – Forest Red Gum grassy woodland on flats (HN528)

Family	Scientific Name	Common Name	Exotic	Plot /Transect										
				2	5	6	7	10	11	12	16	22	23	25
Acanthaceae	*Brunoniella australis*	Blue Trumpet		2	2	2	2	2	2	2	2	2	1	2
Adiantaceae	*Cheilanthes sieberi* subsp. *sieberi*	Rock Fern				1	1			1		1	1	2
Amaranthaceae	*Alternanthera denticulata*	Lesser Joyweed							1					
Amaranthaceae	*Alternanthera pungens*	Khaki Weed	*	1			1		1				2	
Anthericaceae	*Caesia parviflora* var. *parviflora*									2				
Anthericaceae	*Caesia parviflora* var. *vittata*				x			1	1		1			2
Anthericaceae	*Dichopogon fimbriatus*	Nodding Chocolate Lily										x		
Anthericaceae	*Tricoryne elatior*	Yellow Autumn-lily							1			2	1	
Apiaceae	*Centella asiatica*	Indian Pennywort				1	1					2		2
Apocynaceae	*Araujia sericifera*	Moth Vine	*	1							2	1		1
Apocynaceae	*Marsdenia viridiflora* subsp. *viridiflora*	*Marsdenia viridiflora* R. Br. subsp. *viridiflora* population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas											2	
Asparagaceae	*Asparagus asparagoides*	Bridal Creeper	*	1						1	1			
Asteraceae	*Bidens pilosa*	Cobbler's Pegs	*	1	2	1	1					1		1
Asteraceae	*Bidens subalternans*	Greater Beggar's Ticks	*	2	1	2			2	2		1		1
Asteraceae	*Calotis lappulacea*	Yellow Burr-daisy											1	
Asteraceae	*Cirsium vulgare*	Spear Thistle	*		1		1	2		1		1	1	1
Asteraceae	*Conyza bonariensis*	Flaxleaf Fleabane	*		1			1	1	1		1	1	1
Asteraceae	*Cymbonotus lawsonianus*	Bear's Ear					1							
Asteraceae	*Euchiton sphaericus*	Star Cudweed			1		1		1			2		
Asteraceae	*Glossocardia bidens*	Cobbler's Tack		1										
Asteraceae	*Hypochaeris radicata*	Catsear	*											1
Asteraceae	*Ozothamnus diosmifolius*	White Dogwood										x		

Family	Scientific Name	Common Name	Exotic	Plot /Transect										
				2	5	6	7	10	11	12	16	22	23	25
Asteraceae	*Senecio hispidulus*	Hill Fireweed							x					
Asteraceae	*Senecio madagascariensis*	Fireweed	*	1			2	1		1		1		
Asteraceae	*Sigesbeckia orientalis* subsp. *orientalis*	Indian Weed						1		1	1			
Asteraceae	*Sonchus oleraceus*	Common Sowthistle	*	1	1					1		1		1
Asteraceae	*Taraxacum officinale*	Dandelion	*	1						1		1		
Asteraceae	*Vernonia cinerea*					2	1	2						
Asteraceae	*Vittadinia cuneata*	A Fuzzweed					x						1	1
Brassicaceae	*Lepidium* sp.	A Peppercress	*	1										
Brassicaceae	*Sisymbrium* sp.		*				1							
Cactaceae	*Opuntia stricta*	Common Prickly Pear, Smooth Pest Pear	*				x							
Campanulaceae	*Wahlenbergia gracilis*	Sprawling Bluebell			1				1			2	2	
Chenopodiaceae	*Atriplex semibaccata*	Creeping Saltbush											1	
Chenopodiaceae	*Chenopodium album*	Fat Hen	*		1	1	1						1	
Chenopodiaceae	*Einadia hastata*	Berry Saltbush		2	1	1	2	3	2	2	1	1	2	
Chenopodiaceae	*Einadia nutans* subsp. *nutans*	Climbing Saltbush		2	1		1	3	2		2	1	1	1
Chenopodiaceae	*Einadia polygonoides*	Knotweed Goosefoot											1	
Chenopodiaceae	*Einadia trigonos* subsp. *Trigonos*								1	2	1		1	1
Chenopodiaceae	*Enchylaena tomentosa*	Ruby Saltbush											1	
Chenopodiaceae	*Maireana microphylla*	Small-leaf Bluebush										3		
Chenopodiaceae	*Salsola kali* var. *kali*	Buckbush											1	
Commelinaceae	*Commelina cyanea*	Native Wandering Jew		2	2	2	2		2		1			
Convolvulaceae	*Dichondra repens*	Kidney Weed		2	2	2	2	2	2	2	1			1
Crassulaceae	*Bryophyllum delagoense*	Mother of millions	*		x								3	
Cyperaceae	*Bolboschoenus fluviatilis*	Marsh Club-rush		1										
Cyperaceae	*Cyperus gracilis*	Slender Flat-sedge		1	1		1		1	1	1		1	2
Cyperaceae	*Cyperus* sp.			1								1		
Cyperaceae	*Fimbristylis dichotoma*	Common Fringe-sedge					1		2	1		2		1

Family	Scientific Name	Common Name	Exotic	Plot /Transect										
				2	5	6	7	10	11	12	16	22	23	25
Dilleniaceae	*Hibbertia diffusa*	Wedge Guinea Flower								2				
Ericaceae	*Lissanthe strigosa*	Peach Heath			x	1	1							
Goodeniaceae	*Goodenia hederacea*	Ivy Goodenia				x	1		1					2
Juncaceae	*Juncus subsecundus*	Finger Rush			1									
Juncaceae	*Juncus usitatus*											x		
Lamiaceae	*Ajuga australis*	Austral Bugle								1				
Lamiaceae	*Mentha satureioides*	Native Pennyroyal					1			2				2
Lobeliaceae	*Isotoma fluviatilis*	Swamp Isotome						x						
Lobeliaceae	*Pratia purpurascens*	Whiteroot												2
Lomandraceae	*Lomandra filiformis* subsp. *filiformis*			3	2		2		2	1	1	3	2	2
Lomandraceae	*Lomandra multiflora* subsp. *multiflora*	Many-flowered Mat-rush								1		x		2
Loranthaceae	*Amyema pendulum* subsp. *pendulum*													1
Malvaceae	*Modiola caroliniana*	Red-flowered Mallow	*	1										
Malvaceae	*Sida rhombifolia*	Paddy's Lucerne	*	2	2	2	2		2		2	2	2	1
Myoporaceae	*Eremophila debilis*	Amulla				x	1	2		2	2			
Myrtaceae	*Eucalyptus crebra*	Narrow-leaved Ironbark									x			
Myrtaceae	*Eucalyptus eugenioides*	Thin-leaved Stringybark					x				x			
Myrtaceae	*Eucalyptus fibrosa*	Red Ironbark			3						x			3
Myrtaceae	*Eucalyptus moluccana*	Grey Box		4				4	4	4	4	3	4	4
Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum			4	4	4					3		3
Myrtaceae	*Melaleuca decora*								x				x	
Oleaceae	*Olea europaea* subsp. *cuspidata*	African Olive	*	2	2		1		2	4	3	2		1
Oxalidaceae	*Oxalis corniculata*	Creeping Oxalis	*		1		1	1	1					
Oxalidaceae	*Oxalis perennans*										1	1		1
Phormiaceae	*Dianella revoluta* var. *revoluta*	A Blue Flax Lily											x	
Phyllanthaceae	*Phyllanthus similis*					1								

Family	Scientific Name	Common Name	Exotic	Plot /Transect										
				2	5	6	7	10	11	12	16	22	23	25
Phyllanthaceae	*Phyllanthus virgatus*	Wiry Spurge		1			1					1		1
Phytolaccaceae	*Phytolacca octandra*	Inkweed	*						x					
Pittosporaceae	*Bursaria spinosa* subsp. *spinosa*	Native Blackthorn			3	4	2	4	4	5	4	2	3	
Plantaginaceae	*Plantago gaudichaudii*	Narrow Plantain		2			1		1					1
Plantaginaceae	*Plantago lanceolata*	Lamb's Tongues	*	2			1							
Plantaginaceae	*Plantago varia*										x			
Poaceae	*Aristida ramosa*	Purple Wiregrass		2	3	2	2		1	2	1	3		2
Poaceae	*Aristida vagans*	Threeawn Speargrass		2	1	2			2			2	3	
Poaceae	*Austrodanthonia bipartita*	Wallaby Grass					1							
Poaceae	*Austrodanthonia racemosa*	Wallaby Grass		2										
Poaceae	*Austrodanthonia racemosa* var. *racemosa*	A Wallaby Grass							2			1		1
Poaceae	*Austrodanthonia tenuior*	A Wallaby Grass							1				2	
Poaceae	*Axonopus fissifolius*	Narrow-leafed Carpet Grass	*			2								
Poaceae	*Bothriochloa macra*	Red Grass		1	1		1							
Poaceae	*Briza minor*	Shivery Grass	*										1	
Poaceae	*Briza subaristata*		*				1					2		
Poaceae	*Chloris divaricata* var. *divaricata*	Slender Chloris				2	3	3	2	1	1		2	
Poaceae	*Chloris gayana*	Rhodes Grass	*	2										1
Poaceae	*Chloris* sp.		*	2										
Poaceae	*Chloris truncata*	Windmill Grass											3	
Poaceae	*Chloris ventricosa*	Tall Chloris			3									3
Poaceae	*Cymbopogon refractus*	Barbed Wire Grass			1					1				
Poaceae	*Cynodon dactylon*	Common Couch			2								1	
Poaceae	*Dichelachne micrantha*	Shorthair Plumegrass							1					
Poaceae	*Echinochloa crus-galli*	Barnyard Grass	*	1										
Poaceae	*Echinopogon caespitosus*	Bushy Hedgehog-grass												1
Poaceae	*Echinopogon ovatus*	Forest Hedgehog Grass										1		

Family	Scientific Name	Common Name	Exotic	Plot /Transect										
				2	5	6	7	10	11	12	16	22	23	25
Poaceae	*Ehrharta erecta*	Panic Veldtgrass	*	1						2				
Poaceae	*Entolasia stricta*	Wiry Panic												1
Poaceae	*Eragrostis curvula*	African Lovegrass	*	2	2									
Poaceae	*Eragrostis leptostachya*	Paddock Lovegrass		1	2	2	2		1	1	1	2	1	1
Poaceae	*Eriochloa pseudoacrotricha*	Early Spring Grass									1			
Poaceae	*Microlaena stipoides* var. *stipoides*	Weeping Grass		2	2	4	3	1				4	1	2
Poaceae	*Panicum decompositum* var. *tenuius*								1	1	1			
Poaceae	*Panicum effusum*	Hairy Panic					1							
Poaceae	*Paspalum dilatatum*	Paspalum	*	2	2	1	2							
Poaceae	*Pennisetum clandestinum*	Kikuyu Grass	*										1	
Poaceae	*Setaria parviflora*		*	2	3	3	2	2	2	1	2	3	2	2
Poaceae	*Setaria pumila*	Pale Pigeon Grass	*								2			
Poaceae	*Sporobolus africanus*	Parramatta Grass	*											1
Poaceae	*Sporobolus creber*	Slender Rat's Tail Grass		2	2		1		1	1		1		
Poaceae	*Sporobolus elongatus*	Slender Rat's Tail Grass					1						1	
Poaceae	*Themeda australis*	Kangaroo Grass		2	2		3	2	1	1		2	1	1
Polygonaceae	*Acetosella vulgaris*	Sheep Sorrel	*							1				
Portulacaceae	*Portulaca oleracea*	Pigweed											1	
Rosaceae	*Rubus fruticosus* sp. agg.	Blackberry complex	*		1									
Rubiaceae	*Asperula conferta*	Common Woodruff		1	1		1		1			2		1
Rubiaceae	*Galium gaudichaudii*	Rough Bedstraw						1						
Rubiaceae	*Opercularia varia*	Variable Stinkweed			1	1				1				
Santalaceae	*Exocarpos cupressiformis*	Cherry Ballart											x	
Sapindaceae	*Dodonaea viscosa* subsp. *cuneata*	Wedge-leaf Hop-bush							1					
Solanaceae	*Lycium ferocissimum*	African Boxthorn	*	1			x	2	2		1	1		1
Solanaceae	*Solanum nigrum*	Black-berry Nightshade	*	1					1	1				1

Family	Scientific Name	Common Name	Exotic	Plot /Transect										
				2	5	6	7	10	11	12	16	22	23	25
Solanaceae	*Solanum prinophyllum*	Forest Nightshade		1	1	1	1	1	1	1	1	1		
Solanaceae	*Solanum pseudocapsicum*	Madeira Winter Cherry	*	1	1	1		2	1			1		
Solanaceae	*Solanum sisymbriifolium*		*	1						1		1	2	1
Solanaceae	*Solanum* sp.		*		2	1		1	1					
Stackhousiaceae	*Stackhousia* sp.											1		
Sterculiaceae	*Brachychiton populneus*	Kurrajong							x					
Verbenaceae	*Lantana camara*	Lantana	*							x				
Verbenaceae	*Verbena bonariensis*	Purpletop	*		1				1					
Fabaceae	*Acacia decurrens*	Black Wattle										1		3
Fabaceae	*Acacia falcata*													2
Fabaceae	*Acacia floribunda*	White Sally										x		
Fabaceae	*Daviesia ulicifolia*	Gorse Bitter Pea							1					
Fabaceae	*Desmodium brachypodum*	Large Tick-trefoil				1				2				
Fabaceae	*Desmodium varians*	Slender Tick-trefoil		2			1			1				1
Fabaceae	*Dillwynia sieberi*				x	1			2					1
Fabaceae	*Glycine microphylla*	Small-leaf Glycine				2	2	2	2	1		1		1
Fabaceae	*Glycine tabacina*	Variable Glycine		2	1	2			1	2	1	2	1	2
Fabaceae	*Hardenbergia violacea*	False Sarsaparilla							1					
Fabaceae	*Indigofera australis*	Australian Indigo			1									
Fabaceae	*Senna pendula* var. *glabrata*		*									2		
Fabaceae (Faboideae)	*Pultenaea parviflora*												x	

Note: 1 – **EP**: Endangered population under the TSC Act. **V**: Vulnerable under the TSC Act and the EPBC Act **, E:** endangered under the EPBC Act.

2 – *Cover abundance rankings within each survey area:* **1** Foliage sparsely or very sparsely present, cover less than 5%; **2** 1-5% Plentiful, foliage cover 1-5 %; **3** 5-25% foliage cover; **4** 26-50% foliage cover; **5** 51-75% foliage cover; **6** 76-100% foliage cover; **x** – opportunistic record.

Appendix Table 9 Plant species recorded in Good condition Grey Box – Forest Red Gum grassy woodland on flats (HN528)

Family	Scientific Name	Common Name	Exotic	8	19	24	28	30	31	32	35	37	42
Acanthaceae	*Brunoniella australis*	Blue Trumpet		1		1		2		1	1		1
Adiantaceae	*Cheilanthes sieberi subsp. sieberi*	Rock Fern				2			2		1		
Adiantaceae	*Pellaea falcata*	Sickle Fern											x
Alliaceae	*Agapanthus* sp.		*										x
Amaranthaceae	*Alternanthera denticulata*	Lesser Joyweed									1		
Amaranthaceae	*Alternanthera pungens*	Khaki Weed	*			1							
Anthericaceae	*Tricoryne elatior*	Yellow Autumn-lily				1	1		1				
Apiaceae	*Centella asiatica*	Indian Pennywort		2		2	2	2	1		2		1
Apocynaceae	*Araujia sericifera*	Moth Vine	*								1		
Asteraceae	*Bidens pilosa*	Cobbler's Pegs	*	1					2				
Asteraceae	*Bidens subalternans*	Greater Beggar's Ticks	*							1			
Asteraceae	*Brachyscome aculeata*	Hill Daisy								1			
Asteraceae	*Cirsium vulgare*	Spear Thistle	*	1						1	1		1
Asteraceae	*Conyza bonariensis*	Flaxleaf Fleabane	*								1		
Asteraceae	*Euchiton sphaericus*	Star Cudweed				1	1	1			1		
Asteraceae	*Gamochaeta americana*	Cudweed	*	1									
Asteraceae	*Gamochaeta purpurea*	Purple Cudweed	*			1					1		
Asteraceae	*Hypochaeris radicata*	Catsear	*				1				1		
Asteraceae	*Ozothamnus diosmifolius*	White Dogwood							x				
Asteraceae	*Senecio madagascariensis*	Fireweed	*	2	1	1	2	1	2	1	2	2	1
Asteraceae	*Sonchus* sp.	Sowthistle	*							1			
Asteraceae	*Taraxacum officinale*	Dandelion	*	1	1		1	1				1	
Brassicaceae	*Lepidium* sp.	A Peppercress	*							1			
Campanulaceae	*Wahlenbergia gracilis*	Sprawling Bluebell				1		1	1		1	1	
Chenopodiaceae	*Chenopodium album*	Fat Hen	*	1									
Chenopodiaceae	*Einadia hastata*	Berry Saltbush								3			
Chenopodiaceae	*Einadia nutans* subsp. *nutans*	Climbing Saltbush							2	1			
Chenopodiaceae	*Einadia polygonoides*	Knotweed Goosefoot							1				

Family	Scientific Name	Common Name	Exotic	8	19	24	28	30	31	32	35	37	42
Chenopodiaceae	*Einadia trigonos* subsp. *trigonos*								2	2			
Clusiaceae	*Hypericum gramineum*	Small St John's Wort		1	1		2				1		
Clusiaceae	*Hypericum perforatum*	St. Johns Wort	*		2								
Commelinaceae	*Commelina cyanea*	Native Wandering Jew							1	3	1		
Convolvulaceae	*Dichondra repens*	Kidney Weed				2			2	2	2		2
Cyperaceae	*Carex* sp.					2							
Cyperaceae	*Cyperus brevifolius*		*				1		1				
Cyperaceae	*Cyperus gracilis*	Slender Flat-sedge				1			1	1			
Cyperaceae	*Cyperus* sp.								1				
Cyperaceae	*Fimbristylis dichotoma*	Common Fringe-sedge		2		2	2	2	1	1	1	1	1
Ericaceae	*Lissanthe strigosa*	Peach Heath				1							
Ericaceae	*Melichrus urceolatus*	Urn Heath										x	
Fabaceae	*Acacia baileyana*	Cootamundra Wattle											x
Fabaceae	*Acacia falcata*										1		
Fabaceae	*Daviesia ulicifolia*	Gorse Bitter Pea						x	x			x	
Fabaceae	*Desmodium varians*	Slender Tick-trefoil			1					2			
Fabaceae	*Glycine clandestina*	Twining glycine									1		
Fabaceae	*Glycine microphylla*	Small-leaf Glycine			1	1	1	1					
Fabaceae	*Glycine tabacina*	Variable Glycine		1	1	2	2	2	2	2	2		1
Fabaceae	*Pultenaea microphylla*	A Bush Pea				x							
Fabaceae	*Trifolium subterraneum*	Subterranean Clover	*				1						
Gentianaceae	*Centaurium* sp.		*									1	
Gentianaceae	*Schenkia australis*	Spike Centaury		1									
Goodeniaceae	*Goodenia hederacea*	Ivy Goodenia						1					
Lamiaceae	*Ajuga australis*	Austral Bugle									1		
Lomandraceae	*Lomandra filiformis* subsp. *filiformis*					2		1			2		1
Lomandraceae	*Lomandra multiflora* subsp. *multiflora*	Many-flowered Mat-rush									1		
Loranthaceae	*Amyema pendulum* subsp. *pendulum*					x							
Malvaceae	*Modiola caroliniana*	Red-flowered Mallow	*								1		

Family	Scientific Name	Common Name	Exotic	8	19	24	28	30	31	32	35	37	42
Malvaceae	*Sida rhombifolia*	Paddy's Lucerne	*			1		1	1	3	1		1
Myrsinaceae	*Anagallis arvensis*	Scarlet Pimpernel	*		1								
Myrtaceae	*Eucalyptus moluccana*	Grey Box				1			2	1	1		
Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum							4	4	3		
Myrtaceae	*Kunzea ambigua*	Tick Bush					x						
Myrtaceae	*Melaleuca sieberi*											x	
Myrtaceae	*Melaleuca styphelioides*	Prickly-leaved Tea Tree				x							
Oleaceae	*Olea europaea subsp. cuspidata*	African Olive	*				1				1		
Oxalidaceae	*Oxalis corniculata*	Creeping Oxalis	*							1	1		
Oxalidaceae	*Oxalis perennans*				1	1	1		1				1
Phyllanthaceae	*Phyllanthus virgatus*	Wiry Spurge					2				1		
Pittosporaceae	*Bursaria spinosa* subsp. *spinosa*	Native Blackthorn				1	4		2	4	3	3	
Plantaginaceae	*Plantago lanceolata*	Lamb's Tongues	*	1			1		1	1			1
Poaceae	*Aristida ramosa*	Purple Wiregrass			2	4	2	2		1	3		
Poaceae	*Aristida vagans*	Threeawn Speargrass					2		2	2	2	1	
Poaceae	*Austrodanthonia racemosa* var. *racemosa*	A Wallaby Grass				2							
Poaceae	*Axonopus fissifolius*	Narrow-leafed Carpet Grass	*	3		3						1	
Poaceae	*Bothriochloa macra*	Red Grass			3			2		1			
Poaceae	*Briza subaristata*		*		2								1
Poaceae	*Chloris divaricata* var. *divaricata*	Slender Chloris				3							
Poaceae	*Chloris gayana*	Rhodes Grass	*			1			2				
Poaceae	*Chloris ventricosa*	Tall Chloris									2		
Poaceae	*Cymbopogon refractus*	Barbed Wire Grass					1		1				
Poaceae	*Cynodon dactylon*	Common Couch		2	2		3	3	3			2	2
Poaceae	*Dichelachne micrantha*	Shorthair Plumegrass				1					1		
Poaceae	*Ehrharta erecta*	Panic Veldtgrass	*							2			
Poaceae	*Entolasia stricta*	Wiry Panic							1				
Poaceae	*Eragrostis brownii*	Brown's Lovegrass		1									
Poaceae	*Eragrostis curvula*	African Lovegrass	*			1		1	3				1

Family	Scientific Name	Common Name	Exotic	8	19	24	28	30	31	32	35	37	42
Poaceae	*Eragrostis leptostachya*	Paddock Lovegrass				2	2	2	2		1		
Poaceae	*Microlaena stipoides* var. *stipoides*	Weeping Grass			3	2	3			4	2		
Poaceae	*Panicum decompositum* var. *tenuius*							2	1				
Poaceae	*Paspalum dilatatum*	Paspalum	*	3	4	1	4	3		2		2	1
Poaceae	*Setaria parviflora*		*	2	3	3	3	3		2	1	3	2
Poaceae	*Sporobolus africanus*	Parramatta Grass	*								1		1
Poaceae	*Sporobolus creber*	Slender Rat's Tail Grass					2	2		1	3		
Poaceae	*Sporobolus elongatus*	Slender Rat's Tail Grass		2	1								
Poaceae	*Themeda australis*	Kangaroo Grass		5	4	2	4	5	4		2	5	6
Portulacaceae	*Portulaca oleracea*	Pigweed							2				
Ranunculaceae	*Clematis aristata*	Old Man's Beard									1		
Rosaceae	*Rubus fruticosus* sp. agg.	Blackberry complex	*								1		
Rubiaceae	*Asperula conferta*	Common Woodruff		2				1					
Rubiaceae	*Galium gaudichaudii*	Rough Bedstraw					1						
Rubiaceae	*Opercularia aspera*	Coarse Stinkweed											1
Rubiaceae	*Opercularia varia*	Variable Stinkweed								1			
Santalaceae	*Exocarpos cupressiformis*	Cherry Ballart									1		
Solanaceae	*Lycium ferocissimum*	African Boxthorn	*						2				
Solanaceae	*Solanum nigrum*	Black-berry Nightshade	*							1	1		
Solanaceae	*Solanum prinophyllum*	Forest Nightshade							1	2	1		
Solanaceae	*Solanum sisymbriifolium*		*			1			1	1	1		
Stackhousiaceae	*Stackhousia viminea*	Slender Stackhousia									2		
Sterculiaceae	*Brachychiton populneus*	Kurrajong									1		
Verbenaceae	*Verbena bonariensis*	Purpletop	*	1	2	2					2	1	
Verbenaceae	*Verbena hispida*	Rough Verbena	*		1								1
Verbenaceae	*Verbena rigida* var. *rigida*	Veined Verbena	*							1			

Note: 1 – *Cover abundance rankings within each survey area:* **1** Foliage sparsely or very sparsely present, cover less than 5%; **2** 1-5% Plentiful, foliage cover 1-5 %; **3** 5-25% foliage cover; **4** 26-50% foliage cover; **5** 51-75% foliage cover; **6** 76-100% foliage cover; **x** – opportunistic record.

Appendix Table 10 Plant species recorded in Good and Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529) and in Good condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)

Family	Scientific Name	Common Name	Plot/transect									
			Exotic	1	2	21	36	38	39	40	41	43
Acanthaceae	*Brunoniella australis*	Blue Trumpet		2	2	2		1		3		1
Acanthaceae	*Brunoniella pumilio*	Dwarf Blue Trumpet					2					
Adiantaceae	*Cheilanthes sieberi subsp. sieberi*	Rock Fern		1					1	1	2	2
Agavaceae	*Yucca aloifolia*	Spanish Bayonet	*							x		
Amaranthaceae	*Alternanthera denticulata*	Lesser Joyweed		x	1							
Amaranthaceae	*Alternanthera pungens*	Khaki Weed	*									1
Amaranthaceae	*Gomphrena celosioides*	Gomphrena Weed	*				1				1	
Amaranthaceae	*Nyssanthes diffusa*	Barbwire Weed					1					
Anthericaceae	*Caesia parviflora var. parviflora*									2		
Anthericaceae	*Caesia parviflora var. vittata*			2								
Anthericaceae	*Caesia sp.*						1				1	
Anthericaceae	*Laxmannia gracilis*	Slender Wire Lily		1								1
Apiaceae	*Daucus glochidiatus*	Native Carrot								x		
Apocynaceae	*Araujia sericifera*	Moth Vine	*			2		1		2		
Asparagaceae	*Asparagus asparagoides*	Bridal Creeper	*							1		
Aspleniaceae	*Asplenium flabellifolium*	Bird's Nest Fern									1	
Asteraceae	*Bidens pilosa*	Cobbler's Pegs	*		2	2	1	2		1		1
Asteraceae	*Bidens subalternans*	Greater Beggar's Ticks	*	1	3	2		1				
Asteraceae	*Calotis lappulacea*	Yellow Burr-daisy								x		
Asteraceae	*Cassinia uncata*	Sticky Cassinia		x								
Asteraceae	*Cirsium vulgare*	Spear Thistle	*			1		1		1	1	
Asteraceae	*Conyza bonariensis*	Flaxleaf Fleabane	*		2	1						
Asteraceae	*Conyza sumatrensis*	Tall fleabane	*								1	
Asteraceae	*Cymbonotus lawsonianus*	Bear's Ear					1				1	
Asteraceae	*Euchiton sphaericus*	Star Cudweed					1					
Asteraceae	*Lagenifera stipitata*	Blue Bottle-daisy		1						1		

Family	Scientific Name	Common Name	Plot/transect									
			Exotic	1	2	21	36	38	39	40	41	43
Asteraceae	*Senecio hispidulus*	Hill Fireweed								x		
Asteraceae	*Senecio madagascariensis*	Fireweed	*		1	1	2		2		1	1
Asteraceae	*Sigesbeckia orientalis subsp. orientalis*	Indian Weed			3	3	2	2				
Asteraceae	*Solenogyne bellioides*	Solengyne					1			x		
Asteraceae	*Soliva sessilis*	Bindyi	*									1
Asteraceae	*Sonchus oleraceus*	Common Sowthistle	*				1					1
Asteraceae	*Taraxacum officinale*	Dandelion	*						1			2
Asteraceae	*Vernonia cinerea*			2						1		
Asteraceae	*Vittadinia cuneata*	A Fuzzweed			1							
Boraginaceae	*Echium plantagineum*	Patterson's Curse	*								1	
Brassicaceae	*Lepidium sp.*	A Peppercress	*			1						
Campanulaceae	*Wahlenbergia communis*	Tufted Bluebell								x		
Campanulaceae	*Wahlenbergia gracilis*	Sprawling Bluebell							1			
Campanulaceae	*Wahlenbergia stricta*	Tall Bluebell										1
Chenopodiaceae	*Einadia hastata*	Berry Saltbush		2						1		1
Chenopodiaceae	*Einadia nutans subsp. nutans*	Climbing Saltbush		1	1		1			1		1
Chenopodiaceae	*Einadia polygonoides*	Knotweed Goosefoot			1							
Chenopodiaceae	*Einadia trigonos subsp. Trigonos*					3		3				1
Clusiaceae	*Hypericum gramineum*	Small St John's Wort				1			1			
Commelinaceae	*Commelina cyanea*	Native Wandering Jew		x	2	2		3		1	2	1
Convolvulaceae	*Dichondra repens*	Kidney Weed		2	2	2	2	2		2	2	
Crassulaceae	*Crassula sieberiana*	Australian Stonecrop								x		
Cyperaceae	*Bolboschoenus caldwellii*										1	
Cyperaceae	*Carex inversa*	Knob Sedge			1							
Cyperaceae	*Cyperus gracilis*	Slender Flat-sedge			1	2	1					
Cyperaceae	*Cyperus sp.*									1		
Cyperaceae	*Fimbristylis dichotoma*	Common Fringe-sedge							2			
Cyperaceae	*Lepidosperma laterale*	Variable Sword-sedge		1								1

Family	Scientific Name	Common Name	Plot/transect									
			Exotic	1	2	21	36	38	39	40	41	43
Ericaceae	*Lissanthe strigosa*	Peach Heath		1								
Fabaceae	*Acacia decurrens*	Black Wattle										3
Fabaceae	*Acacia elongata*	Swamp Wattle								x		
Fabaceae	*Acacia implexa*	Hickory Wattle		x								
Fabaceae	*Acacia parramattensis*	Parramatta Wattle		x								
Fabaceae	*Daviesia ulicifolia*	Gorse Bitter Pea		x								
Fabaceae	*Desmodium brachypodum*	Large Tick-trefoil					1			1		
Fabaceae	*Desmodium varians*	Slender Tick-trefoil		1	2	1				1	2	1
Fabaceae	*Dillwynia sieberi*			1								
Fabaceae	*Glycine clandestina*	Twining glycine		1						x		1
Fabaceae	*Glycine microphylla*	Small-leaf Glycine					1	1	1	1		
Fabaceae	*Glycine tabacina*	Variable Glycine		2	1	1	1	1	1	1	2	2
Gentianaceae	*Centaurium sp.*		*						1			
Geraniaceae	*Geranium homeanum*									x	2	
Goodeniaceae	*Goodenia hederacea*	Ivy Goodenia		1								1
Lamiaceae	*Ajuga australis*	Austral Bugle								2		
Lamiaceae	*Mentha satureioides*	Native Pennyroyal				2						
Lamiaceae	*Plectranthus parviflorus*			x	3	1	2	2		2	2	
Lobeliaceae	*Pratia purpurascens*	Whiteroot		1								2
Lomandraceae	*Lomandra filiformis subsp. filiformis*			1								
Lomandraceae	*Lomandra multiflora subsp. multiflora*	Many-flowered Mat-rush		1						1		
Lomandraceae	*Lomandra micrantha subsp. tuberculata*	Small-flowered Mat-rush										1
Loranthaceae	*Amyema gaudichaudii*											2
Malvaceae	*Modiola caroliniana*	Red-flowered Mallow	*		1		1	1			1	
Malvaceae	*Sida cunninghamii*	Ridge Sida									1	
Malvaceae	*Sida rhombifolia*	Paddy's Lucerne	*			3	2	3	1	1	2	1
Myoporaceae	*Eremophila debilis*	Amulla					2			2		
Myrtaceae	*Eucalyptus eugenioides*	Thin-leaved Stringybark								x		

Family	Scientific Name	Common Name	Plot/transect									
			Exotic	1	2	21	36	38	39	40	41	43
Myrtaceae	*Eucalyptus fibrosa*	Red Ironbark		3								1
Myrtaceae	*Eucalyptus moluccana*	Grey Box			4	4	4			4		
Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum					1	4	2	3	1	
Myrtaceae	*Melaleuca decora*			4								4
Myrtaceae	*Melaleuca nodosa*			x								1
Oleaceae	*Olea europaea subsp. cuspidata*	African Olive	*	x	3	3		3		3	3	
Oxalidaceae	*Oxalis corniculata*	Creeping Oxalis	*									1
Oxalidaceae	*Oxalis perennans*				1	1	1		1			
Phyllanthaceae	*Phyllanthus hirtellus*	Thyme Spurge		x								
Phyllanthaceae	*Phyllanthus virgatus*	Wiry Spurge								1	1	
Phytolaccaceae	*Phytolacca octandra*	Inkweed	*			1						1
Pittosporaceae	*Bursaria spinosa subsp. spinosa*	Native Blackthorn		3			1				1	3
Plantaginaceae	*Plantago gaudichaudii*	Narrow Plantain			2	1	1			1	1	
Plantaginaceae	*Plantago lanceolata*	Lamb's Tongues	*			1	1		1		2	
Plantaginaceae	*Veronica plebeia*	Trailing Speedwell									1	1
Poaceae	*Aristida ramosa*	Purple Wiregrass		3						1	3	2
Poaceae	*Aristida vagans*	Threeawn Speargrass		2							2	3
Poaceae	*Austrodanthonia racemosa*	Wallaby Grass		2								
Poaceae	*Austrodanthonia sp.*	A Wallaby Grass									1	
Poaceae	*Austrodanthonia tenuior*	A Wallaby Grass										1
Poaceae	*Austrostipa rudis subsp. nervosa*	A Speargrass		4								
Poaceae	*Bothriochloa macra*	Red Grass			2		2		2		2	
Poaceae	*Chloris divaricata var. divaricata*	Slender Chloris				1						
Poaceae	*Chloris gayana*	Rhodes Grass	*						3			2
Poaceae	*Chloris truncata*	Windmill Grass								1	2	
Poaceae	*Chloris ventricosa*	Tall Chloris					3			3	2	
Poaceae	*Cynodon dactylon*	Common Couch							2		2	1
Poaceae	*Echinopogon caespitosus*	Bushy Hedgehog-grass		1								

Family	Scientific Name	Common Name	Plot/transect									
			Exotic	1	2	21	36	38	39	40	41	43
Poaceae	*Ehrharta erecta*	Panic Veldtgrass	*					2				
Poaceae	*Entolasia stricta*	Wiry Panic		2			1					1
Poaceae	*Eragrostis curvula*	African Lovegrass	*	1								1
Poaceae	*Eragrostis leptostachya*	Paddock Lovegrass		1			1	1	1	1	2	2
Poaceae	*Microlaena stipoides var. stipoides*	Weeping Grass		2		3	3	4		3	3	3
Poaceae	*Oplismenus aemulus*				1	2	2	3				
Poaceae	*Oplismenus imbecillis*					1		1				
Poaceae	*Panicum simile*	Two-colour Panic		1					2	2	1	
Poaceae	*Paspalum dilatatum*	Paspalum	*	1			1		2	1		
Poaceae	*Pennisetum clandestinum*	Kikuyu Grass	*								2	
Poaceae	*Poa labillardierei*	Tussock									x	
Poaceae	*Setaria parviflora*		*				2	1	2		1	3
Poaceae	*Setaria pumila*	Pale Pigeon Grass	*	1					1			
Poaceae	*Sporobolus creber*	Slender Rat's Tail Grass		2			1					2
Poaceae	*Sporobolus elongatus*	Slender Rat's Tail Grass					2				2	
Poaceae	*Themeda australis*	Kangaroo Grass		1					5	2	2	
Polygonaceae	*Rumex brownii*	Swamp Dock						1			1	
Ranunculaceae	*Clematis glycinoides var. glycinoides*									x		
Rubiaceae	*Asperula conferta*	Common Woodruff					1			1	2	
Rubiaceae	*Coprosma quadrifida*	Prickly Currant Bush		x								
Rubiaceae	*Opercularia aspera*	Coarse Stinkweed							1			
Rubiaceae	*Opercularia varia*	Variable Stinkweed		1								
Rubiaceae	*Pomax umbellata*	Pomax		1								
Santalaceae	*Exocarpos cupressiformis*	Cherry Ballart										1
Santalaceae	*Exocarpos strictus*	Dwarf Cherry		x								
Sapindaceae	*Dodonaea viscosa subsp. cuneata*	Wedge-leaf Hop-bush		1								
Solanaceae	*Cestrum parqui*	Green Cestrum	*									1
Solanaceae	*Lycium ferocissimum*	African Boxthorn	*		3	2	2					

Family	Scientific Name	Common Name	Plot/transect									
			Exotic	1	2	21	36	38	39	40	41	43
Solanaceae	*Solanum nigrum*	Black-berry Nightshade	*		1	1	1					
Solanaceae	*Solanum prinophyllum*	Forest Nightshade			1	1	1	2		1		
Solanaceae	*Solanum pseudocapsicum*	Madeira Winter Cherry	*			1	1	1				
Solanaceae	*Solanum pungetium*	Eastern Nightshade				1						
Solanaceae	*Solanum sisymbriifolium*		*	1		1						1
Verbenaceae	*Lantana camara*	Lantana	*		3					1		
Verbenaceae	*Verbena bonariensis*	Purpletop	*				1		1		1	
Vitaceae	*Clematicissus opaca*	Pepper Vine							x			1

Note: 1 – *Cover abundance rankings within each survey area:* **1** Foliage sparsely or very sparsely present, cover less than 5%; **2** 1-5% Plentiful, foliage cover 1-5 %; **3** 5-25% foliage cover; **4** 26-50% foliage cover; **5** 51-75% foliage cover; **6** 76-100% foliage cover; **x** – opportunistic record.

Appendix Table 11 Plant species recorded in Good and Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)

Family	Scientific Name	Common Name	Exotic	9	13	14	15	17	18	26	27	29	33	34
Acanthaceae	*Brunoniella australis*	Blue Trumpet		1	2		2	2	2	2	2	3		1
Adiantaceae	*Cheilanthes sieberi subsp. sieberi*	Rock Fern					1				2		2	2
Amaranthaceae	*Alternanthera denticulata*	Lesser Joyweed		1		1		2		1		2		
Amaranthaceae	*Alternanthera pungens*	Khaki Weed	*									1		
Amaranthaceae	*Gomphrena celosioides*	Gomphrena Weed	*		1				1	1	1			
Anthericaceae	*Caesia parviflora var. parviflora*									1				
Anthericaceae	*Tricoryne elatior*	Yellow Autumn-lily								1	1			
Apiaceae	*Centella asiatica*	Indian Pennywort		1	2		1	1			2	2		
Apocynaceae	*Araujia sericifera*	Moth Vine	*	1	1			1	2					
Apocynaceae	*Parsonsia straminea*	Common Silkpod			x									
Arecaceae	*Phoenix canariensis*	Canary Island Date Palm	*									x		
Asparagaceae	*Asparagus asparagoides*	Bridal Creeper	*	3			2	1				1		
Asteraceae	*Bidens pilosa*	Cobbler's Pegs	*	1				2	2	1			2	
Asteraceae	*Bidens subalternans*	Greater Beggar's Ticks	*	1	1	2	1		2					
Asteraceae	*Cirsium vulgare*	Spear Thistle	*	1	1	1		1		1				
Asteraceae	*Conyza bonariensis*	Flaxleaf Fleabane	*	1				1						
Asteraceae	*Cymbonotus lawsonianus*	Bear's Ear											1	
Asteraceae	*Epaltes australis*	Spreading Nut-heads							x			1		
Asteraceae	*Gamochaeta calviceps*	Cudweed	*								1	1		
Asteraceae	*Lagenifera stipitata*	Blue Bottle-daisy												1
Asteraceae	*Ozothamnus diosmifolius*	White Dogwood										x		
Asteraceae	*Senecio madagascariensis*	Fireweed	*	1	1		1	1	1		1		1	1
Asteraceae	*Sigesbeckia orientalis subsp. orientalis*	Indian Weed							1					
Asteraceae	*Solenogyne bellioides*	Solengyne			1						1			
Asteraceae	*Soliva sessilis*	Bindyi	*											1
Asteraceae	*Sonchus oleraceus*	Common Sowthistle	*	1		1		1					1	1

Family	Scientific Name	Common Name	Exotic	9	13	14	15	17	18	26	27	29	33	34
Asteraceae	*Vernonia cinerea var. cinerea*											1		
Asteraceae	*Vittadinia cuneata*	A Fuzzweed		1										
Asteraceae	*Vittadinia pustulata*	Fuzzweed						1			1			
Asteraceae	*Xanthium occidentale*	Noogoora Burr	*					1						
Basellaceae	*Anredera cordifolia*	Madeira Vine	*		x									
Brassicaceae	*Rorippa palustris*	Yellow Cress	*					1						
Cactaceae	*Opuntia stricta*	Common Prickly Pear, Smooth Pest Pear	*		1									
Campanulaceae	*Wahlenbergia gracilis*	Sprawling Bluebell						1				1		
Casuarinaceae	*Casuarina glauca*	Swamp Oak		4	3	4			3					
Chenopodiaceae	*Atriplex prostrata*		*	1				1						
Chenopodiaceae	*Chenopodium album*	Fat Hen	*			1		1						2
Chenopodiaceae	*Einadia hastata*	Berry Saltbush		2	1	1		1	1	1	1		2	2
Chenopodiaceae	*Einadia nutans subsp. nutans*	Climbing Saltbush		3	1			1					1	
Chenopodiaceae	*Einadia polygonoides*	Knotweed Goosefoot		1										1
Chenopodiaceae	*Einadia trigonos subsp. Trigonos*			2		2								
Clusiaceae	*Hypericum perforatum*	St. Johns Wort	*	1										
Commelinaceae	*Commelina cyanea*	Native Wandering Jew		2	1	2	1	2		2			3	
Convolvulaceae	*Dichondra repens*	Kidney Weed		1	2	2	1	1	2	2		2		1
Crassulaceae	*Bryophyllum delagoense*	Mother of millions	*						1					
Cyperaceae	*Carex sp.*						1							
Cyperaceae	*Cyperus gracilis*	Slender Flat-sedge		1	1					2	1			1
Cyperaceae	*Cyperus polystachyos*			1				2				1		
Cyperaceae	*Eleocharis cylindrostachys*							2				2		
Cyperaceae	*Fimbristylis dichotoma*	Common Fringe-sedge								1	1	1	1	1
Ericaceae	*Astroloma humifusum*	Native Cranberry									2			
Ericaceae	*Lissanthe strigosa*	Peach Heath					1							
Euphorbiaceae	*Ricinus communis*	Castor Oil Plant	*									x		
Fabaceae	*Acacia decurrens*	Black Wattle					3	2	1					

Family	Scientific Name	Common Name	Exotic	9	13	14	15	17	18	26	27	29	33	34
Fabaceae	*Desmodium varians*	Slender Tick-trefoil					2		1					1
Fabaceae	*Dillwynia sieberi*							1						
Fabaceae	*Glycine microphylla*	Small-leaf Glycine			1	1	2		1	1		1		
Fabaceae	*Glycine tabacina*	Variable Glycine		1	2			1			1	2		
Fabaceae	*Senna pendula var. glabrata*		*					x						
Fabaceae	*Trifolium subterraneum*	Subterranean Clover	*					1						
Haloragaceae	*Myriophyllum variifolium*							2						
Juncaceae	*Juncus acutus subsp. acutus*	Sharp Rush	*								1			
Juncaceae	*Juncus usitatus*							1		1				
Juncaginaceae	*Triglochin microtuberosa*			2				2						
Lamiaceae	*Mentha satureioides*	Native Pennyroyal							1					
Lamiaceae	*Plectranthus parviflorus*						2		1					
Lemnaceae	*Lemna disperma*							2						
Lemnaceae	*Lemna sp.*				x									
Lobeliaceae	*Pratia purpurascens*	Whiteroot					1							
Lomandraceae	*Lomandra filiformis subsp. filiformis*				1			1					1	
Malvaceae	*Modiola caroliniana*	Red-flowered Mallow	*	1										
Malvaceae	*Sida rhombifolia*	Paddy's Lucerne	*	2	2	2	2	2	2	2	2	2	2	1
Marsileaceae	*Marsilea mutica*							2						
Myoporaceae	*Eremophila debilis*	Amulla		2	1	1		1		2				
Myrtaceae	*Angophora subvelutina*	Broad-leaved Apple					x							
Myrtaceae	*Eucalyptus amplifolia subsp. Amplifolia*				2		3	3		4				3
Myrtaceae	*Eucalyptus baueriana*	Blue Box			x									
Myrtaceae	*Eucalyptus eugenioides*	Thin-leaved Stringybark			x				x			x	3	
Myrtaceae	*Eucalyptus moluccana*	Grey Box		4	4			4	4	4	2	4		1
Myrtaceae	*Eucalyptus tereticornis*	Forest Red Gum			3	x	3					3		
Myrtaceae	*Kunzea ambigua*	Tick Bush									1			
Myrtaceae	*Melaleuca armillaris subsp. armillaris*	Bracelet Honey-myrtle										x		
Myrtaceae	*Melaleuca decora*												4	

Family	Scientific Name	Common Name	Exotic	9	13	14	15	17	18	26	27	29	33	34
Myrtaceae	*Melaleuca linariifolia*	Flax-leaved Paperbark			x	x				1	3			
Myrtaceae	*Melaleuca styphelioides*	Prickly-leaved Tea Tree		1	1	x	3			3			3	
Oleaceae	*Ligustrum lucidum*	Large-leaved Privet	*				3							
Oleaceae	*Ligustrum sinense*	Small-leaved Privet	*				1							
Oleaceae	*Notelaea longifolia*	Large Mock-olive			x									
Oleaceae	*Olea europaea subsp. cuspidata*	African Olive	*	3	1		3	2	4	2	3	4	2	
Onagraceae	*Ludwigia peruviana*		*	2										
Oxalidaceae	*Oxalis corniculata*	Creeping Oxalis	*	1		1								
Oxalidaceae	*Oxalis perennans*				1		1		1	1		1		1
Phormiaceae	*Dianella revoluta var. revoluta*	A Blue Flax Lily						1						
Phyllanthaceae	*Phyllanthus virgatus*	Wiry Spurge			1					1	1	1	1	
Pittosporaceae	*Bursaria spinosa subsp. spinosa*	Native Blackthorn		4	1	x	3	4	4	3	3	2		
Plantaginaceae	*Plantago gaudichaudii*	Narrow Plantain									1			
Plantaginaceae	*Plantago lanceolata*	Lamb's Tongues	*			1	1			1				
Plantaginaceae	*Veronica plebeia*	Trailing Speedwell		1							1			
Poaceae	*Aristida ramosa*	Purple Wiregrass		1	1			2		2	1	2	1	
Poaceae	*Aristida vagans*	Threeawn Speargrass		1							3		2	
Poaceae	*Austrodanthonia racemosa var. racemosa*	A Wallaby Grass		1	1			1						
Poaceae	*Austrodanthonia tenuior*	A Wallaby Grass									2			
Poaceae	*Bothriochloa macra*	Red Grass			1				1	2	2	1		1
Poaceae	*Bromus catharticus*	Praire Grass	*							1				
Poaceae	*Chloris divaricata var. divaricata*	Slender Chloris		2	2			1	2		2			1
Poaceae	*Chloris gayana*	Rhodes Grass	*					3		1			1	
Poaceae	*Chloris truncata*	Windmill Grass										1		
Poaceae	*Chloris ventricosa*	Tall Chloris								2	1	2		2
Poaceae	*Cortaderia selloana*	Pampas Grass	*										x	
Poaceae	*Cymbopogon refractus*	Barbed Wire Grass							1	1				
Poaceae	*Cynodon dactylon*	Common Couch		2		1		2		2	2	3		2
Poaceae	*Dichelachne micrantha*	Shorthair Plumegrass									1			

Family	Scientific Name	Common Name	Exotic	9	13	14	15	17	18	26	27	29	33	34
Poaceae	*Echinochloa crus-galli*	Barnyard Grass	*					1				2		
Poaceae	*Echinopogon caespitosus*	Bushy Hedgehog-grass					1							
Poaceae	*Echinopogon ovatus*	Forest Hedgehog Grass							1					
Poaceae	*Ehrharta erecta*	Panic Veldtgrass	*	2	1	2	2			1			2	2
Poaceae	*Entolasia marginata*	Bordered Panic								1				
Poaceae	*Entolasia stricta*	Wiry Panic		1			1							
Poaceae	*Eragrostis curvula*	African Lovegrass	*							1	1		2	
Poaceae	*Eragrostis leptostachya*	Paddock Lovegrass		1	1	1			1	1	2	2		
Poaceae	*Eriochloa pseudoacrotricha*	Early Spring Grass			2			2			1	3		
Poaceae	*Microlaena stipoides var. stipoides*	Weeping Grass		3	2	3	4	2	4		2	3	4	4
Poaceae	*Oplismenus aemulus*						1		3					
Poaceae	*Oplismenus imbecillis*				1		2							
Poaceae	*Panicum simile*	Two-colour Panic									1			
Poaceae	*Paspalum dilatatum*	Paspalum	*		3	4	1	2	2	1	2			2
Poaceae	*Pennisetum clandestinum*	Kikuyu Grass	*					1		1				
Poaceae	*Poa affinis*											1		
Poaceae	*Setaria parviflora*		*	2	2	2	1	2	2	2	3	2	2	1
Poaceae	*Setaria pumila*	Pale Pigeon Grass	*			3								
Poaceae	*Sporobolus africanus*	Parramatta Grass	*											1
Poaceae	*Sporobolus creber*	Slender Rat's Tail Grass									1			3
Poaceae	*Sporobolus elongatus*	Slender Rat's Tail Grass				1						1		
Poaceae	*Themeda australis*	Kangaroo Grass			3		2		2		1			
Polygonaceae	*Persicaria decipiens*	Slender Knotweed										x		
Polygonaceae	*Persicaria hydropiper*	Water Pepper						3						
Polygonaceae	*Rumex brownii*	Swamp Dock		1				1						
Proteaceae	*Grevillea robusta*	Silky Oak			x									
Ranunculaceae	*Clematis aristata*	Old Man's Beard			x									
Ranunculaceae	*Clematis glycinoides*	Headache Vine					2							
Rosaceae	*Rubus fruticosus sp. agg.*	Blackberry complex	*		x			1				x		

Family	Scientific Name	Common Name	Exotic	9	13	14	15	17	18	26	27	29	33	34
Rubiaceae	*Asperula conferta*	Common Woodruff			1									
Rubiaceae	*Galium gaudichaudii*	Rough Bedstraw		1			1		1		1			
Santalaceae	*Exocarpos strictus*	Dwarf Cherry						3						
Sapindaceae	*Dodonaea viscosa* subsp. *angustissima*	Narrow-leaf Hop-bush											x	
Solanaceae	*Cestrum parqui*	Green Cestrum	*					x				x		
Solanaceae	*Lycium ferocissimum*	African Boxthorn	*	1	1					2				
Solanaceae	*Solanum laxum*	Potato Climber	*	1										
Solanaceae	*Solanum nigrum*	Black-berry Nightshade	*	1				1		1				
Solanaceae	*Solanum prinophyllum*	Forest Nightshade		1	1		2			1		1	1	
Solanaceae	*Solanum pseudocapsicum*	Madeira Winter Cherry	*	1	1				1	1				
Solanaceae	*Solanum sisymbriifolium*		*						1	1		1		1
Solanaceae	*Solanum sp.*		*	1										
Stackhousiaceae	*Stackhousia viminea*	Slender Stackhousia									1			
Verbenaceae	*Lantana camara*	Lantana	*				1		1					
Verbenaceae	*Verbena bonariensis*	Purpletop	*	1			1		1					
Verbenaceae	*Verbena hispida*	Rough Verbena	*					1	1					

Note: 1 – *Cover abundance rankings within each survey area:* **1** Foliage sparsely or very sparsely present, cover less than 5%; **2** 1-5% Plentiful, foliage cover 1-5 %; **3** 5-25% foliage cover; **4** 26-50% foliage cover; **5** 51-75% foliage cover; **6** 76-100% foliage cover; **x** – opportunistic record.

Appendix Table 12 Plant species recorded in Good condition artificial freshwater wetland on floodplain (HN630)

Family	Scientific Name	Common Name	Exotic	Targeted frog survey 2	Targeted frog survey 4	Targeted frog survey 5	Targeted frog survey 8	Targeted frog survey 9	Targeted frog survey 10	Targeted frog survey 11
Alismataceae	*Damasonium minus*	Starfruit			x					
Amaranthaceae	*Alternanthera denticulata*	Lesser Joyweed								x
Apiaceae	*Centella asiatica*	Indian Pennywort								x
Cyperaceae	*Cyperus brevifolius*		*						x	
Cyperaceae	*Cyperus difformis*	Dirty Dora		x					x	
Cyperaceae	*Cyperus haspan subsp. haspan*				x					
Cyperaceae	*Cyperus polystachyos*				x					
Cyperaceae	*Cyperus sanguinolentus*							x		
Cyperaceae	*Eleocharis cylindrostachys*							x		
Cyperaceae	*Eleocharis sphacelata*	Tall Spike Rush					x		x	x
Cyperaceae	*Schoenoplectus validus*					x				
Haloragaceae	*Myriophyllum sp.*					x				
Haloragaceae	*Myriophyllum variifolium*							x		
Hydrocharitaceae	*Ottelia ovalifolia subsp. ovalifolia*	Swamp Lily		x		x				
Juncaceae	*Juncus acutus subsp. acutus*	Sharp Rush	*		x					
Juncaceae	*Juncus usitatus*			x	x	x	x	x		
Juncaginaceae	*Triglochin rheophila*			x						
Lobeliaceae	*Isotoma fluviatilis*	Swamp Isotome						x		
Marsileaceae	*Marsilea mutica*				x	x			x	x

Family	Scientific Name	Common Name	Exotic	Targeted frog survey 2	Targeted frog survey 4	Targeted frog survey 5	Targeted frog survey 8	Targeted frog survey 9	Targeted frog survey 10	Targeted frog survey 11
Myrtaceae	*Eucalyptus amplifolia subsp. Amplifolia*				x					
Myrtaceae	*Eucalyptus moluccana*	Grey Box			x					
Myrtaceae	*Melaleuca styphelioides*	Prickly-leaved Tea Tree		x						
Onagraceae	*Ludwigia peploides subsp. montevidensis*	Water Primrose				x				
Onagraceae	*Ludwigia peruviana*		*							x
Philydraceae	*Philydrum lanuginosum*	Frogsmouth			x	x				x
Poaceae	*Bothriochloa macra*	Red Grass						x		
Poaceae	*Cynodon dactylon*	Common Couch		x						
Poaceae	*Themeda australis*	Kangaroo Grass						x		
Polygonaceae	*Persicaria sp.*	Knotweed	*		x					
Potamogetonaceae	*Potamogeton crispus*	Curly Pondweed		x						
Typhaceae	*Typha orientalis*	Broad-leaved Cumbungi		x				x	x	x

Notes- 1. **x**: recorded.

Appendix Table 13 Plot/transect data

Vegetation Type ID	Plot ID	Native plant species richness	Native over-storey cover	Native mid-storey cover	Native ground cover (grasses)	Native ground cover (shrubs)	Native ground cover (other)	Exotic plant cover	Number of trees with hollows	Over storey regeneration	Total length of fallen logs	Easting	Northing	Zone
Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)														
HN528	Bench-mark	29	20.5-25.5	25.5-30.5	26.8-30.8	0-5	14.8-18.8	0	> = 0	1	> = 0			
	2	25	31	0.2	8	0	32	30	0	1	4	288802	6248373	56
	5	31	15.5	19	60	10	12	34	0	1	9	288973	6247709	56
	6	24	23	31	62	8	44	14	0	1	0	288791	6247303	56
	7	37	25	3.5	64	0	32	24	1	1	2	288762	6246421	56
	10	17	15.5	17.5	50	2	70	52	0	1	5.5	288486	6246492	56
	11	39	19	18.5	30	2	44	84	0	1	0	287178	6246508	56
	12	30	24	20	40	2	46	21	0	1	7.5	287940	6247231	56
	16	25	13	22.5	18	0	26	30	0	1	0	290521	6247693	56
	22	35	15.5	3	24	0	66	70	0	1	0	290384	6248799	56
	23	33	13	0.5	30	0	52	20	0	1	0	290020	6248327	56
	25	37	22	26.5	64	10	34	14	0	1	2	291230	6249070	56
	31	28	30	6	50	4	16	40	0	1	55	288224	6248287	56
	32	21	25	6.2	42	2	54	28	0	1	27	291216	6248011	56
	35	33	12.5	4	64	4	34	10	0	1	2	287696	6247808	56
	Avg.	29.6	20.3	12.7	43.3	3.1	40.1	33.6	0.1	1	8.1			
Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)														
HN528	Bench-mark	29	20.5-25.5	25.5-30.5	26.8-30.8	0-5	14.8-18.8	0	> = 0	1	> = 0			
	8	11	0	0	60	0	8	76	0	1	2.5	288711	6246316	56
	19	11	0	0	50	0	6	82	0	1	0	285294	6246653	56
	24	27	4.5	0	60	0	4	62	0	1	2	291274	6248951	56
	28	20	0	22.5	62	2	16	64	0	1	0	287867	6248140	56
	30	18	0	0	54	58	0	6	0	1	0	288269	6248478	56

Vegetation Type ID	Plot ID	Native plant species richness	Native over-storey cover	Native mid-storey cover	Native ground cover (grasses)	Native ground cover (shrubs)	Native ground cover (other)	Exotic plant cover	Number of trees with hollows	Over storey regeneration	Total length of fallen logs	Easting	Northing	Zone
	37	9	0	0.7	72	0	2	38	0	1	0	286697	6247210	56
	42	12	0	0	82	0	6	36	0	1	0	287673	6246850	56
	Avg.	15.4	0.6	3.3	62.9	8.6	6.0	52.0	0	1	0.6			
Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)														
HN529	Bench-mark	29	18.5-23.5	20-30	23-31	0-5	11.75-19.75	0	> = 0	1	> = 0			
	20	19	12.5	0	38	2	54	42	0	1	2	285969	6246951	56
	21	20	27.5	1	32	0	48	44	1	1	23	286501	6246518	56
	36	30	15	0.2	68	0	24	40	0	1	22	286260	6246850	56
	38	15	13.5	9.5	88	0	28	24	0	1	23	286965	6246970	56
	40	42	19.5	23	82	0	30	26	0	1	12.5	288239	6246491	56
	Avg.	25.2	17.6	6.7	61.6	0.4	36.8	35.2	0.2	1	16.5			
Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)														
HN529	Bench-mark	29	18.5-23.5	20-30	23-31	0-5	11.75-19.75	0	> = 0	1	> = 0			
	39	15	0	0.5	62	0	6	40	0	1	0	286389	6246721	56
	41	32	0	0	56	0	46	34	0	1	0	288059	6246493	56
	Avg.	23.5	0.0	0.3	59.0	0.0	26.0	37.0	0	1	0			
Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)														
HN526	Bench-mark	24	27.5-32.5	21-31	24.45-30.45	0-10	24.45-30.45	0	> = 1	1	> = 50			
	9	31	22.5	3.5	14	0	34	76	0	1	65	288674	6245964	56
	13	39	17	6.8	24	0	40	78	0	1	0.5	291043	6246896	56
	15	27	13	17.5	80	2	22	20.5	3	1	22	290362	6246764	56
	17	34	16	25	62	38	4	30	2	1	6	290999	6249167	56
	18	24	23.5	13	34	62	2	36	0	1	57	285412	6246670	56
	26	27	18	19.5	16	70	0	30	0	1	32	288076	6248308	56
	29	32	17	0.5	36	18	0	16	1	1	30	287987	6247873	56

Vegetation Type ID	Plot ID	Native plant species richness	Native over-storey cover	Native mid-storey cover	Native ground cover (grasses)	Native ground cover (shrubs)	Native ground cover (other)	Exotic plant cover	Number of trees with hollows	Over storey regeneration	Total length of fallen logs	Easting	Northing	Zone
	33	15	6.5	49	40	0	26	32	1	1	0			56
	Avg.	28.6	16.7	16.9	38.3	23.8	16.0	39.8	0.9	1	26.6	288936.1	6247377.4	
Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)														
HN526	Bench-mark	24	27.5-32.5	21-31	24.45-30.45	0-10	24.45-30.45	0	> = 1	1	> = 50			
	14	16	28.5	1.5	26	0	36	80	0	1	36	291160	6247177	56
	27	34	0	4.8	48	60	0	6	0	1	5	287973	6247981	56
	34	18	5	0	64	0	8	6	0	1	0	291563	6247266	56
	Avg.	22.7	11.2	2.1	46.0	20.0	14.7	30.7	0	1	13.7			
Good condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)														
HN512	Bench-mark	38	15.1-25.6	13.8-30.3	14.7-24.6	0-10	14.7-24.6	0	> = 0	1	> = 0			
	1	47	21.5	21.5	46	4	26	0	0	1	3	291848	6248951	56
Poor condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)														
HN512	Bench-mark	38	15.1-25.6	13.8-30.3	14.7-24.6	0-10	14.7-24.6	0	> = 0	1	> = 0			
	43	32	0	22.5	24	0	4	4	0	1	4	291815	6249035	
Exotic grassland														
HN528	Bench-mark	0	-	-	-	-	-	0	> =	1	> =			
	3	9	0	0	50	0	2	64	0	1	0	288754	6248196	56
	4	14	0.5	0	20	0	2	88	0	1	0	288661	6247838	56
	Avg.	11.5	0.3	0.0	35.0	0.0	2.0	76.0	0	1	0			

Appendix Table 14 Fauna species recorded in broad habitat types at the airport site

Scientific Name	Common Name	Exotic	TSC Status	EPBC Status	Woodland/pad dock trees	Dams/Wetlands	Riparian Corridor	Grassland and Cleared Land	SMEC (2014)	Biosis (1997)
Fish										
Anguilla reinhardtii	Eel					O				
Gambusia holbrooki	Mosquito Fish	*				W				
Amphibians										
Pseudophryne bibronii	Bibron's Toadlet					O				
Litoria latopalmata	Broad-palmed Frog					O				W
Limnodynastes peronii	Brown-striped Frog					W				W
Crinia signifera	Common Eastern Froglet					OW	W		W	W
Litoria fallax	Eastern Dwarf Tree Frog							O		W
Litoria peronii	Peron's Tree Frog					OW	W			W
Uperoleia laevigata	Smooth Toadlet					W				W
Limnodynastes tasmaniensis	Spotted Grass Frog					OW	O	W		W
Litoria tyleri	Tyler's Tree Frog									W
Litoria verreauxii	Verreaux's Frog					W	W			W
Uperoleia rugosa	Wrinkled Toadlet							W		
Birds										
Anhinga novaehollandiae	Australasian Darter					O		W		O
Tachybaptus novaehollandiae	Australasian Grebe					O			O	O
Anas rhynchotis	Australasian Shoveler					O				
Falco longipennis	Australian Hobby				OW					O
Alisterus scapularis	Australian King-Parrot				O					
Cracticus tibicen	Australian Magpie				OW			W	O	O

Scientific Name	Common Name	Exotic	TSC Status	EPBC Status	Woodland/paddock trees	Dams/Wetlands	Riparian Corridor	Grassland and Cleared Land	SMEC (2014)	Biosis (1997)
Aegotheles cristatus	Australian Owlet-nightjar				O					
Pelecanus conspicillatus	Australian Pelican				O					O
Anthus novaeseelandiae	Australian Pipit							O		O
Corvus coronoides	Australian Raven				O			O	O	O
Acrocephalus australis	Australian Reed-Warbler					O				
Aerodramus terraereginae	Australian Swiftlet							O		
Threskiornis molucca	Australian White Ibis					O				
Chenonetta jubata	Australian Wood Duck					O			O	O
Ceyx azureus	Azure Kingfisher					O		O		O
Geopelia humeralis	Bar-shouldered Dove						OW		O	
Manorina melanophrys	Bell miner				O		W		OW	W
Ixobrychus flavicollis	Black Bittern		V				O			
Milvus migrans	Black kite							O		
Cygnus atratus	Black Swan					OW				
Coracina novaehollandiae	Black-faced Cuckoo-shrike				O		O		O	O
Elseyornis melanops	Black-fronted Dotterel					O				O
Elanus axillaris	Black-shouldered Kite							O		O
Himantopus himantopus	Black-winged Stilt					O				O
Oxyura australis	Blue-billed Duck		V			O				
Falco berigora	Brown Falcon				O				O	O
Accipiter fasciatus	Brown Goshawk				W					
Coturnix ypsilophora	Brown Quail							O		
Cincloramphus cruralis	Brown Songlark									O
Acanthiza pusilla	Brown Thornbill				O					

Scientific Name	Common Name	Exotic	TSC Status	EPBC Status	Woodland/pad dock trees	Dams/Wetlands	Riparian Corridor	Grassland and Cleared Land	SMEC (2014)	Biosis (1997)
Gallirallus philippensis	Buff-banded Rail				O					
Acanthiza reguloides	Buff-rumped Thornbill				O					
Ardea ibis	Cattle Egret			C,J		O		O		
Anas castanea	Chestnut Teal					O			O	
Sturnus tristis	Common Myna	*			OW		O		O	O
Sturnus vulgaris	Common Starling	*			W	O				O
Ocyphaps lophotes	Crested Pigeon				OW		O	W	O	O
Platycercus elegans	Crimson Rosella				OW		O		O	O
Taeniopygia bichenovii	Double-barred Finch				OW		O		O	O
Gallinula tenebrosa	Dusky Moorhen				O	O			O	O
Artamus cyanopterus	Dusky Woodswallow							O		O
Tyto javanica	Eastern Barn Owl				OW					O
Ardea modesta	Eastern Great Egret					O				
Platycercus eximius	Eastern Rosella				O		O		O	O
Falcunculus frontatus frontatus	Eastern Shrike-tit				O					
Acanthorhynchus tenuirostris	Eastern Spinebill				OW					
Eopsaltria australis	Eastern Yellow Robin				O		O		O	O
Turdus merula	Eurasian Blackbird	*			O,Q		O			
Fulica atra	Eurasian Coot					O	O		O	O
Carduelis carduelis	European Goldfinch	*			O					
Petrochelidon ariel	Fairy Martin							W		O
Cacomantis flabelliformis	Fan-tailed Cuckoo						O			
Lichenostomus fuscus	Fuscous Honeyeater				W					
Eolophus roseicapillus	Galah				W	O				O
Pachycephala pectoralis	Golden Whistler				O		O			

Scientific Name	Common Name	Exotic	TSC Status	EPBC Status	Woodland/pad dock trees	Dams/Wetlands	Riparian Corridor	Grassland and Cleared Land	SMEC (2014)	Biosis (1997)
Cisticola exilis	Golden-headed Cisticola					O		W		
Phalacrocorax carbo	Great Cormorant					O				O
Cracticus torquatus	Grey Butcherbird				OW		OW		O	O
Rhipidura albiscapa	Grey Fantail				O		O		O	O
Colluricincla harmonica	Grey Shrike-thrush				OW		O			
Anas gracilis	Grey Teal					O	O			
Aythya australis	Hardhead					O			O	
Poliocephalus poliocephalus	Hoary-headed Grebe					O				O
Passer domesticus	House Sparrow	*						O		O
Microeca fascinans	Jacky Winter				O				O	
Gallinago hardwickii	Latham's Snipe			C,J,K		O				
Dacelo novaeguineae	Laughing Kookaburra				O		O		O	O
Phalacrocorax sulcirostris	Little Black Cormorant					O	O			
Cacatua sanguinea	Little Corella					W			O	
Hieraaetus morphnoides	Little Eagle		V		O			O		
Glossopsitta pusilla	Little Lorikeet		V		O					
Microcarbo melanoleucos	Little Pied Cormorant					O	O		O	
Corvus mellori	Little Raven				W	W	W	OW		
Anthochaera chrysoptera	Little Wattlebird				O					
Cacatua tenuirostris	Long-billed Corella				OW	O		W	O	O
Grallina cyanoleuca	Magpie-lark				OW	O	O		O	O
Vanellus miles	Masked Lapwing						OW	W	O	O
Dicaeum hirundinaceum	Mistletoebird				O					O
Falco cenchroides	Nankeen Kestrel									O

Scientific Name	Common Name	Exotic	TSC Status	EPBC Status	Woodland/pad dock trees	Dams/Wetlands	Riparian Corridor	Grassland and Cleared Land	SMEC (2014)	Biosis (1997)
Nycticorax caledonicus	Nankeen Night Heron									O
Philemon corniculatus	Noisy Friarbird				W					
Manorina melanocephala	Noisy Miner				OW		OW		O	O
Oriolus sagittatus	Olive-backed Oriole				OW		O		OW	
Anas superciliosa	Pacific Black Duck					OW	O		O	O
Geopelia striata	Peaceful Dove				O					O
Falco peregrinus	Peregrine Falcon				O					
Phalacrocorax varius	Pied Cormorant					O			O	O
Strepera graculina	Pied Currawong								O	
Malacorhynchus membranaceus	Pink-eared Duck					O				
Porphyrio porphyrio	Purple Swamphen					O	OW		O	O
Trichoglossus haematodus	Rainbow Lorikeet				OW					
Anthochaera carunculata	Red Wattlebird								O	
Neochmia temporalis	Red-browed Finch				O		O	O		O
Psephotus haematonotus	Red-rumped Parrot				O					O
Pycnonotus jocosus	Red-whiskered Bulbul	*			O		OW		O	O
Myiagra inquieta	Restless Flycatcher				O					O
Columba livia	Rock Dove	*								O
Petroica rosea	Rose Robin				O					
Platalea regia	Royal Spoonbill					O				O
Rhipidura rufifrons	Rufous Fantail				O					
Pachycephala rufiventris	Rufous Whistler				O		O		O	O
Todiramphus sanctus	Sacred Kingfisher									O
Ptilonorhynchus	Satin Bowerbird				W					

Scientific Name	Common Name	Exotic	TSC Status	EPBC Status	Woodland/paddock trees	Dams/Wetlands	Riparian Corridor	Grassland and Cleared Land	SMEC (2014)	Biosis (1997)
violaceus										
Myzomela sanguinolenta	Scarlet Honeyeater				O					
Petroica boodang	Scarlet Robin		V		O					
Zosterops lateralis	Silvereye				OW		O	O		O
Pardalotus punctatus	Spotted Pardalote				W					O
Streptopelia chinensis	Spotted Turtle-Dove	*			O					O
Threskiornis spinicollis	Straw-necked Ibis					O		O		O
Pardalotus striatus	Striated Pardalote				W					
Acanthiza lineata	Striated Thornbill				O		O		O	
Cacatua galerita	Sulphur-crested Cockatoo						W	W	O	O
Malurus cyaneus	Superb Fairy-wren				O				OW	O
Podargus strigoides	Tawny Frogmouth				O		O			O
Megalurus timoriensis	Tawny Grassbird									O
Petrochelidon nigricans	Tree Martin							O		
Myiagra sp.	unidentified Flycatcher				O					
Daphoenositta chrysoptera	Varied Sittella		V				O			
Aquila audax	Wedge-tailed Eagle							O		
Smicrornis brevirostris	Weebill				O			O		
Hirundo neoxena	Welcome Swallow					O		O		O
Haliastur sphenurus	Whistling Kite				O		O	O		
Haliaeetus leucogaster	White-bellied Sea-eagle			C	O	O				
Sericornis frontalis	White-browed Scrubwren				W		OW		O	
Egretta novaehollandiae	White-faced Heron					O			O	O

Scientific Name	Common Name	Exotic	TSC Status	EPBC Status	Woodland/pad dock trees	Dams/Wetlands	Riparian Corridor	Grassland and Cleared Land	SMEC (2014)	Biosis (1997)
Ardea pacifica	White-necked Heron					OW		O	O	
Lichenostomus penicillatus	White-plumed Honeyeater				O					
Gerygone albogularis	White-throated Gerygone				O		O	O	O	O
Hirundapus caudacutus	White-throated Needletail			C,J,K				O		
Cormobates leucophaea	White-throated Treecreeper									O
Corcorax melanorhamphos	White-winged Chough				W,Q				O	O
Rhipidura leucophrys	Willie Wagtail				OW,Q	O	O		O	O
Acanthiza nana	Yellow Thornbill				O		OW		O	O
Platalea flavipes	Yellow-billed Spoonbill					O			O	O
Acanthiza chrysorrhoa	Yellow-rumped Thornbill				O		O		O	O
Calyptorhynchus funereus	Yellow-tailed Black-cockatoo									O
Gastropods										
Bradybaena similaris	Asian trampsnail	*			O		O			
Austrorhytida cappillacea	Common Southern Carnivorous Snail				O					
Meridolum corneovirens	Cumberland Plain Land Snail		E		O		O			
Cantareus aspersa	Garden Snail	*			O	O	O	O		
Mammals										
Rattus rattus	Black Rat	*			O					H
Lepus capensis	Brown Hare	*			O,Q		O			O
Felis catus	Cat	*								O
Trichosurus vulpecula	Common Brushtail				O		O			O

Scientific Name	Common Name	Exotic	TSC Status	EPBC Status	Woodland/paddock trees	Dams/Wetlands	Riparian Corridor	Grassland and Cleared Land	SMEC (2014)	Biosis (1997)
	Possum									
Pseudocheirus peregrinus	Common Ringtail Possum						O			
Canis lupus familiaris	Dog	*								O
Macropus giganteus	Eastern Grey Kangaroo							O		
Vulpes vulpes	Fox	*			O,Q	O	O			O
Capra hircus	Goat	*			O					
Mus musculus	House Mouse	*						O		
Oryctolagus cuniculus	Rabbit	*			O,Q		O	O	F,P	O
Wallabia bicolor	Swamp Wallaby				O,Q		O		O	
Chalinolobus morio	Chocolate Wattled Bat				U					U
Mormopterus norfolkensis	East Coast Freetail Bat		V		U					
Miniopterus schreibersii oceanensis	Eastern Bentwing-bat		V							U
Falsistrellus tasmaniensis	Eastern False Pipistrelle		V							U
Mormopterus ridei	Eastern Freetail Bat				U					
Nyctophilus gouldi	Gould's Long-eared Bat									U
Chalinolobus gouldii	Gould's Wattled Bat				U					U
Pteropus poliocephalus	Grey-headed Flying-fox		V	V			O			O
Myotis macropus	Large-footed Myotis (pr)		V			U	U			
Vespadelus darlingtoni	Large Forest Bat (pr)				U					U
Nyctophilus geoffroyi	Lesser Long-eared Bat									U
Vespadelus vulturnus	Little Forest Bat									U

Scientific Name	Common Name	Exotic	TSC Status	EPBC Status	Woodland/pad dock trees	Dams/Wetlands	Riparian Corridor	Grassland and Cleared Land	SMEC (2014)	Biosis (1997)
Tadarida australis	White-striped Freetail-bat				U		U			
Nyctophilus sp.					U					
Vespadelus sp.					U					
Reptiles										
Eulamprus tenuis	Barred-sided Skink									T
Lampropholis delicata	Dark-flecked Garden Sunskink							O	O	T
Tiliqua scincoides	Eastern Blue-tongue				O			O		
Pseudonaja textilis	Eastern Brown Snake				O			O		
Chelodina longicollis	Eastern Snake-necked Turtle					O				
Physignathus lesueurii	Eastern Water Dragon					O				O
Eulamprus quoyii	Eastern Water-skink					O	O			O
Cryptoblepharus pulcher	Elegant Snake-eyed Skink				O		O			
Amphibolurus muricatus	Jacky Lizard				O					
Varanus varius	Lace Monitor				O				O	
Lampropholis guichenoti	Pale-flecked Garden Sunskink									T
Pseudechis porphyriacus	Red-bellied Black Snake					O		O		O

Note:

1. Broad habitat types refer to areas where these species were recorded during the current survey by GHD.
2. Species listings: O- Observed, W- Heard, OW- Observed and heard, Q- Camera, T- Trapped or netted, U- Ultrasonic recording, U? – ultrasonic recording (probable result); F- Tracks or scratchings, P- Scat, H- Hairs, feather or skin
3. Status listings: E- endangered species, V- vulnerable species, C- China-Australia Migratory Bird Agreement, J- Japan-Australia Migratory Bird Agreement, K- Republic of Korea-Australia Migratory Bird Agreement

Appendix D – Assessments of significance for MNES

Legislative requirement

The desktop assessment, field surveys and impact assessment included above have been used to identify MNES that are known or may occur at the airport site and that have the potential to suffer a significant impact. Assessments of significance have been prepared using the *Matters of National Environmental Significance Significant impact guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999* (DotE 2013a) for the following MNES of relevance to the airport:

- Cumberland Shale Plains Woodland and Shale-Gravel Transition Forest (Cumberland Plain Woodland) which is listed as a CEEC under the EPBC Act and occurs at the airport site. A specific assessment of significance is provided below for impacts on this community, including the removal of 90 hectares of vegetation within the local occurrence of the community.
- *Pultenaea parviflora*, which is listed as a vulnerable species under the EPBC Act and occurs at the airport site. A specific assessment of significance is provided below for impacts on this species, including the removal of at least four individuals of the species and of known and potential habitat.
- The threatened flora species White-flowered Wax Plant, Spiked Rice-flower and Downy Wattle, which are listed as endangered species and Small-flower Grevillea and Austral Toadflax, listed as vulnerable species. A general assessment of significance is provided below for potential impacts on these species, including the removal of potential habitat.
- The Grey-headed Flying-fox, which is listed as a vulnerable species under the EPBC Act and which has been observed at the airport site. A specific assessment of significance is provided below for impacts on this species, including the removal of foraging habitat.
- The Swift Parrot, which is listed as an endangered species under the EPBC Act and which may occur at the airport site during annual winter migrations. A specific assessment of significance is provided below for impacts on this species, including the removal of potential winter foraging habitat.
- The Blue Mountains World Heritage Area (BMWHA), which is located around ten kilometres to the west of the airport site and may be affected by potential indirect impacts. A detailed assessment of significance of impacts on the BMWHA will be included in a Final Draft of this report after a multidisciplinary workshop is held to help identify and assess potential impacts.

DRAFT

Cumberland Plain Woodland Critically Endangered Ecological Community

Larger and better condition patches of Grey Box - Forest Red Gum grassy woodland on flats, Grey Box - Forest Red Gum grassy woodland on hills and Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest at the airport site comprise occurrences of Cumberland Plain Woodland. Cumberland Plain Woodland is listed as a critically endangered ecological community (CEEC) under the EPBC Act. Patches of woodland at the airport site that comprise an occurrence of Cumberland Plain Woodland are shown on Figure 6. There are 153.3 hectares of Cumberland Plain Woodland as defined under the EPBC Act at the airport site.

Derived native grassland and moderate/good –poor condition vegetation at the airport site does not meet the condition criteria for a local occurrence of the CEEC Cumberland Plain Woodland as defined under the EPBC Act and associated guidelines. This vegetation does not qualify because native tree species are not present with a minimum projected foliage cover of greater than 10% (DEWHA, 2010d). Patches with native tree cover greater than 10% but that are isolated from other native vegetation and are less than 0.5 hectares in area have also been excluded in accordance with the guidelines (DEWHA, 2010d).

Cumberland Plain Woodland, a CEEC.

According to the DotE (2013) 'significant impact criteria' for endangered or critically endangered ecological communities, an action is likely to have a significant impact on a community if there is a real chance or possibility that it will:

Reduce the extent of an ecological community

Construction of the airport would directly reduce the extent of the ecological community through the removal of 88.9 hectares of Cumberland Plain Woodland in the stage one construction impact zone. This is a significant reduction in the extent of the ecological community in the locality and a notable reduction at the regional scale given the extent of historical clearing of Cumberland Plain Woodland. Less than 10% of the estimated pre-European extent of the vegetation types that collectively comprise this community remains (OEH, 2015c).

Longer term development at the airport site would further reduce the extent of the community by up to 57 hectares. Longer term development would further increase the significance of impacts of Stage 1 and would comprise a significant impact in its own right.

Fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines

Construction of Stage 1 of the airport would contribute to fragmentation at a local and regional scale by removing patches of habitat, severing vegetated corridors and by creating an extensive, permanent footprint that would comprise a significant barrier to many species.

The local occurrence of the community is in a highly fragmented, rural landscape. Fragmentation of native vegetation and associated fauna habitats in the locality has previously occurred through clearing for agriculture, residences and farm buildings and construction of linear infrastructure (such as transmission lines and roads). These land uses have created barriers to movement for many fauna species, particularly those that are limited by dispersal abilities and habitat preferences. The suite of fauna species recorded in field surveys is dominated by generalist species of open country such as birds and bats, reflecting the fragmented nature of vegetation at the airport site (see Section 4.3.1).

At a regional scale Cumberland Plain Woodland is severely fragmented, with more than half of the remaining tree cover mapped by Tozer *et al* (2010) occurring in patches of less than 80 hectares and half of all mapped patches being smaller than 3 hectares (NSW Scientific Committee 2009). The construction of the airport would contribute to fragmentation at a regional scale by further removing patches of woodland, including a total of 90 hectares of Cumberland Plain Woodland remnants in patches that are at least five hectares in area. Larger patches have greater inherent value due to their rarity (DotE, 2015c).

Construction of Stage 1 would create a gap in habitat that is around 1060 hectares in area and about 1.5 km wide from north to south and almost 7 km long from east to west. This area would be mostly inhospitable to fauna and would be a barrier to ecological processes such as dispersal, pollination and seed fall. Mobile, aerial fauna species that comprise part of the ecological community may continue to occur in areas of open space at the airport site and move around or through it. The airport will include specific design features to make it less hospitable to birds and bats to help mitigate the risk of plane collisions. The proposed runway, terminals, carpark and other built features would comprise a significant barrier to the majority of fauna species particularly in combination with security fences. Light, noise, aircraft and vehicle movement may further deter fauna species from crossing these gaps in habitat. Many generalist species of open country that currently occur at the airport site and the majority of component species in Cumberland Plain Woodland would not be able to move over or through the airport. Overall, despite the current patchy and fragmented distribution of vegetation at the airport site and in the locality, construction of Stage 1 would comprise a significant increase in the degree of fragmentation of Cumberland Plain Woodland.

Longer term development at the airport site would further increase the degree of fragmentation of the community in the locality and the region. A second runway and associated infrastructure would increase the gap in habitat at the airport site to a total area of up to 1700 hectares and would be around 2.5 km wide from north to south. The likely realignment of The Northern Road, orbital road links, realigned transmission lines and rail links to the airport would further isolate or fragment habitat.

These impacts on habitat connectivity would be partially mitigated by the retention of habitat in the proposed environmental conservation zone. The conservation zone is around 122 hectares in area, including around seven hectares of Cumberland Plain Woodland out of a total of 60 hectares of

woodland and forest. A further 62 hectares would be revegetated. It is placed around the perimeter of the airport site, encompassing the riparian corridors of Badgerys Creek and Duncans Creek and some moderate sized patches of Cumberland Plain Woodland. The environmental conservation zone would help to maintain opportunity for fauna movements via vegetated corridors around the airport site.

Adversely affect habitat critical to the survival of an ecological community

The community occurs on specific soil types within a restricted distribution that coincides with the Sydney region. The natural extent of the community has been extensively cleared and is subject to ongoing development pressure. All occupied habitat other than the smallest or most degraded remnants would be critical to the survival of the community. Any patches of the community that are greater than five hectares in area are considered inherently valuable due to their rarity (DotE 2015b). The local occurrence of the community at the site is in moderate to good condition and includes multiple continuous patches of vegetation of at least five hectares and up to around 50 hectares in area and as such comprises habitat critical to the survival of the community.

Modify or destroy abiotic (non-living) factors (such as water, nutrients of soil) necessary for an ecological community's survival, including reduction of groundwater levels or substantial alteration of surface water drainage patterns

Construction of Stage 1 would include substantial earthworks and complete modification of abiotic factors in the Stage 1 construction impact zone. This is equivalent to the estimated reduction in extent of the community described above.

The airport design and land use plan includes measures to manage surface and groundwater that have been purposefully designed to avoid substantial alteration of surface water drainage patterns. A CEMP is recommended for construction of the airport, which would contain measures to reduce direct and indirect impacts (e.g. erosion and sedimentation) on native vegetation adjoining the airport site, including this community.

Any alterations as a result of construction of the airport are unlikely to result in destruction of abiotic conditions necessary for the ecological communities' survival outside of the airport site.

Cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting

The project would remove native plants and displace or harm native animals that are component species of the community. Construction of Stage 1 of the airport is likely to comprise a significant reduction in the extent of this community in the locality. However the individual plants and animals affected within the Stage 1 construction impact zone are unlikely to be an ecologically significant proportion of any of the individual species that make up the broader occurrence of the community in the locality or region. The areas of floristically similar vegetation in the locality and region are likely to be sufficient to maintain viable local populations of the species that comprise the community. Construction of the airport may affect the species composition of patches of this community in the vicinity by promoting species that are more tolerant of edge habitats and/or noise, light and traffic. This is likely to include aggressive fauna species like the Noisy Miner that would tolerate these conditions and may occur at the expense of other species. The airport is unlikely to substantially modify the composition of any vegetation beyond the airport site and immediately adjoining areas. As such, the airport is not likely to cause a substantial change in the composition of the community outside of the direct disturbance footprint.

Cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including but not limited to:

Assisting invasive species, that are harmful to the listed ecological community, to become established, or

Construction of the airport would involve a substantial area of vegetation removal and would create some new edges in vegetation and habitat adjoining the site. Construction activities may, in general, increase the degree of weed infestation in adjacent areas through dispersal of weed propagules (seeds, stems and flowers) into areas of native vegetation via erosion (wind and water), workers shoes

and clothing or construction vehicles. Recommendations have been made in Section 8 to minimise the spread of weeds during construction.

A CEMP is recommended for the construction of the airport, which would contain measures to manage weeds and to reduce the risk of spreading weeds off site in soil or water. The airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site and to avoid substantial alteration of surface water drainage patterns outside of the airport site.

Operation of the airport poses a biosecurity risk. There is the potential for the introduction of new species as a result of the transport of goods on aircraft. For example, the one record of Yellow Crazy Ants from New Zealand is likely to have been a transit passenger (on taro in air baggage) (Biosecurity New Zealand, undated). Invasion of Yellow Crazy Ants is listed as a key threatening process under the TSC Act (see section 8.1). Any escaped novel species could potentially establish in nearby vegetated areas, or be transported to other areas of native vegetation with cargo, and impact the local native flora and fauna.

The final Airport Plan for Stage 1 and then for longer term development at the airport site would include specific measures to manage weeds at the airport site, to mitigate biosecurity risks and to reduce the risk of off site impacts. This plan would be integrated with Australian Government border control and biosecurity risk management measures. The proposed environmental conservation zone would provide a buffer between the airport and adjoining areas of native vegetation along its eastern, southern and western boundaries, including the riparian corridors of Badgerys Creek and Duncans Creek. The extent of native vegetation cover would be increased in the environmental conservation zone and weeds would be managed. This reduces the chance that weeds would spread or that other edge effects would penetrate into habitat outside the airport site. The airport would have a minor effect on the extent or seriousness of edge effects in the locality and is unlikely to introduce any new weed species or increase the significance of weed infestations.

No invasive species that may cause the Cumberland Plain Woodland to decline are likely to become established in the locality as a result of the airport.

Causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community

Construction vehicles and equipment would cause a minor localized increase in the risk of hydrocarbon contamination or other pollutants for the duration of remediation activities. A CEMP is recommended for construction of the airport, which would contain measures to manage harmful substances and to avoid impacts on vegetation, soil or water. Any accidental mobilisation of harmful substances during construction would not be ‘regular’ (if at all) and is highly unlikely to kill or inhibit the growth of any species in the ecological community in areas adjoining the airport site.

The operation of the airport and associated transport and commercial activities would involve bulk fuel storage and is likely to include transport of harmful substances. Open space within the Stage 1 airport would be actively managed, which may include use of fertilisers and herbicides. Any such use, storage or transport of potential pollutants would be conducted under appropriate controls and with reference to relevant environmental legislation. Any inappropriate or illegal activities or accidental mobilisation of contaminants would not be ‘regular’ (if at all) and is highly unlikely to result in effects that would kill or inhibit the growth of species in the ecological community.

The proposed environmental conservation zone would provide a buffer between the airport and adjoining areas of native vegetation along its eastern, southern and western boundaries including the riparian corridors of Badgerys Creek and Duncans Creek. The environmental conservation zone increases the distance between potential sources of contamination such as runways, storage areas and parking areas and these sensitive receptors. The airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site and to avoid substantial alteration of surface water quality or drainage patterns outside of the airport site. These measures would help to mitigate the risk of any impacts on the ecological community outside of the airport site.

Interfere with the recovery of an ecological community

The ‘recovery plan decision’ for Cumberland Plain Woodland is currently: ‘Recovery Plan required, at the time of listing a recovery plan was in preparation for Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest (17/11/2009)’ (DotE, 2015c).

The main threats to Cumberland Plain Woodland are clearing for urban, industrial or rural

development, the consequent fragmentation of native vegetation remnants, inappropriate grazing and fire regimes, weed invasion and the low level of protection in reserves (Threatened Species Scientific Committee, 2008b).

The approved conservation advice lists priority recovery and threat abatement actions that can be taken to support the recovery of the community (Threatened Species Scientific Committee, 2018b). The following are relevant to the airport:

'Implement appropriate management regimes to maintain the biodiversity, including threatened species, of the ecological community' (Threatened Species Scientific Committee, 2008b).

The project would permanently remove 88.9 hectares of vegetation within the local occurrence of the community for Stage 1 of the airport and a further 57 hectares for longer term development. Construction of Stage 1 would create a gap in habitat that is around 1060 hectares in area and about 1.5 km wide from north to south and almost 7 km long from east to west. This would increase to up to 1600 hectares in area and 2.5 km wide from north to south for the longer term development at the airport site. The airport would significantly increase the degree of fragmentation of the community and its habitat in the locality and region.

Construction of the airport would substantially interfere with the recovery of the community. In the longer term the proposed offset package would assist with the recovery of the community through the conservation and management of Cumberland Plain Woodland in offset sites (see Section 9.3).

Conclusion of Assessment of Significance:

Stage 1 of the airport is likely to have a significant impact on the local and regional occurrence of Cumberland Plain Woodland through a substantial reduction in the extent of the community and increase in the degree of fragmentation which would in turn result in a substantial negative effect on the potential for recovery of the community.

Longer term development at the airport site would further reduce the extent of the community, fragment habitat and interfere with its recovery. This additional reduction would further increase the significance of impacts of Stage 1 and would comprise a significant impact in its own right.

The proposed offset package would compensate for these significant impacts and would assist with the recovery of the community through the conservation and management of Cumberland Plain Woodland in offset sites.

Pultenaea parviflora

Four individuals of *Pultenaea parviflora* were recorded on the southern side of Longleys Road between Ferndale and Taylors Road by SMEC (2014) and these records were verified by GHD during the current field surveys (Figure 5D). This is a significant reduction from the 68 individuals previously recorded along both sides of Longleys Road at this location in 1999 (Biosis 1999; SMEC 2014). The former locations of the additional 64 individuals currently contain cleared, ploughed cropland or severely weed infested road edges and do not comprise occupied or potential habitat for this species (see photo in Table 26). Seed and cutting collections were made from this population by the Royal Botanic Gardens Trust on a number of occasions in 1990 and 1991, with the aim of testing propagation methods for the species and also ultimately replanting the species at the airport as part of landscaping works (RBGS 1992).

Pultenaea parviflora a vulnerable species

According to the DotE (2013a) 'significant impact criteria' for vulnerable species, an action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

The Stage 1 construction impact zone includes at least four individuals comprising a local population of *Pultenaea parviflora.* Construction of the airport would also remove up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat for this species. These impacts may be partially mitigated by the proposed translocation of the four individuals at the airport site into an area of suitable habitat in the environmental conservation zone (see Section 8).

The known population of four plants at the airport site is a significant reduction from the 68 individuals previously recorded along both sides of Longleys Road in this location in 1999 (Biosis 1999; SMEC 2014). The former locations of the additional 64 individuals currently contain cleared, ploughed cropland or severely weed infested road edges and do not comprise occupied or potential habitat for this species (see photo in Table 20). Seed and cutting collections were made from this population by the Royal Botanic Gardens Trust on a number of occasions in 1990 and 1991, with the aim of testing propagation methods for the species and also ultimately replanting the species at the airport as part of landscaping works (RBGS 1992).

The EPBC Act assessment of significance guidelines 1.1 include specific criteria for assessing impacts on a vulnerable species, which primarily relate to impacts on an important population (DotE 2013a).

An 'important population' is a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:

- Key source populations either for breeding or dispersal.
- Populations that are necessary for maintaining genetic diversity, and/or.
- Populations that are near the limit of the species range (DotE 2013a).

The population of *P. parviflora* at the airport site is not an important population because:

- It is not identified in a recovery plan.
- It would not be important for breeding or dispersal because it only includes four plants and it is in a comparatively isolated and poor quality patch of habitat that is surrounded by extensive areas of cleared cropland or grazing country.
- It is not important for maintaining genetic diversity because it only comprises four plants that are in close proximity and as such would be unlikely to contain much genetic diversity. Further, this genetic material has already been retained via the Royal Botanic Gardens Trust sampling and propagation program (RBGS 1992).
- This population is near the limit of the species range as it at the western extent of recognised outlier populations near Kemps Creek (OEH, 2015b). The majority of this population is associated with with a parcel of land with tertiary gravel and shale/gravel transition habitat located at Kemps Creek around three kilometres to the east of the site (OEH, 2015a) that is to be set aside as an offset for the South West Growth Centres. The population at the airport site would make a very minor contribution to the viability of this population.

The population of *P. parviflora* at the airport site would not be secure and would be unlikely to be maintained or increased if the airport was not constructed and the current situation continued. The four individuals in the remaining population are in a strip of highly modified vegetation less than three metres wide between a road and ploughed cropland. This strip is seriously infested with exotic perennial grasses and other environmental weeds as well as

Pultenaea parviflora a vulnerable species
dense growth of Native Blackthorn. The four *P. parviflora* at the airport site are at risk due to competition for light, water or nutrients and/or accidental slashing or spraying in the short to medium term. Overall the population at the site has low viability and would make a minor contribution to the maintenance or recovery of the species and does not comprise an 'important population' as defined in the significant impact criteria for vulnerable species (DotE 2013a). Therefore the airport would not lead to a long-term decrease in the size of an important population of the species.
Reduce the area of occupancy of an important population
As described above the population of *Pultenaea parviflora* at the airport site is not an important population. Construction of the airport would reduce the area of occupation of the species in general by removing about 100m^2 of occupied habitat containing four plants.
Fragment an existing important population into two or more populations
As described above the population of *P. parviflora* at the airport site is not an important population. Construction of the airport would not fragment an existing population of the species in general into two or more populations because it would remove only about 100m^2 of occupied habitat containing four plants that is already completely isolated from other populations in the wider locality.
Adversely affect habitat critical to the survival of a species
There is no recovery plan for the species and no critical habitat has been formally identified (DotE, 2015b). The occupied habitat at the airport site comprises highly modified vegetation less than three metres wide between a road and ploughed cropland. This strip is infested with exotic perennial grasses and other environmental weeds as well as dense growth of Native Blackthorn. The habitat to be removed would make a minor contribution to the conservation and recovery of the species. As such, the airport would not adversely affect habitat critical to the survival of the species.
Disrupt the breeding cycle of an important population
As described above the population of *Pultenaea parviflora* at the airport site is not an important population. There is a population of *P. parviflora* at a parcel of land located at Kemps Creek around three kilometres to the east of the site (OEH, 2015a) that would probably comprise an important population given the number of plants present, area of habitat and its location since it ia recognised as an outlier population of the species (OEH, 2015b). The project may affect the breeding cycle of the species in general by removing four individuals of the species and through a reduction in the extent of native vegetation that may provide shelter and food for pollinator species. Given the distance of the airport site from Kemps Creek these potential impacts would be highly unlikely to tangibly disrupt the breeding cycle of this important population.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
The airport would require the removal of 120.6 hectares of potential habitat for *P. parviflora* in Stage 1 and up to 78.6 hectares of potential habitat for longer term development at the airport site. Construction of the airport would also increase the degree of fragmentation of habitat for the species at the local and regional scale. The condition and quality of habitat varies across the airport site however the habitat containing the four individuals in the known population

Pultenaea parviflora a vulnerable species
comprises a strip of highly modified vegetation less than three metres wide between a road and ploughed cropland. The four Pultenaea parviflora at the airport site are at risk due to competition for light, water or nutrients and/or accidental slashing or spraying in the short to medium term. Much of the remaining habitat at the airport site and surrounding locality is effectively isolated from these known plants and despite targeted surveys there is no evidence that these areas contain any additional P. parviflora individuals (Biosis 1999; SMEC 2014; OEH, 2015a). Construction and operation of the airport would not affect habitat for the known important population of the species at Kemps Creek because it around three kilometres away. Construction of the airport would affect habitat which, because of its condition and context, is likely to make a very minor contribution to the viability of Pultenaea parviflora. Given the above considerations the airport is not likely to modify, destroy, remove or isolate or decrease the availability or quality of habitat for P. parviflora to the extent that the species is likely to further decline.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
Construction of the airport would involve a substantial area of vegetation removal and would create some new edges in vegetation and habitat adjoining the site. Construction activities may, in general, increase the degree of weed infestation in adjacent areas through dispersal of weed propagules (seeds, stems and flowers) into areas of native vegetation via erosion (wind and water), workers shoes and clothing or construction vehicles. Recommendations have been made in Section 8 to minimise the spread of weeds. A CEMP is recommended for the construction of the airport, which would contain measures to manage weeds and to reduce the risk of spreading weeds off site in soil or water. The airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site and to avoid substantial alteration of surface water drainage patterns outside of the airport site. The final Airport Plan for Stage 1 and then for longer term development at the airport site would include specific measures to manage weeds at the airport and to reduce the risk of off site impacts. The proposed environmental conservation zone would provide a buffer between the airport and adjoining areas of native vegetation along its eastern, southern and western boundaries including the riparian corridors of Badgerys Creek and Duncans Creek. The extent of native vegetation cover would be increased in the environmental conservation zone and weeds would be managed. This reduces the chance that weeds would spread or that other edge effects would penetrate into habitat outside the airport site. The airport would have a minor effect on the extent or seriousness of edge effects in the locality and is unlikely to introduce any new weed species or increase the significance of weed infestations. No invasive species that may cause *Pultenaea parviflora* to decline are likely to become established in the locality as a result of the airport.
Introduce disease that may cause the species to decline
The airport would be unlikely to increase the potential for significant disease vectors to affect this species. Diseases potentially affecting native vegetation in general at the airport site and adjacent areas include Root Rot Fungus (*Phytophthora cinnamomi*) and Myrtle Rust. To minimise the chance of introducing new plant pathogens, machinery would be washed down before moving from area to area and personnel excluded from walking through habitat areas unless necessary. Potential impacts are likely to be limited to the immediate construction footprint for the airport.
Interfere substantially with the recovery of the species
The recovery plan decision for the species is: 'Recovery Plan not required, included on the Not Commenced List (1/11/2009)' (DotE, 2015b). Construction of the airport would remove about 100m^2 of occupied habitat containing four plants that is already completely isolated from other populations. Construction of the airport would not interfere substantially with the recovery of the species.

Pultenaea parviflora a vulnerable species
Conclusion
Construction of Stage 1 of the airport would remove four individual *Pultenaea parviflora* comprising the known local population of the species at the airport site. The airport would also require the removal of 120.6 hectares of potential habitat for the species for Stage 1 and up to 78.6 hectares of potential habitat for longer term development at the airport site. The population of *P. parviflora* at the site is not an 'important population' as defined in the significant impact criteria for vulnerable species (DotE 2013a) and is likey to have very low long-term viability under existing conditions. Therefore the airport would not result in any direct impacts on an important population of the species and would not interfere with the recovery of *P. parviflora.* Given the above considerations, the airport would not result in a significant negative impact on *P. parviflora*.

Threatened flora species with a moderate likelihood of occurrence

There is potential habitat for up to an additional five threatened flora species listed under the EPBC Act: Spiked Rice-flower (*Pimelea spicata*); Downy Wattle (*Acacia pubescens*); White-flowered Wax Plant (*Cynanchum elegans*); *Grevillea parviflora* subsp. *parviflora* and *Thesium australe*. Construction and operation of the airport would not affect any known populations of these threatened plants. Despite targeted surveys there is no evidence that the airport site or any adjoining areas of vegetation contain populations of these threatened plants (Biosis 1999; SMEC 2014; OEH, 2015a). There is a moderate risk of impacts on a local population of these threatened plants through the removal, modification or fragmentation of potential habitat at the airport site.

Threatened flora: the endangered species White-flowered Wax Plant, Spiked Rice-flower and Downy Wattle; and the vulnerable species Small-flower Grevillea and Austral Toadflax.

According to the DotE (2013a) 'significant impact criteria' for threatened species, an action is likely to have a significant impact on a species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of a population of an endangered species or an important population of a vulnerable species

Construction and operation of the airport would not affect any known populations of these threatened plants. Despite targeted surveys there is no evidence that the airport site or any adjoining areas of vegetation contain populations of these threatened plants (Biosis 1999; SMEC 2014; OEH, 2015a). There is a chance that these species may be present at the airport site in low numbers such as in areas of habitat that were not directly observed or in the soil seed bank. There is also a chance that these species could colonise this habitat at some point in the future. As such there is a moderate risk of impacts on a local population of these threatened plants through the removal, modification or fragmentation of potential habitat at the airport site.

The airport would remove potential habitat for these threatened plants as described below and would directly reduce the size of a population of a plant species if any individuals are present at the airport site.

With regards to potential impacts on the vulnerable species Small-flower Grevillea and Austral Toadflax an 'important population' is a population that is necessary for a species' long-term survival and recovery. This may include populations identified as such in recovery plans, and/or that are:

- Key source populations either for breeding or dispersal.
- Populations that are necessary for maintaining genetic diversity, and/or.
- Populations that are near the limit of the species range (DotE 2013a).

The airport site is highly unlikely to contain an important population because:

- It is not identified in any recovery plans.
- It is not known to contain any individuals of these species despite targeted survey. If these species were present at the airport site in numbers large enough to be important for breeding or dispersal or maintaining genetic diversity, it is likely that they would have been detected.
- A population at the airport site would not be near the limit of these species range Austral Todflax is known from populations scattered across eastern NSW, along the coast, and from the Northern to Southern Tablelandsas well as Tasmania, Queensland and in eastern Asia. Small-flower Grevillea is sporadically distributed throughout the Sydney Basin with sizeable populations around Picton, Appin and Bargo, the Cessnock - Kurri Kurri area, Holdsworthy, Castlereagh and from Putty to Wyong and Lake Macquarie on the Central Coast (OEH, 2015b)..

Overall any populations of these threatened plant species that may occur at the airport site are likely to be small and have relatively low viability and would make a minor contribution to the maintenance or recovery of these species. Removal of potential habitat or of individual plants that may be present at the airport site is unlikely to lead to a long-term decrease in the size of an important population of these species.

Threatened flora: the endangered species White-flowered Wax Plant, Spiked Rice-flower and Downy Wattle; and the vulnerable species Small-flower Grevillea and Austral Toadflax.
Reduce the area of occupancy of an endangered species or an important population of a vulnerable species
As described above the airport would not affect an important population of Small-flower Grevillea or Austral Toadflax (if it would affect the species at all). Construction of the airport may, in general, reduce the area of occupancy of the five threatened plant species listed above by removing up to 220.9 hectares of potential habitat that may be occupied. Despite targeted surveys there is no evidence that these areas contain any individuals of these threatened plants (Biosis 1999; SMEC 2014; OEH, 2015a) and so the actual area of occupied habitat that could be removed is likely to be considerably smaller. In the context of the regional distribution of these species, this quantum of impact would have a minor effect (if at all).
Fragment an existing population of an endangered species or an important population of a vulnerable species into two or more populations
As described above the airport would not affect an important population of Small-flower Grevillea or Austral Toadflax (if it would affect these species at all). Construction of the airport is highly unlikely to fragment an existing population of White-flowered Wax Plant, Spiked Rice-flower and Downy Wattle into two or more populations because no individuals of these species are known from the site or adjoining areas despite targeted survey. The removal of any individuals or occupied habitat at the airport site would only affect individuals that are already relatively isolated from other populations.
Adversely affect habitat critical to the survival of a species
No critical habitat has been formally identified for any of these threatened plant species (DotE, 2015b). There is no evidence that the habitat at the airport site is of particular value or significance to these threatened plant species and there are around 10,014 hectares of similar shale woodland vegetation in the locality (NPWS, 2006; Tozer *et al* 2010). Given the absence of known populations, moderate condition and degree of fragmentation of the habitat to be removed it is likely to make a minor contribution to the conservation and recovery of these species. As such, the airport would not adversely affect habitat critical to the survival of these species.
Disrupt the breeding cycle of an endangered species or an important population of a vulnerable species
As described above the airport would not affect an important population of Small-flower Grevillea or Austral Toadflax (if it would affect these species at all). The project may affect the breeding cycle of the five threatened plant species listed above in general through a reduction in the extent of native vegetation that may provide habitat and movement opportunities for pollinator species. There are occasional records of these threatened plant species in the vicinity of the airport site but none within patches of connected vegetation (OEH 2015a) or any other evidence that the habitat at the airport site would be important to their breeding cycles. There are around 10,014 hectares of similar shale woodland vegetation in the locality (NPWS 2006; Tozer *et al* 2010) that provide refuge for pollinator species, potential habitat and at least partial connectivity for recruitment. The removal of vegetation at the airport site would be highly unlikely to tangibly disrupt the breeding cycle of any threatened plant populations outside of the site.

Threatened flora: the endangered species White-flowered Wax Plant, Spiked Rice-flower and Downy Wattle; and the vulnerable species Small-flower Grevillea and Austral Toadflax.

Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The quantum of potential impacts on these threatened plants varies between species, based on their individual habitat requirements as follows:

- White-flowered Wax Plant: up to 145 .7 hectares of better quality potential habitat and a further 134 hectares of poor quality potential habitat.
- Spiked Rice-flower: up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat.1
- Downy Wattle: up to 2.2 hectares of better quality potential habitat and a further 0.4 hectares of poor quality potential habitat.
- Small-flower Grevillea: up to 2.2 hectares of better quality potential habitat and a further 0.4 hectares of poor quality potential habitat.
- Austral Toadflax: up to 90.8 hectares of better quality potential habitat and a further 130.5 hectares of poor quality potential habitat.

Construction of the airport would also increase the degree of fragmentation of habitat for the species at the local and regional scale. The condition and quality of habitat varies across the airport site however the majority is in moderate or poor condition. Despite targeted surveys there is no evidence that these areas contain any individuals of these threatened plants (Biosis 1999; SMEC 2014; OEH, 2015a) and so the habitat is probably of limited value.

Construction of the airport would involve a substantial area of vegetation removal and would create some new edges in vegetation and habitat adjoining the site. Construction activities may, in general, increase the degree of weed infestation in adjacent areas through dispersal of weed propagules, erosion or sedimentation and generation of dust or other contaminants. A CEMP is recommended for the construction of the airport, which would contain measures to manage weeds and to manage indirect and off site impacts. The final Airport Plan for Stage 1 and then for longer term development at the airport site would include specific measures to manage weeds at the airport site, to mitigate biosecurity risks and to reduce the risk of off site impacts. This plan would be integrated with Australian Government border control and biosecurity risk management measures. The airport is unlikely to substantially affect any habitat for these threatened plants outside the construction impact zone.

Given the above considerations the project is not likely to modify, destroy, remove or isolate or decrease the availability or quality of habitat for these threatened plants to the extent that these species are likely to further decline.

Result in invasive species that are harmful to a threatened species becoming established in the species' habitat

Construction of the airport would involve a substantial area of vegetation removal and would create some new edges in vegetation and habitat adjoining the site. Construction activities may, in general, increase the degree of weed infestation in adjacent areas through dispersal of weed propagules (seeds, stems and flowers) into areas of native vegetation via erosion (wind and water), workers shoes and clothing or construction vehicles. Recommendations have been made in Section 8 to minimise the spread of weeds.

A CEMP is recommended for the construction of the airport, which would contain measures to manage weeds and to reduce the risk of spreading weeds off site in soil or water. The airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site and to avoid substantial alteration of surface water drainage patterns outside of the airport site.

Threatened flora: the endangered species White-flowered Wax Plant, Spiked Rice-flower and Downy Wattle; and the vulnerable species Small-flower Grevillea and Austral Toadflax.
The proposed environmental conservation zone would provide a buffer between the airport and adjoining areas of native vegetation along its eastern, southern and western boundaries including the riparian corridors of Badgerys Creek and Duncans Creek. The extent of native vegetation cover would be increased in the environmental conservation zone and weeds would be managed. This reduces the chance that weeds would spread or that other edge effects would penetrate into habitat outside the airport site. The airport would have a minor effect on the extent or seriousness of edge effects in the locality and is unlikely to introduce any new weed species or increase the significance of weed infestations. No invasive species that may cause these threatened plant species to decline are likely to become established in the locality as a result of the airport.
Introduce disease that may cause the species to decline
The airport would be unlikely to increase the potential for significant disease vectors to affect this species. Diseases potentially affecting native vegetation in general at the airport site and adjacent areas include Root Rot Fungus (*Phytophthora cinnamomi*) and Myrtle Rust. To minimise the chance of introducing new plant pathogens, machinery would be washed down before moving from area to area and personnel excluded from walking through habitat areas unless necessary. Potential impacts are likely to be limited to the immediate construction footprint for the airport.
Interfere substantially with the recovery of the species
Construction of the airport would increase the degree of fragmentation of habitat for the species at the local and regional scale. The condition and quality of habitat varies across the airport site however the majority is in moderate or poor condition. Despite targeted surveys there is no evidence that these areas contain any individuals of these threatened plants (Biosis 1999; SMEC 2014; OEH, 2015a) and so the habitat is probably of limited value and any populations of these species that may be present would probably have limited viability. The removal of potential habitat for these threatened plants and individuals that may be present is unlikely to substantially interfere with the recovery of these species.
Conclusion
Construction and operation of the airport would not affect any known populations of these threatened plants. Despite targeted surveys there is no evidence that the airport site or any adjoining areas of vegetation contain populations of these threatened plants (Biosis 1999; SMEC 2014; OEH, 2015a). There is a moderate risk of impacts on a local population of these threatened plants through the removal, modification or fragmentation of potential habitat at the airport site. Any populations of these threatened plant species at the airport site are likely to have relatively low viability and would make a minor contribution to the maintenance or recovery of these species. The airport is unlikely to interfere with the recovery of any of these threatened plant species. Based on the above considerations the airport would not result in a significant negative impact on these threatened plant species.

Grey-headed Flying-fox

Grey-headed Flying-foxes (*Pteropus poliocephalus*) roost and breed in large colonies (camps). All the flying-fox camps in eastern Australia are linked into one population and numbers in any one camp are influenced by food availability and the requirements of mating and raising young. Fluctuations in the size of a camp can vary week by week, month by month or in some cases from one night to the next, and reflect the nomadic nature of Grey-headed Flying-foxes. There are at least seven camps mapped within 20 kilometres of the airport site, including to the north, east and south, and many more within a 50 kilometre radius. There are no camps on site or in the immediate vicinity of the airport site that would be directly impacted.

The Grey-headed Flying-fox is a highly mobile species which regularly travels up to 50 kilometres in a night to forage, and has been shown to make migratory movements of almost 1000 kilometres within a year (Churchill 2008, Webb and Tidemann 1996).

Grey-headed Flying-foxes were observed flying over the airport site and would forage at the site when eucalypts are in flower. The primary food source for Grey-headed Flying-foxes is blossom from *Eucalyptus* species and related genera but in some areas it also utilises a wide range of rainforest fruits (Eby and Law 2008).

All native woodland and forest at the airport site provides foraging habitat for this species. Dominant canopy species include Forest Red Gum (*Eucalyptus tereticornis*), Grey Box (*Eucalyptus molluccana*) and Broad-leaved Ironbark (*Eucalyptus fibrosa*). Grey Box and Forest Red Gum are identified as significant species in the blossom diet of the Grey-headed Flying-fox (Eby and Law 2008). Forest Red Gum scores in the upper quartile of all diet plants for the region for productivity and reliability of flowering (0.67). This species flowers in late winter and spring, partly during the 'food bottleneck' (Eby and Law 2008). Grey Box has low productivity and reliability (0.35). It flowers in late summer and early autumn. Broad-leaved Ironbark has high productivity but is an unreliable flowerer (0.54). It flowers in summer and early autumn, providing forage habitat during the breeding period (Eby and Law 2008). Habitat at the airport site is thus somewhat productive during food bottlenecks, and would contribute to habitat critical to the survival of the species, as defined in the draft recovery plan (DECCW 2009).

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Flying-foxes are one of the more common aerial fauna species hit by aircraft in Australia and NSW. There is therefore a potential for mortality of individuals from aircraft strike, although the risk is much lower than in tropical areas, where there are larger numbers and mass movements. In addition, the airport is not located in close proximity to a camp or a concentrated highly productive foraging resource, and as such no large movements of bats are likely to occur at the airport. Given these points, there is only a low risk of mortality of individuals as a result of aircraft strike (Avisure 2015) given the scattered, patchy nature of food resources surrounding the airport. Mortality rates are unlikely to be of a magnitude that would lead to a long-term decrease in the size of an important population of the species.

Grey-Headed Flying-fox, a vulnerable species.
According to the DotE (2013) 'significant impact criteria' for vulnerable species, an action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:
Lead to a long-term decrease in the size of an important population of a species
All of the Grey-headed Flying-fox populations in eastern NSW are linked and hence can be considered one important population. Impacts that could lead to the long-term decrease in the size of an important population of the

Grey-Headed Flying-fox, a vulnerable species.

Grey-headed Flying-fox relate to the loss or disturbance of camp sites and roosting/breeding habitat and the loss of critical foraging habitat within a 50 kilometre radius of local camps. As noted above, this is the expected maximum foraging distance of the species from a roost site (Eby 1996). The airport site does not contain a roosting camp of the Grey-headed Flying-fox but is located within 50 kilometres of multiple known camps located in the Sydney basin, and construction would remove woodland and forest that would provide foraging habitat when trees are in flower.

Individuals from various roost camps are likely to forage in native woodland and forest at the airport site when trees are flowering. Construction of Stage 1 of the airport will result in the direct loss of approximately 120.6 hectares of native vegetation, including eucalypts that flower in the food bottle neck and the breeding period for the Grey-headed Flying-fox, and that contribute to critical habitat for the species as defined by in the recovery plan (DECC 2009). Longer term development at the airport site would lead to further loss of 78.6 hectares of foraging habitat. Cumulative and facilitated development in the locality would follow as a result of construction, resulting in further clearing of foraging habitat for the species.

The airport would require the removal of 120.6 hectares of foraging habitat (native woodland forest vegetation) for Stage 1, and an additional 78.6 hectares of foraging habitat for longer term development, which is a large area of foraging habitat in an already highly fragmented rural landscape. Further development of the locality would follow as a result of construction of the airport, resulting in further clearing of foraging habitat for the species. The proportion of habitat to be removed for Stage 1 is about 0.70 per cent of the available habitat (native woodland and forest vegetation) in the locality, and a much smaller proportion of the available habitat within 50 km of local roost sites. Extensive areas of foraging habitat are located within the Greater Blue Mountains World Heritage Area to the west of the airport site.

Patches of native vegetation in the airport site are already highly fragmented. Construction of the airport would increase existing fragmentation of foraging habitat in a mainly agricultural landscape by impacting on patches of native vegetation but would not create a barrier to the species' existing ability to move through the area. Loss of habitat will increase the distances between habitat patches and that may impact energy costs in particular during periods when food is scarce.

The airport site comprises a substantial area of foraging habitat for the Grey-headed Flying-fox that would be lost as a result of construction of the Stage 1 area. These habitat areas contribute to foraging resources at critical times in the lifecycle of the species, and when considered in the context of further loss from longer term development at the airport site, and other facilitated and cumulative impacts in the locality, this clearing could contribute to the long-term decline of the Grey-headed Flying-fox important population.

There is a potential for mortality of individuals from aircraft strike, although the risk is low given the location of the airport, lack of camps in close proximity, and lack of a concentrated highly productive foraging resource in the area. Mortality rates are unlikely to be of a magnitude that would lead to a long-term decrease in the size of an important population of the species.

Reduce the area of occupancy of an important population

The project will not directly impact on any known roost camps in the locality. The impacts of construction of the airport on the Grey-headed Flying-fox population would be primarily confined to loss of foraging habitat caused by direct clearing of native vegetation during the construction phase, and with facilitated and cumulative impacts of longer term development in the locality, the reduction in foraging habitat in the area would further reduce available habitat in the locality. Patches of native vegetation in the airport site are already highly fragmented. Construction of the airport would increase existing fragmentation of foraging habitat in a mainly agricultural landscape by impacting on patches of native vegetation but would not create a barrier to the species' existing ability to move through the area.

There is some potential for loss of individuals on occasion through aircraft strike, however the risk of this is considered low (Avisure 2015).

In terms of occupancy, the airport would not directly impact any camp sites, but would reduce the current are of foraging habitat in the short term and the long-term. Bats will still move

through the area as the airport would not create a barrier and mortality through aircraft strike is low. As such, the overall occupancy area of the population would not change, but within the locality the foraging area would be reduced.

Fragment an existing important population into two or more populations

The project will not have any direct impact on local camps.

Patches of native vegetation in the airport site are already highly fragmented. Construction of the airport would increase existing fragmentation of foraging habitat in a mainly agricultural landscape by impacting on patches of native vegetation but would not create a barrier to the species' existing ability to move through the area. As discussed above, while the airport represents a risk of aircraft strike of individuals, it would not be an impermeable barrier to their movement. Highly mobile species such as the Grey-headed Flying-fox are expected to be less impacted by fragmentation and this species is well-adapted to accessing widely spaced habitat resources given its mobility and preference for seasonal fruits and blossom. This species' typically exhibits very large home ranges and Grey-headed Flying-foxes are known to travel distances of at least 50 kilometres from roost sites to access seasonal foraging resources (Eby 1996).

The project would therefore not fragment an existing important population of the Grey-headed Flying-fox into two or more populations.

Adversely affect habitat critical to the survival of a species

In the draft recovery plan for the Grey-headed Flying-fox (DECCW 2009), foraging habitat that meets at least one of the following criteria can be explicitly identified as habitat critical to the survival of the species. These criteria include natural habitat that is:

- Productive during winter and spring, when food bottlenecks have been identified.
- Known to support populations of >30,000 individuals, within an area of 50 kilometre radius.
- Productive during the final weeks of gestation, and during the weeks of birth, lactation and conception (Sept-May).
- Productive during the final stages of fruit development and ripening in commercial crops affected by Grey-headed Flying-foxes.
- Known to be continuously occupied as a camp site.

In addition, it is not possible to predict what localities will be productive in which months, and therefore what localities will provide essential habitat for the species. All foraging habitat has the potential to be productive during general food shortages and to therefore provide a resource critical to survival (DECCW 2009).

No roost camp has been identified within the airport site, and the local camps would not be directly impacted by construction of the airport.

Construction of the airport would remove 120.6 hectares of potential habitat for Stage 1 and additional 78.6 hectares during development for future stages. Eucalypt species present at the airport site are not particularly productive during the 'food bottleneck' or the breeding season and may support individuals from various local camps when the trees are in flower but are not likely to support the population as a whole. As such, the foraging habitat present at the airport site is not explicitly critical habitat.

The airport site comprises a substantial area of foraging habitat for the Grey-headed Flying-fox that would be lost as a result of construction of the Stage 1 area. These habitat areas contribute to foraging resources at critical times in the lifecycle of the species, and may be provide critical resources during food shortages. In this sense, habitat at the airport provides a resource critical

Grey-Headed Flying-fox, a vulnerable species.
to survival. When considered in the context of further loss from longer term development at the airport site, and other facilitated and cumulative impacts in the locality, this clearing could contribute to the long-term decline of the Grey-headed Flying-fox important population. Given the size of foraging habitat at the airport site, and area of habitat that would be lost through cumulative and facilitated impacts, the airport does have the potential to affect habitat critical to the long-term survival of the species.
Disrupt the breeding cycle of an important population
No roost camps are present at the airport site. Construction of the airport would not have a direct impact on any local roost camps. The airport would require the removal of 120.6 hectares of foraging habitat for Stage 1, and an additional 78.6 hectares of foraging habitat for longer term development, which is a large area of foraging habitat in an already fragmented rural landscape. Stage 1 would result in the loss of 0.70 percent of foraging habitat in the locality. The airport site may support individuals from various local camps when the trees are in flower, but is not likely to be critical to the survival of the population. Grey-headed Flying-foxes would feed occasionally at the airport site, but given the limited productivity of the vegetation that would be removed, would not depend solely on these foraging habitats. The project site would not form an impermeable barrier to the movement of individuals of this species between roost sites and foraging grounds, however individuals flying across the airport site and approaches may be at risk of mortality from aircraft strike, although this is considered a low risk (Avisure 2015). While the airport would remove a large area of foraging habitat and facilitate further removal of habitat in the locality, there would be no direct impact on breeding camps and the risk of aircraft strike is low. As such the airport is not likely to disrupt the breeding cycle of the local population of this highly mobile species.
Modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
The airport would require the removal of 120.6 hectares of foraging habitat for Stage 1, and an additional 78.6 hectares of foraging habitat for longer term development, which is a large area of foraging habitat in an already fragmented rural landscape. The proportion of habitat to be removed for Stage 1 is 0.70 per cent of the available habitat in the locality, and a much smaller proportion of the available habitat within 50 km of local roost sites. Construction and operation of the airport would not isolate areas of foraging habitat for this highly mobile species, although there is a low risk of mortality from aircraft strike. There is limited potential for indirect impacts such as edge effects on foraging habitat given that few large patches intersect the Stage 1 or airport site boundaries. Any patches that do intersect these boundaries are already subject to substantial edge effects. The project will not directly impact on any local roost camps. The loss and/or modification of foraging habitat is not likely to disrupt the breeding cycle of the local population of this highly mobile species given the extent of suitable foraging habitat within a 50 km radius of local camps. The airport site comprises a substantial area of foraging habitat for the Grey-headed Flying-fox that would be lost as a result of construction of the Stage 1 area. These habitat areas contribute to foraging resources at critical times in the lifecycle of the species, and when considered in the context of further loss from longer term development at the airport site, and other facilitated and cumulative impacts in the locality, this clearing could contribute to the long-term decline of the Grey-headed Flying-fox.
Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat
Weed species have been recorded throughout the airport site. Construction and operation of the

Grey-Headed Flying-fox, a vulnerable species.

airport are unlikely to increase the incidence of weeds or spread weeds to such as extent that remaining foraging habitat for the Grey-headed Flying-fox is impacted by weeds. Mitigation measures to minimise the spread of weeds would be included in the CEMP (see Section 9.2).

The airport is not likely to introduce feral animals to the area or encourage the spread of feral animals that may impact Grey-headed Flying-foxes.

Introduce disease that may cause the species to decline

There are no known disease issues affecting this species that are relevant to the airport. The airport would be unlikely to increase the potential for significant disease vectors to affect this species.

Diseases potentially affecting native vegetation in the airport site and adjacent areas include Root Rot Fungus (*Phytophthora cinnamomi*) and Myrtle Rust. These diseases could affect Grey-headed Flying-fox habitat as they affect plants in the plant family Myrtaceae. To minimise the chance of introducing plant pathogens, machinery would be washed down before moving from area to area and personnel, vehicles and plant would be excluded from habitat areas unless necessary..

Interfere substantially with the recovery of the species

The project would not directly impact on any local roost camps for the local population and no impacts on the breeding success of the local population are anticipated.

The draft recovery plan for the Grey-headed Flying-fox (DECCW 2009) identifies the protection of foraging resources as a key recovery objective. The airport would be located in a highly cleared landscape, and would involve the removal of small patches of somewhat productive native vegetation. In total, 120.6 hectares of foraging habitat would be removed for Stage 1, and an additional 78.6 hectares of foraging habitat for longer term development. Overall, the airport site comprises a substantial area of foraging habitat for the Grey-headed Fling-fox that would be lost as a result of construction of the Stage 1 area. These habitat areas contribute to foraging resources at critical times in the lifecycle of the species, and when considered in the context of further loss from longer term development at the airport site, and other facilitated and cumulative impacts in the locality, this clearing could interfere with the recovery of the species in the locality.

Conclusion

While the airport would not directly impact any breeding camps, the airport is likely to have a significant impact on the Grey-headed Flying-fox as:

- Construction of the airport would remove 120.6 hectares of potential habitat for Stage 1 which represents 0.70 per cent of the potential foraging habitat for the Grey-headed Flying-fox within the locality
- These areas of habitat contribute to the availability of foraging resources for local camps when resources are scarce and at critical lifecycle stages
- The airport will further fragment foraging habitat within an already highly fragmented landscape
- Cumulative and facilitated development in the locality would follow as a result of construction, resulting in further clearing of foraging habitat for the species.

An offset package has been prepared for the airport to compensate for these significant impacts (see Section 9.3). This would include the protection and management of Grey-headed Flying-fox habitat at offset sites in perpetuity.

Swift Parrot

The Swift Parrot (*Lathamus discolor*)breeds in Tasmania. The principal over-wintering habitat for the Swift Parrot on the Australian mainland is the box-ironbark forests and woodlands inland of the Great Dividing Range in Victoria and NSW. Swamp Mahogany (*Eucalyptus robusta*), Spotted Gum (*Corymbia maculata*), Grey Box (*Eucalyptus moluccana*) and Red Bloodwood (*Corymbia gummifera*) are important nectar sources in coastal parts of the non-breeding range. Commonly used lerp infested trees include Inland Grey Box (*Eucalyptus microcarpa)*, Grey Box (*Eucalyptus moluccana)* and Blackbutt (*Eucalyptus pilularis)*. Forest Red Gum (*Eucalyptus tereticornis*) is also considered a feed tree in coastal areas, including the Sydney Metro and Hawkesbury-Nepean areas (Saunders and Tzaros 2011). The occurrence of Swift Parrots at foraging sites is largely linked with the abundance of lerp, nectar and non-aggressive competitors (Swift Parrot Recovery Team 2001). It has been found to preferentially forage in large, mature trees that provide more reliable foraging resources than younger trees (Saunders and Tzaros 2011).

The Swift Parrot returns to some foraging sites on a cyclic basis depending on food availability. In a recent study, over half of all foraging sites in the study were used repeatedly, signifying their potential conservation value (Swift Parrot Recovery Team 2001). Landscapes with winter foraging habitat included scattered trees, remnant vegetation and continuous forests, and within these, Swift Parrots foraged at length on lerp and nectar from a variety of tree species. The occurrence of Swift Parrots at foraging sites was largely linked with the abundance of lerp, nectar and non-aggressive competitors (Swift Parrot Recovery Team 2001).

The feed trees Grey Box (*Eucalyptus molluccana*) and Forest Red Gum (*Eucalyptus tereticornis*) are the dominant canopy species in the airport site. Much of the airport site is vegetated with relatively young regrowth which are not the preferred foraging habitat for the species, although some patches containing large, old-growth trees are also present. The airport site is thus likely to be low quality winter foraging habitat for the Swift Parrot although it may provide shelter or supplementary foraging resources for migrating individuals. There are eight records of the Swift Parrot in the locality, but the species has not been recorded during current surveys which were undertaken when the species was known to be present in the Sydney basin, and when appropriate eucalypts were flowering.

Swift Parrot *Lathamus discolor*, an endangered species.
According to the DotE (2013) 'significant impact criteria', an action is likely to have a significant impact on an endangered species if there is a real chance or possibility that it will:
Lead to a long-term decrease in the size of a population
The Swift Parrot occurs as a single population, which migrates annually from breeding grounds in Tasmania to winter foraging grounds on the western slopes and coastal plains of mainland eastern Australia. The critical resources necessary for maintaining the life cycle of the species are suitable habitat within breeding and wintering grounds. The study area contains areas of eucalypt forest supporting winter flowering tree species that constitute suitable winter feeding habitat for migrating individuals of the Swift Parrot. Construction of the airport has the potential to reduce breeding success, through removing foraging resources critical to the survival of breeding adult birds during the winter season. Grey Box (Eucalyptus moluccana) and Forest Red Gum (E. tereticornis) are important feed trees in the Sydney region and occur throughout woodland vegetation at the airport site, although many of these trees are young regrowth, which reduces their current value for the species. The airport would require the removal of 120.6 hectares of potential foraging habitat for the Swift Parrot in Stage 1, and an additional 78.6 hectares of foraging habitat for longer term development. The proportion of habitat to be removed for Stage 1 is 0.70 per cent of the available habitat in the locality, and a much smaller proportion of the available habitat in the region. There are few records of the Swift Parrot in the locality, and no individuals were observed during targeted surveys. Native vegetation at the airport site comprises small to

Swift Parrot *Lathamus discolor*, an endangered species.
moderate sized patches, separated by large areas of cleared agricultural land, and dominated by aggressive competitors such as the Noise Miner. Based on these points, it is likely that the airport site is not an important foraging area for the species. Loss of foraging habitat, specifically winter-flowering eucalypt trees that are essential for maintaining the health of the population during its annual winter migration to mainland Australia, could reduce breeding success. Reduced food availability could lead to reduced health and lower survival rates for the return migration to Tasmania in spring. As noted above, the airport site is not likely to be an important foraging area for the species. The loss of vegetation at the airport site is not likely to impact the overall health of the migrating population. Operation of the airport could result in mortality of individuals from aircraft strike. Given the species only occurs in western Sydney for a part of the year, are transient, and tend to move in small flocks, the risk of aircraft strike is low. The operation of the airport would not create a permanent barrier to the movement of individuals across the airport site. Although the airport would require the removal of 120.6 hectares of low quality winter foraging habitat for Stage 1, and 78.6 hectares for longer term development, the proportion of habitat to be removed is small in comparison with existing habitat within the Sydney Basin Bioregion. Evidence gathered on the movements of the species also suggest that visits to the coastal forests are not consistent every year and depend on flowering of the Box-Ironbark woodlands on the south western slopes of NSW and Victoria (Swift Parrot Recovery Team 2001). Swift Parrots tend to return to good quality habitat areas year after year. There are only few records of the species in the locality, suggesting that the area is not important winter foraging habitat. Hence, the loss of small, generally young regrowth patches of foraging habitat within the airport site would not be likely to reduce the health and condition of individual birds such that migration (on the return journey to Tasmania in spring) is disrupted to the extent that it would interfere with the life cycle of the species. On the basis of the above considerations, the construction of the airport is unlikely to lead to a long-term decrease in the size of a population of the Swift Parrot.
Reduce the area of occupancy of the species
The distributional range of the Swift Parrot extends from Tasmania through parts of Victoria and NSW to southeast Queensland. Within this range, the area of occupancy for the species would include breeding grounds in Tasmania, migration routes and foraging habitats on mainland Australia. The impacts of construction of the airport on the Swift Parrot population would be primarily confined to loss of foraging habitat caused by direct clearing of native vegetation during the construction phase, and with facilitated and cumulative impacts of longer term development in the locality, the reduction in foraging habitat in the area would further reduce available habitat in the locality. Patches of native vegetation in the airport site are already highly fragmented. Construction of the airport would increase existing fragmentation of foraging habitat in a mainly agricultural landscape by impacting on patches of native vegetation but would not create a barrier to the species' existing ability to move through the area. There is some potential for loss of individuals on occasion through aircraft strike, however the risk of this is considered low. There is no evidence that the species occurs at the airport site, and there are only few records from the locality, suggesting the area is not important foraging habitat for the species. The loss of potential foraging habitat would represent only a minor fraction of the area of occupancy of the Swift Parrot within the region and a smaller fraction of its entire area of occupancy. The airport would thus have minor impacts on small areas of potential habitat for this species, and would not reduce its area of occupancy to any material extent.
Fragment an existing population into two or more populations
The Swift Parrot is a highly mobile species that routinely traverses large expanses of open water and open country, including Bass Straight, agricultural land and other clearings during its annual migration. The species is not resident in western Sydney, rather is a transient visitor in winter when appropriate eucalypt species are in flower. The Swift Parrot would rely on 'stepping stones' of suitable foraging and roosting habitat during migrations and is thought to prefer 'corridors' of woodland vegetation over which to traverse. Clearing of vegetation for the airport would reduce the incidence of small patches of vegetation, but would not remove a corridor of woodland vegetation. The dispersal or movement of the Swift Parrot across the

Swift Parrot *Lathamus discolor*, an endangered species.
landscape is unlikely to be affected as clearings created by the airport would not isolate habitat with respect to this species. As such, the airport would not fragment an existing population into two or more populations. Furthermore, retention of vegetation in conversation areas, in particular the Badgerys Creek corridor, would maintain stepping stones of habitat in the area.
Adversely affect habitat critical to the survival of a species
The Recovery Plan for the Swift Parrot (Saunders and Tzaros 2011) notes the key habitats for the species comprise habitats which are used for nesting, used by large proportions of the Swift Parrot population, are used repeatedly between seasons, or are used for prolonged periods of time. Habitat critical to the survival of the Swift Parrot includes those areas of priority habitat for which the Swift Parrot has a level of site fidelity or possess phenological characteristics likely to be of importance to the Swift Parrot. There is a lack of records of the species in the study area and few records known in the wider locality. Habitat in the locality is thus not likely to be important to the species. Individuals may however forage on occasion within the airport site as winter-flowering eucalypts are present. Potential habitat in the airport site is of low quality for the species, given that much of it is young regrowth and aggressive competitors such as Noisy Miners are dominant species at the site. Potential habitat may contribute to maintaining the condition and health of parrots sufficient for them to make the return flight to Tasmania during the spring migration, if individuals forage at the airport site. Habitat present may be more important in some years than others such as when resources are scarce inland during drought periods. The loss of 120.6 hectares of winter flowering eucalypt forest would represent an estimated loss of 0.70 per cent of accessible foraging habitat within a 10 km radius of the airport boundary. A further 78.6 hectares would be removed for longer term development. The stands of winter flowering gums within the study area would represent a small proportion of the total area of winter flowering habitat available within the region. Although the airport would contribute to the incremental loss of potential foraging habitat for the Swift Parrot within coastal NSW, this habitat is unlikely to be critical to the survival of this species, given that much of it is young regrowth and aggressive competitors such as the Noisy Minor dominate much of the site.
Disrupt the breeding cycle of a population
Breeding does not occur on mainland Australia. Adult birds would only occur within the study area as part of seasonal foraging behaviour during winter. The area of potential foraging habitat to be removed is restricted to various fragmented patches of eucalypt woodland, often dominated by young regrowth with few old trees. This habitat loss may decrease the availability of winter forage for individuals that disperse nomadically throughout the region during winter, if foraging occurs at the airport site. The reduced availability of potential foraging habitat, particularly during poor flowering seasons and/or drought periods, could theoretically reduce the health and condition of adult birds, which could in turn, lead to poor condition and reduced breeding success. However, the habitats in the study area are not considered critical to the Swift Parrot (see above) and it is unlikely that the condition and health of individuals that may forage in the study area on occasion would be compromised to the extent that breeding success of individuals would be affected. Furthermore, the airport would not fragment a population of the Swift Parrot or create a barrier to local or regional movements of the species between foraging and breeding areas. Given the above points, the airport is unlikely to disrupt the breeding cycle of a population of Swift Parrot.
Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline
The Swift Parrot is a highly mobile species that routinely traverses large expanses of open water and open country, including Bass Straight, agricultural land and other clearings during its annual migration. There is no evidence that the species occurs at the airport site, and there are only few records from the locality, suggesting the area is not important foraging habitat for the species. The airport would require the removal of 120.6 hectares of low quality foraging habitat for the Swift Parrot in Stage 1, and an additional 78.6 hectares of foraging habitat for longer term

Swift Parrot *Lathamus discolor*, an endangered species.
development. Potential habitat in the airport site is of low quality for the species, given that much of it is young regrowth and aggressive competitors such as Noisy Miners are dominant species at the site. Clearing of vegetation for the airport would reduce the incidence of small patches of vegetation, but would not remove a corridor of woodland vegetation. The dispersal or movement of the Swift Parrot across the landscape is unlikely to be affected as clearings created by the airport would not isolate habitat with respect to this species. Given that there is no evidence of the species in the airport site, that there are few records in the locality, only low quality potential habitat would be removed, and the airport would not isolate habitat with respect to this species, the airport is not likely to modify, destroy, remove, isolate or decrease habitat such that the species would decline.
Result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat
Weed species have been recorded throughout the airport site and in adjacent areas. During construction there is potential for noxious and invasive weeds to be spread via earthworks and clearing activities, from seeds and other propagules in the soil and on vegetative material. Measures to manage invasive weed species and rehabilitate disturbed areas would be implemented via the CEMP to reduce the potential for weeds to become established in areas of potential habitat, including the conservation areas and other vegetation proximate or downstream of the airport site. The airport is not likely to introduce feral animals to the area or encourage the spread of feral animals that may impact the Swift Parrot.
Introduce disease that may cause the species to decline
Infection by Psittacine circoviral (beak and feather) disease affecting endangered psittacine species (DECC 2005a) is listed as a key threatening process under the EPBC Act. The Swift Parrot is an endangered psittacine species. The airport is unlikely to introduce or spread the Psittacine circoviral (beak and feather) disease because construction staff and equipment would not come into contact with any birds, or otherwise act as a vector for the disease. Diseases potentially affecting native vegetation in the airport site and surrounds include Root Rot Fungus (Phytophthora cinnamomi) and Myrtle Rust. Phytophthora and Myrtle Rust could affect Swift Parrot habitat as they both affect plants in the plant family Myrtaceae. To minimise the chance of introducing new plant pathogens, machinery would be washed down before moving from area to area and personnel, vehicles and plant would be excluded from habitat areas unless necessary.
Interfere with the recovery of the species
Habitat loss is listed as a current threat to the Swift Parrot in the Recovery Plan (Saunders and Tzaros 2011). The airport would require the removal of 120.6 hectares of low quality potential foraging habitat for Stage 1, and an additional 78.6 hectares of potential foraging habitat for longer term development. This habitat loss will decrease the availability of winter forage for individual parrots that may disperse nomadically through the study area during winter. It may further increase interspecific competition with aggressive species such as the Noisy Miner and Bell Miner in adjacent areas. However, given the habitat to be removed comprises only a minor proportion of potential habitat present in the locality, the airport site is not considered to support critical habitat for this species, the low numbers of records in the locality and lack of evidence of the species at the airport site, the airport is unlikely to interfere with the recovery of the species.
Conclusion
The airport is unlikely to have a significant impact on the Swift Parrot as: • The species does not breed in NSW. • There is no evidence to date that the airport site represents critical or important foraging habitat for the species. There are no records from the site and few from the locality. • Potential habitat includes small patches of mainly regenerating woodland, which

Swift Parrot *Lathamus discolor*, an endangered species.

is not preferred foraging habitat for this species. Only small areas of mature vegetation would be removed.

- Aggressive competitors such as the Noisy Miner are the dominant bird species over much of the site.
- The airport is unlikely to create a barrier to movements.
- The potential for bird strike mortality is low.

Greater Blue Mountains World Heritage Area

The GBMWHA consists of 1.03 million hectares of sandstone plateaux, escarpments and gorges dominated by temperate eucalypt forest. It is noted for the diversity of eucalypts associated with its wide range of habitats as well as significant numbers of rare or threatened species, including endemic and evolutionary relict species (such as the Wollemi Pine). A significant proportion of the Australian continent's biodiversity occur in the area (UNESCO 2015). The GBMWHA protects a large number of pristine and relatively undisturbed catchment areas, some of which make a substantial contribution to maintaining high water quality in a series of water storage reservoirs supplying Sydney and adjacent rural areas (DECC 2009b).

An assessment of significance is provided below with a focus on impacts on the biodiversity values of the GBMWHA.

Greater Blue Mountains World Heritage Area

The World Heritage values for which the GBMWHA was listed include:

- Outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.
- Important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

It is noted for the diversity of eucalypts associated with its wide range of habitats as well as significant numbers of rare or threatened species, including endemic and evolutionary relict species.

According to the significant impact guidelines (DEWHA 2013), an action is likely to have a significant impact on the World Heritage values of a declared World Heritage property (or the National Heritage values of a National Heritage place) if there is a real chance or possibility that it will cause:

- ***one or more of the World Heritage/National Heritage values to be lost***
- ***one or more of the World Heritage/National Heritage values to be degraded or damaged, or***
- ***one or more of the World Heritage/National Heritage values to be notably altered, modified, obscured or diminished***

The airport would be located about 9 km from the eastern edge of the GBMWHA. The GBMWHA covers a vast area, much of which is located well away from the airport. There would be no direct impacts resulting from the construction of the proposed airport on any areas of the GBMWHA. The construction of the airport would not modify or inhibit ecological processes within the area. The proposed airport has been designed to minimise adverse changes in hydrology and water quality. Design and mitigation measures are proposed to manage water quality (such as detention basins and appropriate sediment fencing). Any indirect impacts potentially associated construction (eg sedimentation or introduction of

pollutants into waterways) are likely to be negligible given the distance between the proposed airport and the GBMWHA, the small area of the GBMWHA that could potentially be impacted, and appropriate design and mitigation measures to minimise the risk of off-site impacts during construction.

Based on these considerations there is no real chance or possibility that natural heritage values will be lost or significantly adversely modified as a result of construction of the airport.

Potential operational impacts are unlikely to impact the World Heritage or National Heritage values to such a degree that these would be lost or significantly, degraded or damaged or modified based on the following key considerations with respect to potential indirect impacts:

- Noise: Aircraft noise would impact a relatively small area of the GBMWHA under proposed flight paths. This would be a novel impact in these areas, but is not expected to be substantial impact as there would be no low-flying aircraft over the GBMWHA. Aircraft would be at heights generally greater than 5,000 feet with maximum noise levels typically below 55 dBA, (Wilkinson Murray 2015b) which is likely to be below threshold to disturb fauna behaviours (refer to section 8.2.5). Fauna resident under the proposed flight paths are likely to become habituated to the elevated noise levels in the long term.
- Water quality: A portion of the GBMWHA fronts the Nepean River downstream of its confluence with Duncans Creek. Changes to water quality and hydrology at the airport site have a very low potential to impact water quality in this portion of the GBMWHA. Bio-retention basins would be installed to treat surface runoff before it leaves airport site, and additional mitigation measures will further improve water quality leaving the airport site. Further resolution of mitigation measures would be provided in the final EIS having regard to potential impacts on threatened species and their habitats that may occur downstream of the site and the potential for impacts. There may be changes to flows in Duncans Creek as a result of changes to topography and diversion of flows in this direction. Given the generally poor quality of aquatic habitats in and downstream of the airport site, the small changes in flows are unlikely to have a substantial impact on fish habitat in downstream areas. Impacts on the water quality of the GBMWHA near where Duncans Creek flows into the Nepean River are therefore highly unlikely, particularly given and the distance between the airport site and the portion of the GBMWHA that fronts the Nepean River (refer to section 8.2.5).
- Air quality: Changes to air quality are unlikely given the prevailing wind directions. Any changes to air quality would be temporary and localised. Occasional changes to air quality as a result of wind changes are not likely to impact biodiversity values in the GBMWHA (refer to section 8.2.5).
- Fuel jettisoning: fuel jettisoning over the GBMWHA would be extremely rare, and no fuel would reach the ground. Fuel jettisoning is therefore unlikely to interfere with any ecosystem processes, result in the substantial degradation of habitat, or reduce the viability of any flora or fauna species (refer to section 8.2.5).
- Aircraft crashes: Aircraft traffic would increase emissions of NO_2, PM_{10}, $PM_{2.5}$, CO, SO_2, and air toxics. The highest off-site concentrations of the air quality metrics evaluated were generally predicted to occur to the north and north-east of the proposed airport due to the prevalence of south-westerly winds. As such, these emissions are generally unlikely to affect air quality over the GBMWHA, as it is located to the west of the airport site. Occasional changes to air quality as a result of wind changes would be temporary and localised, and are not likely to impact ecological processes in the GBMWHA.

Greater Blue Mountains World Heritage Area
• Although very unlikely, operation of the proposed airport could result in an aircraft crashing within the GBMWHA. An aircraft crash would mainly cause localised damage to a relatively small area of the GBMWHA. This would be an extremely rare event, if it happens at all (refer to section 8.2.5). • Greenhouse gas emissions: the construction and operation of the proposed airport will contribute to greenhouse gas emissions. Climate change in general is likely to impact biodiversity values within the GBMWHA, potentially changing the species composition and distribution in the long-term. The emissions from the construction and operation of the proposed airport itself, however, are not likely to have a significant impact on the GBMWHA, as it is only a minor part of a much larger and more wide-spread issue (refer to section 8.2.5). Given the above points, the construction and operation of the airport is unlikely to result in one or more of the World Heritage/National Heritage values to be lost, degraded or damaged, or notably altered, modified, obscured or diminished. The proposed airport would not result in a reduction in the diversity of eucalypts or alter biological processes.
With respect to the specific biological and ecological values an action is likely to have a significant impact on a World Heritage property or National Heritage Place if there is a real chance or possibility that the action will:
• **modify or inhibit ecological processes in a National Heritage place** • **reduce the diversity or modify the composition of plant and animal species in all or part of a World Heritage property/National Heritage place** • **cause a long-term reduction in rare, endemic or unique plant or animal populations or species in a World Heritage property/National Heritage place,**
The construction of the airport will not occur within the GBMWHA and would not directly modify or inhibit ecological processes within the area. Parts of the airport site west of the Northern Road drain to Duncans Creek, which drains to the Nepean River. Construction and operation of the airport could result in reduced water quality as a result of erosion, sedimentation and introduction of pollutants into the waterway, as well as changes to flow regimes in Duncans Creek. The airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site and to avoid substantial alteration of surface water drainage patterns outside of the airport site. Additional mitigation measures are proposed to manage water quality to further minimise downstream impacts. Given the distance between the airport and the small area of the GBMWHA that is located adjacent to the Nepean River near the airport, and the inclusion of specific design elements and mitigation measures, any impacts would likely have dissipated by the time the water reaches the GBMWHA. Noise has been shown to have a variety of impacts on fauna, including changing foraging behaviour, impacting breeding success and changing species occurrences (Barber et al 2009). Low-flying aircraft can cause flight response in some species, causing them to abandon nests, and other species are known to avoid higher elevation areas where noise levels are higher, potentially resulting in fragmentation of habitat (Ellis, Ellis, & Mindell, 1991; Landon et al 2003). Most of these impacts occur when noise levels are high (greater than 65 dB), and given the height at which flights are likely to be, these impacts are unlikely. While background noise would increase under the flight tracks, fauna are likely to become habituated to the elevated noise levels in the long term (Anderson et al 1996; Conomy et al 1998) as aircraft would not be flying at low altitudes over the GBMWHA. Operation of aircraft is highly unlikely to permanently alter foraging or breeding behaviour of any fauna species. Any impacts would be localised, with impacts occurring under the main flight paths. The majority of fauna within the vast GBMWHA would not be impacted by aircraft noise. Noise levels are not likely to alter the composition of fauna communities in the GBMWHA. Changes to air quality are unlikely given the prevailing wind directions. Any changes to air quality would be temporary and localised. Occasional changes to air quality as a result of

Greater Blue Mountains World Heritage Area
wind changes are not likely to impact biodiversity values in the GBMWHA. Construction and operation of the airport would increase carbon emissions, through clearing of vegetation, and operation of vehicles and aircraft. Climate change in general is likely to impact biodiversity values within the GBMWHA, potentially changing the species composition and distribution in the long-term. The airport itself, however, is not likely to have a significant impact on the GBMWHA, as it is only a minor part of a much larger and more wide-spread issue. Impacts resulting from fuel jettisoning and aircraft crashes are highly unlikely (see above). Given the above points, the potential for noise impacts and water and air quality impacts are unlikely to modify or inhibit ecological processes, reduce the diversity or modify the composition of plant and animal species, or cause a long-term reduction in rare, endemic or unique plant or animal populations or species in the GBMWHA.
• **fragment, isolate or substantially damage habitat for rare, endemic or unique animal populations or species in a World Heritage property/National Heritage place.**
The construction of the airport will not occur within the GBMWHA. There will be no direct impacts on native vegetation or flora or fauna habitats as a result of construction of the airport. No areas of habitat for rare, endemic or unique animal populations or species would be fragmented, isolated or substantially damaged. Noise would not be at a level that would cause fauna to avoid certain areas, thus potentially fragmenting habitat (refer to section 8.2.5).
• **involve construction of buildings, roads, or other structures, vegetation clearance, or other actions with substantial, long-term or permanent impacts on relevant values, and**
The construction of the airport will not occur within the GBMWHA. As such, the airport would not involve clearing of vegetation within the GBMWHA, and would not result in any permanent impacts such as the construction of roads, buildings or other structures. Potential indirect impacts resulting from operation of the airport are unlikely to result in any substantial, long-term or permanent impacts on biodiversity values of the GBMWHA, as has been detailed above.
• **introduce noise, odours, pollutants or other intrusive elements with substantial, long-term or permanent impacts on relevant values.**
Noise has been shown to have a variety of impacts on fauna, including changing foraging behaviour, impacting breeding success and changing species occurrences (Barber et al 2009). These impacts tend to occur at high decibel levels, such as from low-flying-aircraft. While background noise would increase under the flight paths, fauna are likely to become habituated to the elevated noise levels in the long term (Anderson et al 1996; Conomy et al 1998) as aircraft would not be flying at low altitudes over the GBMWHA. . The airport would be located about 9 km from the eastern edge of the GBMWHA. The GBMWHA covers a vast area, much of which is located well away from the airport. Parts of the airport site west of the Northern Road drain to Duncans Creek, which drains to the Nepean River. Design and mitigation measures for the airport would minimise the risk of reduced water quality as a result of erosion, sedimentation and introduction of pollutants into the waterway. Given the distance between the airport and the small area of the GBMWHA that is located adjacent to the Nepean River near the airport, and the inclusion of specific design elements and mitigation measures, any impacts would likely have dissipated by the time the water reaches the GBMWHA. Changes to air quality are unlikely given the prevailing wind directions. Any changes to air quality would be temporary and localised. Occasional changes to air quality as a result of wind changes are not likely to impact biodiversity values in the GBMWHA. Fuel jettisoning over the GBMWHA would be extremely rare, and no fuel is likely to reach the ground. Fuel jetttisoning is therefore unlikely to interfere with any ecosystem processes, result in the substantial degradation of habitat, or reduce the viability of any flora or fauna species.

Greater Blue Mountains World Heritage Area
Conclusion
The proposed airport is not likely to have a significant impact on the biodiversity values of the GBMWHA given: • There would be no direct impact on the GBMWHA • Indirect impacts associated with the construction and operation of the airport are unlikely to result in the loss or significant modification of biological diversity or biological processes within the GBMWHA, given: – Potential impacts on fauna within the GBMWHA as a result of noise are unlikely to result in changes to species behaviour or habitat use – Potential impacts on the GBMWHA as a result of changes to air quality are likely to be negligible given the distance to the GBMWHA and prevailing wind conditions – The airport design and land use plan includes measures to manage surface water that have been purposefully designed to capture water on site and to avoid substantial alteration of surface water drainage patterns and water quality outside of the airport site. – While greenhouse gas emissions will increase as a result of the construction and operation of the airport, this is unlikely to directly result in the loss of biological diversity or biological processes within the GBMWHA.

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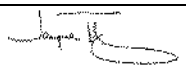
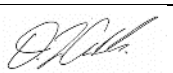
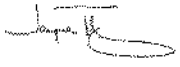
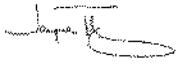
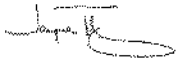
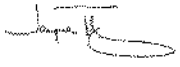
0	B Harrington K Crosby	J Tipping		D Chubb		8/7/15
1	B Harrington K Crosby	J Tipping		D Chubb		28/8/15
2	B Harrington K Crosby	J Tipping		D Chubb		4/9/15
3	B Harrington K Crosby	J Tipping		G. Marshall	*G Marshall*	29/9/15
4	B Harrington K Crosby	J Tipping		D Chubb		8/10/15



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Appendix K2
Offsets strategy





Department of Infrastructure and Regional Development

Western Sydney Airport EIS

Biodiversity Offset Package

October 2015

Limitations

This report has been prepared by GHD for the Commonwealth and may only be used and relied on by the Commonwealth for the purpose agreed between GHD and the Commonwealth as set out in Section 1.2 of this report. GHD otherwise disclaims responsibility to any person other than the Commonwealth arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report in Sections 2 to 5 and GHD disclaims liability arising from any of the assumptions being incorrect.

This offset package is only for the proposal that is the subject of the EIS (i.e. Stage 1 of the Western Sydney Airport).

GHD has prepared this report on the basis of information provided by the Commonwealth and others who provided information to GHD, which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were included in the information provided by the Commonwealth.

The amount of offset required for matters protected under the EPBC Act will be calculated by the Department of the Environment using the offset assessment guide based on inputs identified by GHD in the biodiversity offset package. The Department may choose to adjust values or assumptions in the offset assessment guide which may affect the amount of offset required.

Table of contents

1. Introduction 1
   - 1.1 Background 1
   - 1.2 Purpose of report 3
   - 1.3 BioBanking 4
   - 1.4 Relationship with other reports 5
2. Offset Requirements for EPBC Act-listed Biota 7
   - 2.1 Identification of affected threatened biota 7
   - 2.2 Impacts on affected threatened biota 8
3. Offset Requirements for Impacts on the Environment 23
   - 3.1 Overview 23
   - 3.2 Credit calculations 23
   - 3.3 Biodiversity credits 28
   - 3.4 Assumptions and amendments to the BioBanking methodology 30
4. Proposed Offsets 33
   - 4.1 Proposed offset strategy 33
   - 4.2 Identification of potential offset sites 33
   - 4.3 Description of potential offset sites 34
   - 4.4 Proposed offset areas 39
   - 4.5 Management of offset sites 43
5. Offset Assessment Guide Calculations 47
   - 5.1 Overview 47
   - 5.2 Quality of offset sites 47
   - 5.3 Alternative environmental contributions 53
   - 5.4 Preliminary offset assessment guide calculations 54
6. Delivery of Offsets 61
   - 6.1 Purchase and retirement of biodiversity credits 61
   - 6.2 Identification of additional offsets 64
   - 6.3 Cost of delivery of offsets 65
   - 6.4 Finalisation of the offset package 66
   - 6.5 Consistency with EPBC Act offset policy 66
7. Conclusions 69
8. References 71

Table index

Table 1 Summary of landscape features 24

Table 2 Vegetation zones 25

Table 3 Management zones 26

Table 4 Predicted threatened species (ecosystem credit species) 27

Table 5 Impacts on species credit-type species 28

Table 6 Ecosystem credits required to offset impacts of the proposed airport 29

Table 7 Species credits required to offset impacts of the proposed airport 30

Table 8 Potential offset sites 35

Table 9 Threatened species recorded at the potential offset sites 37

Table 10 Proposed offset areas 40

Table 11 Effect of management actions on quality of habitat in the potential offset sites 44

Table 12 Attribute values entered in the preliminary offset assessment guide calculations for EPBC Act Cumberland Plain Woodland 55

Table 13 Attribute values entered in the preliminary Offset assessment guide calculations for poorer quality Cumberland Plain Woodland 56

Table 14 Attribute values entered in the preliminary Offset assessment guide calculations for the Grey-headed Flying-fox 58

Table 15 Ecosystem credits for impacts on the natural environment 62

Table 16 Species credits potentially available at offset sites 63

Table 17 Consistency with the EPBC Act offset principals 67

Table 18 Vegetation zones, habitat for the affected threatened biota and available biodiversity credits at the Williamswood biobank (GHD 2014a) 78

Table 19 Vegetation zones, habitat for the affected threatened biota and available biodiversity credits at the Oaks biobank (GHD 2014g) 80

Table 20 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Durham biobank (GHD 2014a) 82

Table 21 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Mamre biobank (GHD 2014a) 84

Table 22 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Forrester biobank (GHD 2014a) 86

Table 23 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Luddenham biobank (GHD 2014a) 88

Table 24 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Roper biobank (GHD 2014a) 90

Table 25 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Caddens biobank (GHD 2014a) 92

Table 26 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Dunheved biobank (GHD 2014a) 94

Table 27 Vegetation zones, habitat for the affected threatened biota and available biodiversity credits at the Stage 1 Montpelier biobank (GHD 2015d) 97

Table 28 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Stage 2 Montpelier biobank (GHD in prep.) 100

Table 29 Vegetation zones, habitat for the affected threatened biota and available biodiversity credits at the Menangle Road biobank (GHD 2015e) 103

Table 30 Vegetation zones, habitat for the affected threatened biota and available biodiversity credits at the Bruelle biobank (GHD 2015f) 105

Figure index

Figure 1 Site location 6

Figure 2 Threatened flora and ecological communities 14

Figure 3 Threatened fauna and habitat features 18

Figure 4 Landscape assessment 31

Figure 5 The airport site and potential offset sites 38

Appendices

Appendix A – Potential offset sites

Appendix B – BioBanking Credit Calculations

Glossary of terms

Term	Definition
Airport site	The land declared under the *Airports Regulations 1997* as the airport site for the proposed Western Sydney Airport.
Affected threatened biota	Threatened species listed under the EPBC Act, which are likely to suffer a significant impacts as a result of a proposal and which require biodiversity offsets in accordance with the EPBC Act offset policy
BBAM	The NSW *BioBanking Assessment Methodology* (OEH, 2014).
Biobank site	Land that is designated by a biobanking agreement to be a biobank site.
Biobanking agreement	An agreement entered into between the landowner and the Minister under Part 7A of the TSC Act for establishing a biobank site.
BioBanking Trust Fund	The Trust Fund established under Part 7A of the TSC Act to hold funds from the sale of credits.
Biodiversity credit	A unit of biodiversity value to measure specific development impacts or conservation gains in accordance with the BBAM. Includes ecosystem credits or species credits.
BioBanking credit report	Specifies the number and type of biodiversity credits: required to offset the impacts of a development to obtain a Biobanking statement; or required to offset the impacts of a Major Project in accordance with the FBA; or that would be generated through conservation and management of a biobank site under a BioBanking agreement.
Biodiversity offsets	Specific measures that are put in place to compensate for impacts on biodiversity values.
Biodiversity values	The composition, structure and function of ecosystems, including native species, populations and ecological communities, and their habitats.
CEEC	Critically endangered ecological community
Construction impact zone (CIZ)	Includes the area of bulk earthworks in the northern half of the site (particularly for the establishment of the runway, terminal and aviation support facilities) together with areas of disturbance for ancillary infrastructure in the southern half of the site, including additional permissible activities prior to the construction of the second runway as well as minor activities during Stage 1 (e.g. drainage channels). The construction impact zone does not include the long term development such as the second runway or ancillary development outside the site boundary which will be subject to separate approvals. A full description is provided in Chapter 6 of the EIS.
Department of Infrastructure and Regional Development	The Australian Government Department responsible for proposing Stage 1 of the Western Sydney Airport.
DotE	The Commonwealth Department of the Environment
DPI	The NSW Department of Primary Industries

DSEWPaC	The former Department of Sustainability Environment Water Populations and Communities, now the Commonwealth Department of the Environment
Ecosystem credit	The class of biodiversity credits created or required for the impact on EECs, CEECs and threatened species habitat for species that can be reliably predicted to occur within a vegetation type according to the BBAM.
EEC	Endangered ecological community
Environmental conservation zone	The area at the airport site that would be provided as an environmental conservation zone, as outlined in the land use plan in the draft Airport Plan (see Chapter 4 of the EIS).
EPBC Act	The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FBA	The Framework for Biodiversity Assessment. The methodology to assess impacts on biodiversity that must be used by a proponent to assess all biodiversity values on the development site for a Major Project in accordance with The NSW Biodiversity Offsets Policy for Major Projects.
MNES	'Matters of national environmental significance' listed under the EPBC Act including threatened biota, migratory species, World Heritage/National Heritage sites and Ramsar wetland sites.
NSW-listed biota	Threatened species listed under the NSW TSC Act and their habitats
OEH	The NSW Office of Environment and Heritage
Proposed offset areas	The areas within the proposed offset sites that have been identified in this offset package in order to offset impacts on affected threatened biota listed under the EPBC Act. Only includes vegetation and habitat which is appropriate to offset impacts on the affected threatened biota according to the rules contained in the EPBC Act offset policy and which are linked to biodiversity credits which are available for sale.
Proposed offset sites	The offset sites that have been identified in this offset package in order to offset biodiversity impacts.
PMST	Protected Matters Search Tool, a database administered by the Department of the Environment that contains known and predicted records of matters of national environmental significance listed under the EPBC Act.
Species credit	The class of biodiversity credits created or required for the impact on threatened species that cannot be reliably predicted to use an area of land based on habitat surrogates according to the BBAM.
Stage 1 development	Stage 1 of the airport would comprise one runway and cater for up to approximately 10 million annual passengers. This patronage level may be reached around 2030. Stage 1 would also include construction of aviation logistics. .
TEC	Threatened ecological community.
The airport	The proposed airport that would be constructed on Commonwealth-owned land at Badgerys Creek, NSW. The proposed action that is the subject of this biodiversity assessment report.

The EPBC Act Offsets Policy	The *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* (DSEWPaC 2012)
The locality	Land within a 10 km radius of the airport site.
The Offset assessment guide	The spreadsheet offset calculator that accompanies the *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* (DSEWPaC 2012)
The region	A bioregion defined in a national system of bio-regionalisation. For this study this is the Sydney Basin Bioregion as defined in the Interim Biogeographic Regionalisation for Australia (Thackway and Cresswell 1995).
Threatened biota	Threatened species, populations or communities listed under the EPBC Act and/or the TSC Act.
TSC Act	The NSW *Threatened Species Conservation Act 1995*
Western Sydney Airport (the airport)	The proposed airport that would be constructed on Commonwealth-owned land at Badgerys Creek, NSW. The proposed action that is the subject of this biodiversity assessment report.

1. Introduction

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney (the 'proposed airport'). The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, a delegate of the the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development (DIRD) is undertaking detailed planning and investigations for the proposed airport, including the development of a draft Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the

Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

If an Airport Plan is determined, it will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

The EIS guidelines state that the proposed airport will require biodiversity offsets for residual significant impacts associated with the proposed airport, calculated in accordance with the *Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy* (the offset policy) (DSEWPaC 2012a). The key considerations included in the policy are that:

- offsets are required for significant residual impacts on matters that are protected under the EPBC Act including listed threatened species and communities and the environment, where Commonwealth agencies are proposing to take an action;
- the amount of offset required for threatened species and communities listed under the EPBC Act must be calculated using the 'offset assessment guide' spreadsheet. The offset assessment guide uses a balance sheet approach to calculate the percentage of the proposal's impacts that would be directly offset;
- at least 90 per cent of the proposed airport's impacts must be directly offset and the offset site must be identified, assessed and securely conserved under a covenant and management plan, preferably prior to the impact occurring; and
- up to 10% of the proposed airport's impacts may be indirectly offset through contribution to a research fund or a conservation program.

Further consultation with the Commonwealth Department of the Environment (DotE) has revealed that the estimate of offsets for residual impacts on the environment, including threatened biota and their habitats listed under the New South Wales (NSW) *Threatened Species Conservation Act 1995* (TSC Act), should be calculated using the NSW Biodiversity Banking and Offsets Scheme (BioBanking) assessment methodology.

DotE will require biodiversity offset sites to be securely titled under a legally binding conservation covenant and actively managed under a fully funded plan. There are a variety of mechanisms for achieving this, including BioBanking, Voluntary Conservation Agreements or dedication of land to the National Parks estate.

At this stage of the planning and assessment for the proposed airport, the intent is to deliver biodiversity offsets through conservation of suitable offset sites. The offset sites will be secured by registration of a BioBanking agreement on title to the sites. A BioBanking agreement is recognised as a practical and secure way of delivering biodiversity offsets and is endorsed by DoE as well as the NSW Office of Environment and Heritage (OEH) and Department of Planning and Environment (DPE) for this purpose. This approach would require the purchase of the number and type of biodiversity credits that match the required offset area calculated in accordance with the EPBC Act offsets policy.

Biodiversity offsets for the proposed airport would be provided via a staged approach.

1. development of a biodiversity offset package that accompanies the EIS, comprising:
   - a summary of the biodiversity impact assessment for the airport;
   - an estimate of the quantum of biodiversity offsets required;
   - the preferred approach for delivering biodiversity offsets, including a description of potential offset sites or other environmental contributions; and

- concluding statements demonstrating compliance with the assessment requirements for the EIS and that the offsets proposed for the airport, when implemented would improve or maintain the viability of the protected matters and comply with the offset policy.

2. Delivery of biodiversity offsets in accordance with the conditions for the proposal, comprising:
   - confirmation of the quantum of impacts and biodiversity offsets required;
   - confirmation of the actual biodiversity offset that would be delivered such as a detailed description of specific offset sites or alternative environmental contributions;
   - description of the funding and management arrangements for delivering the biodiversity offset and the timing of delivery; and
   - concluding statements demonstrating compliance with the conditions for the proposal and the offset policy (DSEWPaC 2012a).

This biodiversity offset package report has been prepared using the EPBC Act offset policy, the offsets assessment guide and BioBanking assessment methodology and comprises the first stages in the delivery of biodiversity offsets for the airport.

1.2 Purpose of report

This offset package has been prepared to support the draft EIS for the proposed airport (GHD, 2015b). The information presented in this report has been compiled from the Biodiversity Assessment for the proposed airport (GHD 2015a), a desktop assessment of BioBanking assessments completed by GHD and other specialists in the region and consultation with the Department and other agencies. The offset package should be read in conjunction with the Biodiversity Assessment and the draft EIS.

This report outlines the approach to the delivery of biodiversity offsets for the proposed airport and comprises:

- a description of the proposed airport's impacts and measures to avoid or mitigate impacts;
- identification of the threatened species and communities listed under the EPBC Act that require biodiversity offsets under the offset policy;
- an estimate of the quantum of biodiversity offsets required for affected threatened biota listed under the EPBC Act as calculated with the offset assessment guide;
- an estimate of the quantum of biodiversity offsets required for residual impacts on the environment as calculated using the BioBanking methodology for a major project;
- a description of how BioBanking would be used as the preferred approach to delivering biodiversity offsets;
- identification of potential offset contributions, including biobank sites with biodiversity credits that are available for sale, existing or potential biobank sites that would generate suitable biodiversity credits in the future, or other environmental contributions;
- identification of the suite of biodiversity credits that would be presented to offset impacts on EPBC Act-listed biota, as calculated using the EPBC Act offset policy; and impacts on the environment (including NSW-listed biota), as calculated using Biobanking.
- concluding statements demonstrating compliance with the assessment requirements of the EPBC Act and that the offset package for the airport, when implemented would improve or maintain the viability of the protected matters and comply with the offset policy.

The final quantum of biodiversity offsets required for the proposed airport would be determined by the Department based on the information presented in this offset package and submitted along with the draft EIS for the proposed airport.

The offset package would build upon biodiversity offsets that would be delivered for the North West and South West growth centres strategic assessment, which include the conservation of a minimum of 998 hectares of Cumberland Plain Woodland within the growth centres (DoP 2010). The offset package has been developed with reference to the strategic assessment for the North West and South West growth centres (DoP 2010) and the Cumberland Plain Recovery Plan (DECCW 2010). The offset package will complement regional conservation strategies including by securing offset sites within identified priority conservation lands that are intended to maintain the biodiversity values of the Cumberland Plain (DECCW 2010).

1.3 BioBanking

1.3.1 Overview

BioBanking was established by the former NSW Department of Environment, Climate Change and Water (DECCW) (now the OEH) as a method to address the loss of biodiversity and threatened species. The scheme attempts to create a market framework for the conservation of biodiversity values and the offsetting of development impacts.

BioBanking is established under Part 7A of the *NSW Threatened Species Conservation Act 1995* (TSC Act), which was enabled by the *Threatened Species Conservation Amendment (Biodiversity Banking) Bill 2006*. The *Threatened Species Conservation (Biodiversity Banking) Regulation 2008* provides additional rules for specific aspects of the scheme that are important for its operation.

The Biobanking Assessment Methodology 2014 (BBAM) sets out how biodiversity values will be assessed, establishes rules for calculating the number and class of biodiversity credits, and determines the trading rules that will apply (OEH 2014a). The BBAM includes a software package known as the BioBanking Credit Calculator (the credit calculator) which processes site survey and assessment data. Data is entered into the credit calculator based on information collected in a desktop assessment, site surveys and from using GIS mapping software.

The credit calculator is used to determine:

- the type and extent of surveys required for a BioBanking assessment;
- the number and type of biodiversity credits that are required for a development site to offset impacts on biodiversity either as part of a major project biodiversity assessment or an application for a BioBanking statement;
- the number and type of biodiversity credits generated through the conservation and management of a biobank site.

The BioBanking credit calculator can be used to complete three types of assessments: ‘biobank’, ‘development’ or ‘major project’. BioBanking assessments are be completed by a person accredited in accordance with section 142B(1)(c) of the TSC Act.

1.3.2 Application to this offset package

BioBanking would be used to secure biodiversity offsets for EPBC Act-listed biota. The quantum of offset required for EPBC Act-listed biota has been calculated using the offset assessment guide in accordance with the EPBC Act offset policy as summarised in Section 5. The quantum of offset is expressed as an area of habitat for the affected threatened biota at offset sites. The EPBC Act offset

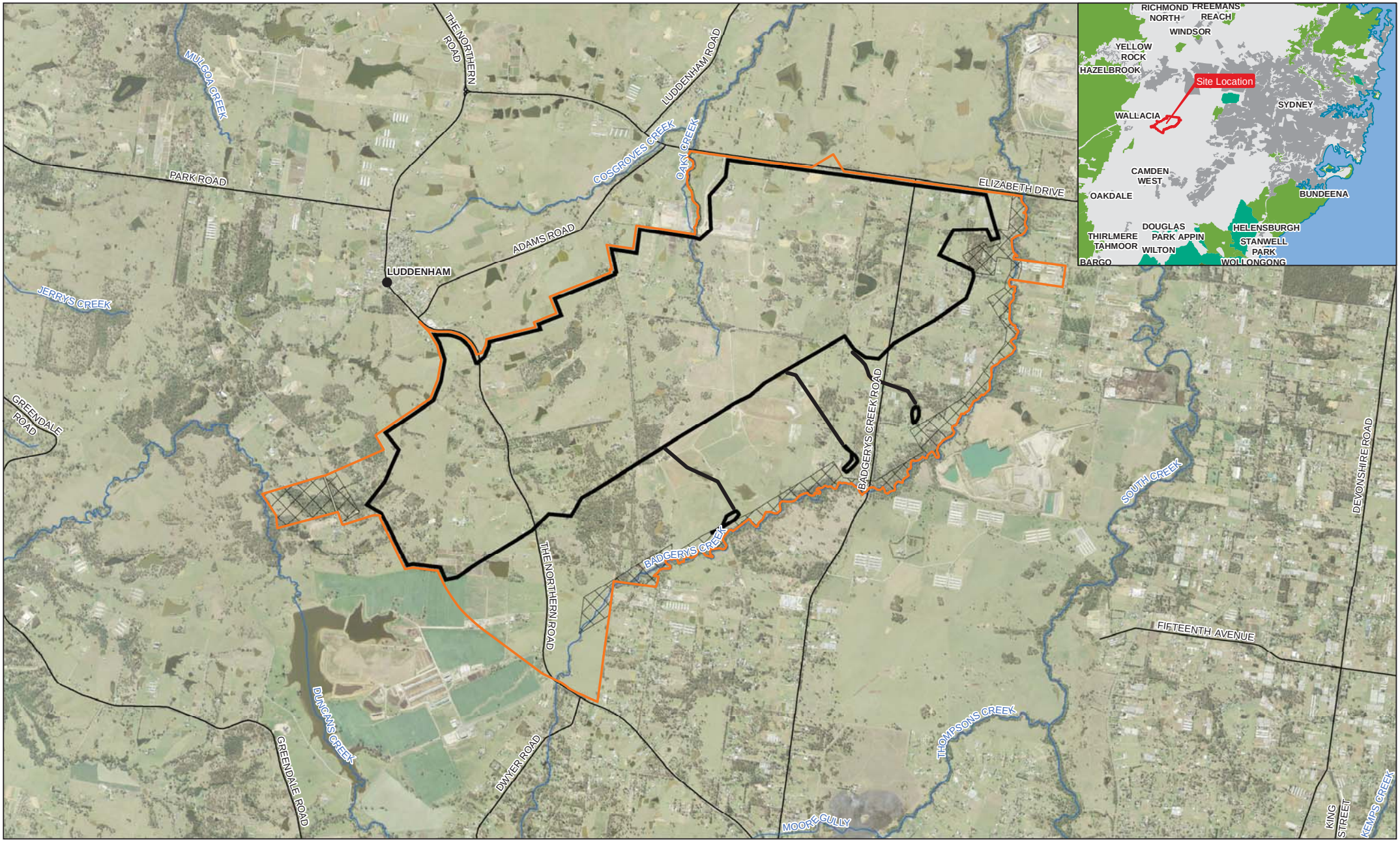
policy requires that offset sites be securely titled for conservation and that arrangements are made to ensure funding of appropriate management actions. The offsets would be secured by the site owner registering a BioBanking agreement on title to the offset site. This would ensure that each site would be securely titled and managed for conservation as a biobank in perpetuity. 'Biobank' type credit calculations will be used to calculate the biodiversity credits that would be generated by the conservation and management of offset sites. The number and type of biodiversity credits that are linked to the offset areas for the affected threatened biota would be purchased.

'Major project' type BioBanking credit calculations were used to estimate the number and type of biodiversity credits required to offset the impacts of the proposal on the environment (see Section 3). The impacts of the proposal on the environment were assessed according to the *BioBanking Assessment Methodology 2014* (OEH 2014a), *BioBanking Assessment Methodology and Credit Calculator Operational Manual* (DECC, 2009) and the *Draft Operational Manual for using the BioBanking Credit Calculator v2.0* (OEH, 2011). Some elements of the BBAM as it is applied to a major project are included in the *Framework for Biodiversity Assessment* (FBA) (OEH 2014b) though the FBA does not apply to the proposed airport. The data and assumptions used to perform the BioBanking credit calculations are summarised in Section 3.2**.** The BioBanking credit report is included as Appendix B.

1.4 Relationship with other reports

This offset package should be read in conjunction with the'Western Sydney Airport Biodiversity Assessment' (GHD 2015a). The Biodiversity Assessment report: provides a detailed description of the existing environment of the airport site; identifies threatened biota and other ecological Matters of National Environmental Significance (MNES) that may be affected by the airport; assesses the potential impacts arising from the construction and operation of the proposed airport; recommends measures to avoid or mitigate impacts; and assesses the significance of residual impacts on threatened biota and other ecological MNES (GHD 2015a). This offset package relies on the biodiversity impact assessment and mitigation measures presented in the Biodiversity Assessment to calculate the quantum of significant residual impacts that require biodiversity offsets.

This offset package is a specialist appendix to the 'Western Sydney Airport Environmental Impact Statement' (the EIS) (GHD 2015b). The EIS provides: a detailed description of the proposed construction and operation of the proposed airport; assesses the potential impacts of the proposed airport on environmental, social and economic receptors; and identifies measures to manage impacts. This offset package relies on the environmental assessment and mitigation measures presented in the draft EIS to inform assessment of potential impacts on biodiversity values. This includes inputs from specialist areas such as hydrology or noise that are beyond the scope of the Biodiversity Assessment.



Paper Size A3

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Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

- The airport site
- Stage one construction impact zone
- Environmental conservation
- Watercourses
- Roads

Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Offset Package

Job Number	21-24265
Revision	A
Date	06 Oct 2015

Site location

Figure 1

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2. Offset Requirements for EPBC Act-listed Biota

2.1 Identification of affected threatened biota

According to the Australian Government's offset policy, biodiversity offsets are required for significant residual impacts on threatened species and communities listed under the EPBC Act (i.e. those significant impacts that cannot otherwise be avoided or mitigated through other measures). A desktop assessment, targeted field surveys and habitat assessments were used to identify the suite of threatened biota listed under the EPBC Act that could occur at the airport site or be affected by the construction or operation of the proposed airport. Assessments of the likely significance of impact on threatened biota with the potential to be affected by the proposed airport have been prepared in accordance with the '*Matters of National Environmental Significance Significant impact guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999'* (DotE 2013a) (see Appendix D of GHD 2015a).

The outcome of these assessments is that the proposed airport is likely to have a significant impact on:

- Cumberland Shale Plains Woodland and Shale-Gravel Transition Forest (Cumberland Plain Woodland) which is listed as a critically endangered ecological community (CEEC) under the EPBC Act and occurs at the airport site. Construction of Stage 1 of the proposed airport would require the permanent removal of 88.9 hectares of vegetation within the local occurrence of Cumberland Plain Woodland as shown on Figure 2. A permanent reduction in extent of this magnitude would threaten the viability and persistence of Cumberland Plain Woodland within the locality. Stage 1 of the proposed airport is likely to have a significant impact on the local and regional occurrence of Cumberland Plain Woodland through a substantial reduction in the extent of the community, an increase in the degree of fragmentation and a substantial negative effect on the potential for recovery of the community.
- The Grey-headed Flying-fox, which is listed as a vulnerable species under the EPBC Act and which has been observed at the airport site. Construction of Stage 1 of the proposed airport would remove 120.4 hectares of potential foraging habitat for the Grey-headed Flying-fox, including foraging resources for local roost camps when resources are scarce and at critical lifecycle stages. The proposed airport will further fragment foraging habitat for this species within an already highly fragmented landscape.

The quantum of impacts on these affected threatened biota that requires biodiversity offsets is described below.

2.2 Impacts on affected threatened biota

2.2.1 Cumberland Plain Woodland CEEC

Area of community in impact zone

Larger and better condition patches of Grey Box - Forest Red Gum grassy woodland on flats, Grey Box - Forest Red Gum grassy woodland on hills and Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest at the airport site comprise occurrences of Cumberland Plain Woodland CEEC, as defined under the EPBC Act and associated guidelines. Patches of woodland at the airport site that comprise an occurrence of EPBC Act Cumberland Plain Woodland are shown on Figure 2. There is 153.3 hectares of Cumberland Plain Woodland as defined under the EPBC Act at the airport site.

Derived native grassland and moderate/good –poor condition vegetation at the airport site does not meet the condition criteria for a local occurrence of the CEEC Cumberland Plain Woodland as defined under the EPBC Act and associated guidelines. This vegetation does not qualify because native tree species are not present with a minimum projected foliage cover of greater than 10% (DEWHA 2010). Some patches with native tree cover greater than 10% but that are isolated from other native vegetation and are less than 0.5 hectares in area have also been excluded in accordance with the guidelines (DEWHA 2010).

Construction of Stage 1 of the proposed airport would require the permanent removal of 88.9 hectares of vegetation within the local occurrence of Cumberland Plain Woodland that is commensurate with the form of the community listed under the EPBC Act as shown on Figure 2. Therefore an impact area of ‘88.9 hectares’ has been entered in the ‘area of community’ field in the ‘impact calculator’ section of the Offset assessment guide for Cumberland Plain Woodland (see Section 5.4).

Specific measures are proposed to manage weeds at the airport site, to mitigate biosecurity risks and to reduce the risk of off-site impacts. The land use plan for the airport site includes around 122 hectares of land that is zoned ‘EC 1 Environmental conservation’ and that would be managed for biodiversity conservation (see Figure 1). The proposed environmental conservation zone would provide a buffer between the proposed airport and adjoining areas of native vegetation along its eastern, southern and western boundaries, including the riparian corridors of Badgerys Creek, Oaky Creek and Duncans Creek. There is no Cumberland Plain Woodland or other sensitive environments to the north of the airport site. The extent of native vegetation cover would be increased in the environmental conservation zone and weeds would be managed. This reduces the chance that weeds would spread or that other edge effects would penetrate into habitat outside the airport site.

The proposed airport would have a minor effect on the extent or seriousness of edge effects in the locality and would be unlikely to introduce any new weed species or increase the significance of weed infestations. The environmental conservation zone would help to maintain a vegetated link around the developed portions of the airport site and provide connectivity between aquatic, riparian and floodplain environments. The environmental conservation zone also increases the distance between potential sources of contamination such as runways, storage areas and parking areas and sensitive receptors outside the airport site. The indicative airport concept design and land use plan in the Airport Plan show proposed measures to manage surface water that have been purposefully designed to capture water on-site and to avoid negative impacts on surface water quality or drainage patterns outside of the airport site. These measures would help to mitigate the risk of any impacts on the ecological community outside of the airport site.

There would be minor residual impacts on areas of Cumberland Plain Woodland outside the airport site through factors such as noise, light spill, risk of fauna mortality through plane strike or other

vehicle collisions and contribution to the degree of habitat fragmentation in the locality. Cumberland Plain Woodland in the vicinity of the airport site is already in moderate to poor condition and affected by clearing for agriculture, grazing, weed infestation and the noise, light and traffic associated with human activities. Given this context and the mitigation measures outlined above and in the Biodiversity Assessment (GHD 2015a), the proposed airport is unlikely to tangibly decrease the extent or quality of Cumberland Plain Woodland outside of the airport site. Therefore no additional areas of the community outside of the airport site have been included in the offset calculations.

Quality of community in impact zone

Cumberland Plain Woodland at the airport site comprises remnant or regrowth native vegetation in moderate condition. The quality of a community is scored out of ten for offset assessment guide calculations. The Department's instructions for the offset assessment guide identify three site characteristics that may contribute to quality: 'site condition', 'site context' and 'species stocking rate'. These three attributes must be weighted according to their relative importance to the offset calculations based on the ecology of the relevant species or community (DSEWPaC 2012b) (i.e. their relative contribution to the total score out of ten). The weighting of these three attributes for Cumberland Plain Woodland at the airport site was defined as follows:

- site condition – 50 per cent comprising an assessment of the condition of the airport site in relation to the ecological requirements of the community and based on vegetation structure, native plant cover, species richness and presence of habitat resources;
- site context – 50 per cent comprising an assessment of the relative importance of the airport site in terms of its position in the landscape based on patch size, connectivity and proximity to threats; and
- species stocking rate – 0 per cent because this attribute is not directly relevant to threatened communities.

Each characteristic was then scored based on the results of the Biodiversity Assessment (GHD 2015a).

Site condition was scored as 6/10 based on the BioBanking plot/transects and other field survey data collected within the vegetation zones that comprise Cumberland Plain Woodland at the airport site as outlined below.

- Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528, around 70 hectares out of the 88.9 hectares of Cumberland Plain Woodland to be removed) - Remnant or regrowth woodland with near-intact over storey. Species richness was above benchmark in eight of the 12 plot/transects sampled in this vegetation zone and most native vegetation cover attributes were at benchmark values for this plant community type in the majority of plot/transects sampled. There were regenerating specimens of all canopy species observed. Few hollow-bearing trees were recorded, including only one in the 14 plots sampled. There were generally low quantities of fallen woody debris, including none in five of the 12 plots sampled. There is frequently high exotic plant cover (10-70 per cent in plot/transects sampled) mainly consisting of grasses and herbs in the under storey.
- Good condition Grey Box - Forest Red Gum grassy woodland on hills - (HN529, around 17 hectares out of the 88.9 hectares of Cumberland Plain Woodland to be removed) - Remnant or regrowth woodland with near-intact over storey that was within or slightly below benchmark values in all five plot/transects sampled. Native mid storey cover was well below benchmark values in four out of the five plot/transects. Species richness, shrub, grass and forb cover attributes and woody debris were at or above benchmark values for this plant community type in

the majority of plot/transects sampled. There were regenerating specimens of all canopy species observed. There are few hollow-bearing trees, including only one in the five plots sampled. There is frequently high exotic plant cover (26-44 per cent in plot/transects sampled) mainly consisting of woody weeds in the mid storey.

- Good condition Broad-leaved Ironbark –*Melaleuca decora* grassy open forest (HN512, around two hectares out of the 88.9 hectares of Cumberland Plain Woodland to be removed) - Near-intact, remnant or regrowth open forest. Species richness and most native vegetation cover attributes were at benchmark values for this plant community type. There were regenerating specimens of all canopy species observed. There were good quantities of hollow-bearing trees, including one in the plot/transect that was sampled and large quantities of fallen woody debris. This vegetation zone contains very little exotic plant cover compared to most of the airport site and included 0 per cent exotic plant cover along the transect sampled. Some exotic plants were observed at low cover/abundances in the surrounding plot (GHD 2015a).

Site context was scored as 6/10, reflecting the position of the local occurrence of the community in a highly fragmented, rural landscape. Fragmentation of native vegetation and associated fauna habitats in the locality has previously occurred through clearing for agriculture, residences and farm buildings and construction of transmission lines and roads. These land uses have created barriers to movement for many fauna species, particularly those that are limited by dispersal abilities and habitat preferences. The patches of Cumberland Plain Woodland that remain at the airport site have high edge to area ratios and are frequently dissected by tracks and fence lines. The suite of fauna species recorded in field surveys is dominated by generalist species of open country such as birds and bats, reflecting the fragmented nature of vegetation at the airport site (see Section 4.3.1 of GHD 2015a). Adjoining areas are dominated by exotic vegetation, including many noxious and environmental weeds that pose a threat to remnant patches. In this context, the species within Cumberland Plain Woodland at the airport site have limited opportunities for dispersal or recruitment and are subject to ongoing threats from exotic plants and pest fauna.

Based on the inputs described above, 'Impact calculator - quantum of impact – quality' (i.e. the quality of habitat in the airport disturbance footprint) was scored as 6/10 overall.

The above values have been entered in the offset assessment guide calculations that are presented in Section 5.4.

Estimated offset requirement

A notional offset assessment guide calculation was performed as a guide to the size and type of offset that would be required to meet the EPBC Act offset requirements for the proposed airport's impacts on Cumberland Plain Woodland. Based on the notional offset assessment guide calculation the airport would require an offset of around 295 hectares of Cumberland Plain Woodland. Offset sites have been identified that contain the majority of the required area of the community and are described in Section 4.3 below. Offset assessment guide calculations based on the available area of Cumberland Plain Woodland in the offset sites that have been identified to date are included in Section 5.4. DotE would perform the final offset assessment guide calculations for the proposed airport. Based on these preliminary calculations the proposed offset sites could provide around 74% of the direct offsets required for the proposed airport's impacts on Cumberland Plain Woodland. Additional offset sites would be identified to address the shortfall according to the criteria and the process described in Section 6.

2.2.2 Grey-headed Flying-fox

Area of habitat in the impact zone

The Grey-headed Flying-fox (*Pteropus poliocephalus*), was recorded foraging at the site or flying over the site during the current and previous surveys (Biosis Research 1999, GHD 2015a). There are no Grey-headed Flying-fox camps located at the airport site, although there are at least seven known camps within 20 kilometres. All native woodland and forest in the airport site provides potential foraging habitat for this species.

The proposed airport would remove 120.4 hectares of foraging habitat associated with the native woodland and forest shown on Figure 3, all of which comprises critical foraging habitat as defined in the Recovery Plan for the Grey-headed Flying-fox (DECCW 2009).

The proposal would not result in a notable increase in the risk of mortality or fragmentation of habitat for this highly mobile species. There is a risk of plane or other vehicle strike during the operation of the airport; however, this is unlikely to harm large numbers of individuals of the species (Avisure 2015, GHD 2015a).

The removal of habitat would be the most notable impact on the Grey-headed Flying-fox arising from the proposed airport. Therefore an area of habitat of '120.4 hectares' has been entered in the 'Impact calculator' section of the offset assessment guide for the Grey-headed Flying-fox (see Section 5.4).

As described above for Cumberland Plain Woodland, there would be minor residual impacts on areas of foraging habitat outside the airport site. Habitat for the Grey-headed Flying-fox in the vicinity of the airport site is already in moderate to poor condition and affected by clearing for agriculture, grazing, weed infestation and the noise, light and traffic associated with human activities. Given this context and the mitigation measures outlined in the Biodiversity Assessment (GHD 2015a), the proposed airport is unlikely tangibly to decrease the extent or quality of habitat outside of the airport site. Therefore no additional areas of the habitat for the Grey-headed Flying-fox outside of the airport site have been included in the offset calculations.

Quality of habitat in the impact zone

As described above, all native woodland and forest in the airport site provides foraging habitat for this species. Dominant canopy species include Forest Red Gum (*Eucalyptus tereticornis*), Grey Box (*Eucalyptus molluccana*) and Broad-leaved Ironbark (*Eucalyptus fibrosa*). Forest Red Gum and Grey Box are recognised as 'significant species' in the blossom diet of the Grey-headed Flying-fox (Eby and Law 2008). Forest Red Gum scores in the upper quartile of all diet plants for the region for productivity and reliability of flowering. This species flowers in late winter and spring, partly during the 'food bottleneck' for the Grey-headed Flying-fox. Grey Box has low productivity and reliability. It flowers in late summer and early autumn. Broad-leaved Ironbark has high productivity but is an unreliable flowerer. This species flowers in summer and early autumn, providing foraging habitat during the breeding period for the Grey-headed Flying-fox (Eby and Law 2008). Habitat in the airport site is thus somewhat productive during food bottlenecks, and qualifies as habitat critical to the survival of the species, as defined in the draft recovery plan (DECCW 2009).

The Department's instructions for the offset assessment guide state that the contribution of the three habitat attributes 'site condition', 'site context' and 'species stocking rate' to habitat quality must be weighted according to the ecology of the relevant species or community (DSEWPaC 2012b). The weighting of these three attributes for the Grey-headed Flying-fox population with respect to the airport site was defined as follows:

- site condition – 40 per cent comprising an assessment of the condition of the airport site in relation to the ecological requirements of the species and based on vegetation condition and presence of food trees and other habitat resources;
- site context – 40 per cent comprising an assessment of the relative importance of the airport site in terms of its position in the landscape based on patch size, connectivity, presence of roost camps and/or proximity to off-site roost camps and proximity to threats; and
- species stocking rate – 20 per cent comprising an assessment of the usage or density of the species at the site. This factor was given less weighting because the species is highly mobile and all individuals in NSW are considered part of one regional population that undertakes nomadic movements to exploit seasonal resources (OEH 2015b). The Grey-headed Flying-fox is a highly mobile species which regularly travels up to 50 kilometres in a night to forage, and has been shown to make migratory movements of almost 1000 kilometres within a year (Churchill 2008, Webb and Tidemann 1996). Given this mobility and population fluctuations in any given area, the local species stocking rate is a relatively minor component of habitat quality.

Each characteristic was then scored based on the results of the Biodiversity Assessment (GHD 2015a).

Site condition was scored as 7/10 based on the following:

- the health and condition of the vegetation zones that comprise Grey-headed Flying-fox habitat based on BioBanking plot/transects and other field survey data. The majority of the habitat at the airport site is Cumberland Plain Woodland (around 90 out of 120 hectares) which is in moderate condition as described above. Forest Red Gum - Rough-barked Apple grassy woodland (the remaining 30 out of 120 hectares) is also in moderate condition comprising remnant or regrowth native vegetation with near-intact over storey that was within or slightly below benchmark values in all five plot/transects (GHD 2015a); and
- the presence of Forest Red Gum and Grey Box as dominant canopy species across the airport site. As described above these two tree species are recognised as ‘significant species’ in the blossom diet of the Grey-headed Flying-fox, are somewhat productive during food bottlenecks (Eby and Law 2008) and qualify as habitat critical to the survival of the species, as defined in the draft recovery plan (DECCW 2009)(GHD 2015a).

Site context was scored as 6/10 based on the following:

- the airport site does not contain a roost camp and has such does not play an especially important role in relation to the overall population of the species. There are several known roost camps within 20 km of the site and so it is appropriately located to provide foraging resources for individuals from these camps; and
- habitat at the airport site is in a highly fragmented, rural landscape. The Grey-headed Flying-fox is a highly mobile species and so this would not limit opportunities for dispersal or recruitment or substantially increase the risk or energy cost of travelling to exploit foraging resources. However adjoining areas are dominated by exotic vegetation, including many noxious and environmental weeds that pose a threat to remnant patches of native vegetation and the productivity of food species.

Species stocking rate was scored as 6/10 comprising an area of productive foraging habitat within the broad range of this highly mobile species. Only a single individual was observed flying over the airport site during a total of 13 nights of survey effort between February and May 2015 (GHD 2015a). The survey period coincided with the late Summer – early Autumn flowering period of the other two main canopy species at the site (Eby and Law 2008). Larger numbers of individuals may be present at other

times of year such as during the late Winter-Spring flowering period of Forest Red Gum (Eby and Law 2008) or in other seasons when food trees are more productive at the site and/or less productive in alternative areas.

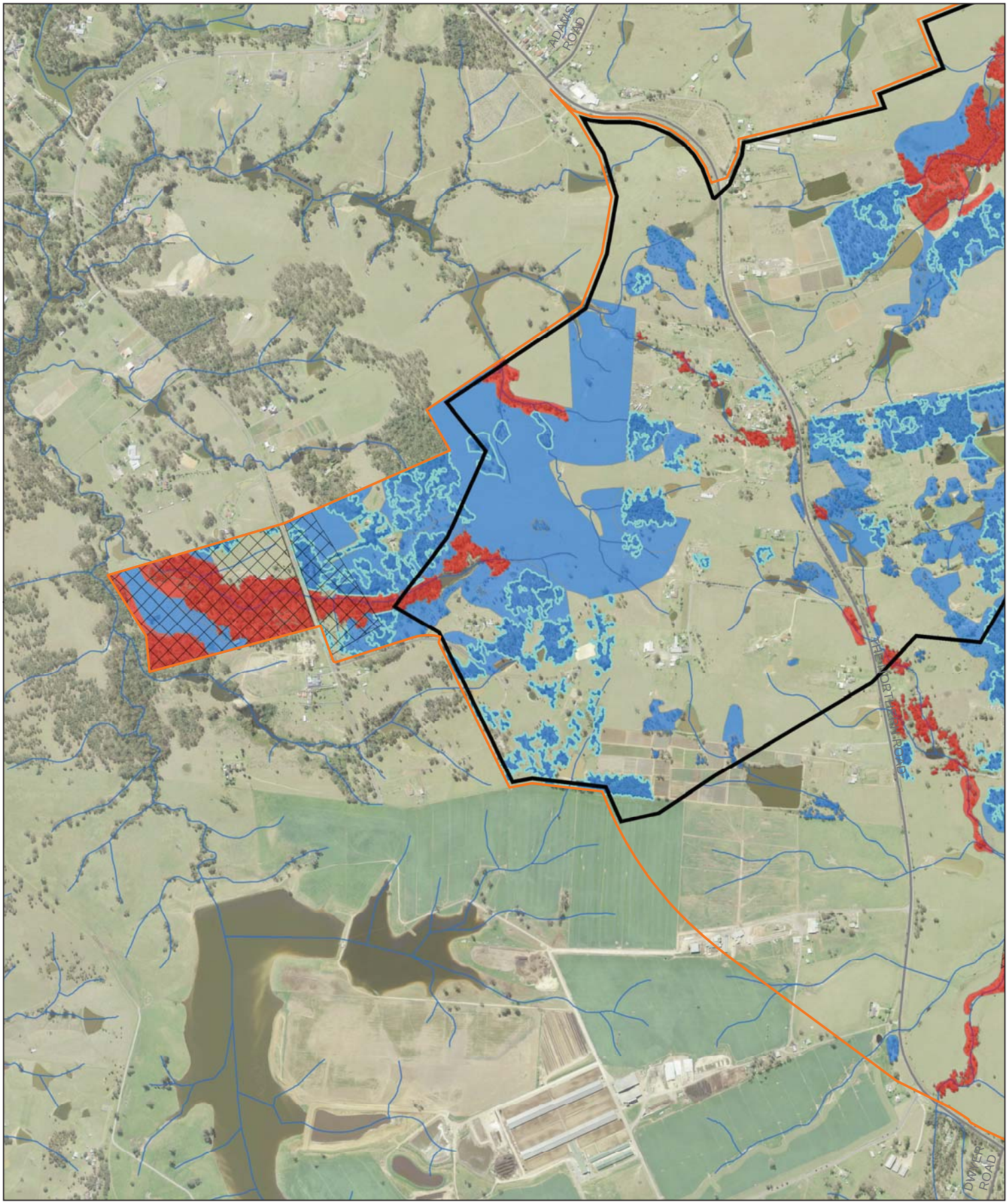
Based on the inputs described above 'Impact calculator - quantum of impact – quality' (i.e. the quality of habitat in the airport disturbance footprint) was scored as 6/10 overall (rounded to the nearest whole number).

These values have been entered in the offset assessment guide calculations that are presented in Section 5.4.

Estimated offset requirement

As described for Cumberland Plain Woodland above, a notional offset assessment guide calculation was performed as a guide to the size and type of offset that would be required to meet the EPBC Act offset requirements for the proposed airport. Based on the notional offset assessment guide calculation the airport would require an offset, including around 300 hectares of habitat for the Grey-headed Flying-fox.

Offset assessment guide calculations based on the available area of Grey-headed Flying-fox habitat in the offset sites that have been identified to date are included in Section 5.4. The Department would perform the final offset assessment guide calculations for the proposed airport. Based on these preliminary calculations the proposed offset sites could provide all of the direct offsets required for the proposed airport's impacts on the Grey-headed Flying-fox.



LEGEND

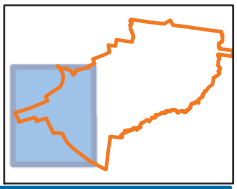
- The airport site
- Stage one construction impact zone
- Environmental conservation
- Swale_Lines_SYMBOLONLY
- Roads
- Watercourses

EPBC Act

- Cumberland Plain Shale Woodlands and Shale Gravel Transition Forest (CEEC under EPBC Act and TSC Act)
- *Pultenaea parviflora* (endangered species under the EPBC Act and TSC Act)

TSC Act

- Cumberland Plain Woodland (CEEC under the TSC Act)
- River Flat Eucalypt Forest (EEC under the TSC Act)
- Shale/gravel Transition Forest (EEC under the TSC Act)
- *Marsdenia viridiflora subsp. viridiflora* (endangered population under the TSC Act)



Paper Size A3

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Offset Package

Job Number	21-24265
Revision	A
Date	06 Oct 2015

Threatened flora and ecological communities

Figure 2A

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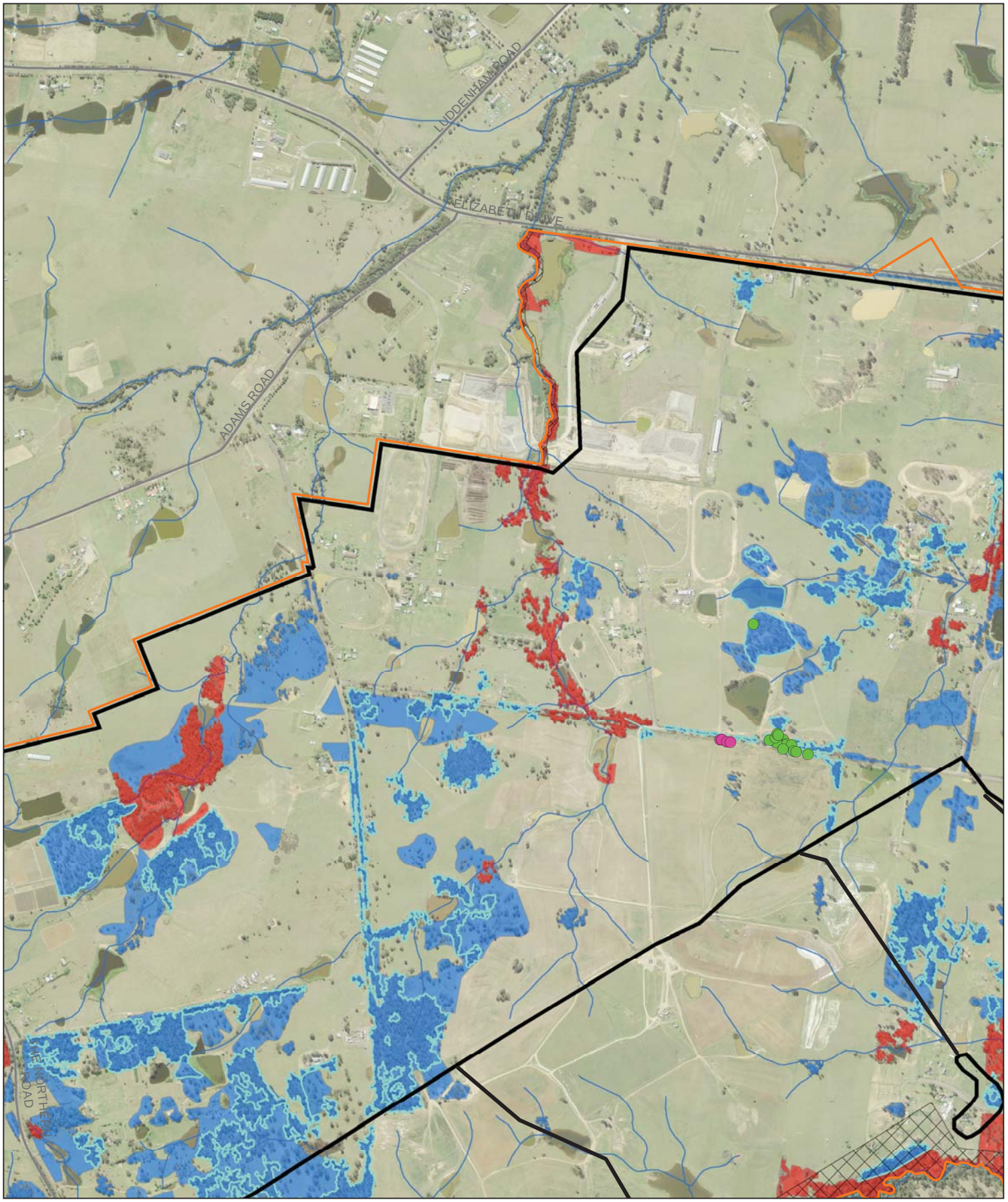

LEGEND

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TSC Act

- Cumberland Plain Woodland (CEEC under the TSC Act)
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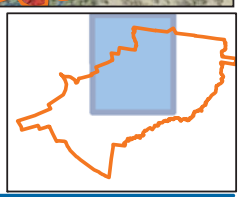
- Shale/gravel Transition Forest (EEC under the TSC Act)
- *Marsdenia viridiflora subsp. viridiflora* (endangered population under the TSC Act)



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Offset Package

Job Number	21-24265
Revision	A
Date	06 Oct 2015

Threatened flora and ecological communities

Figure 2B

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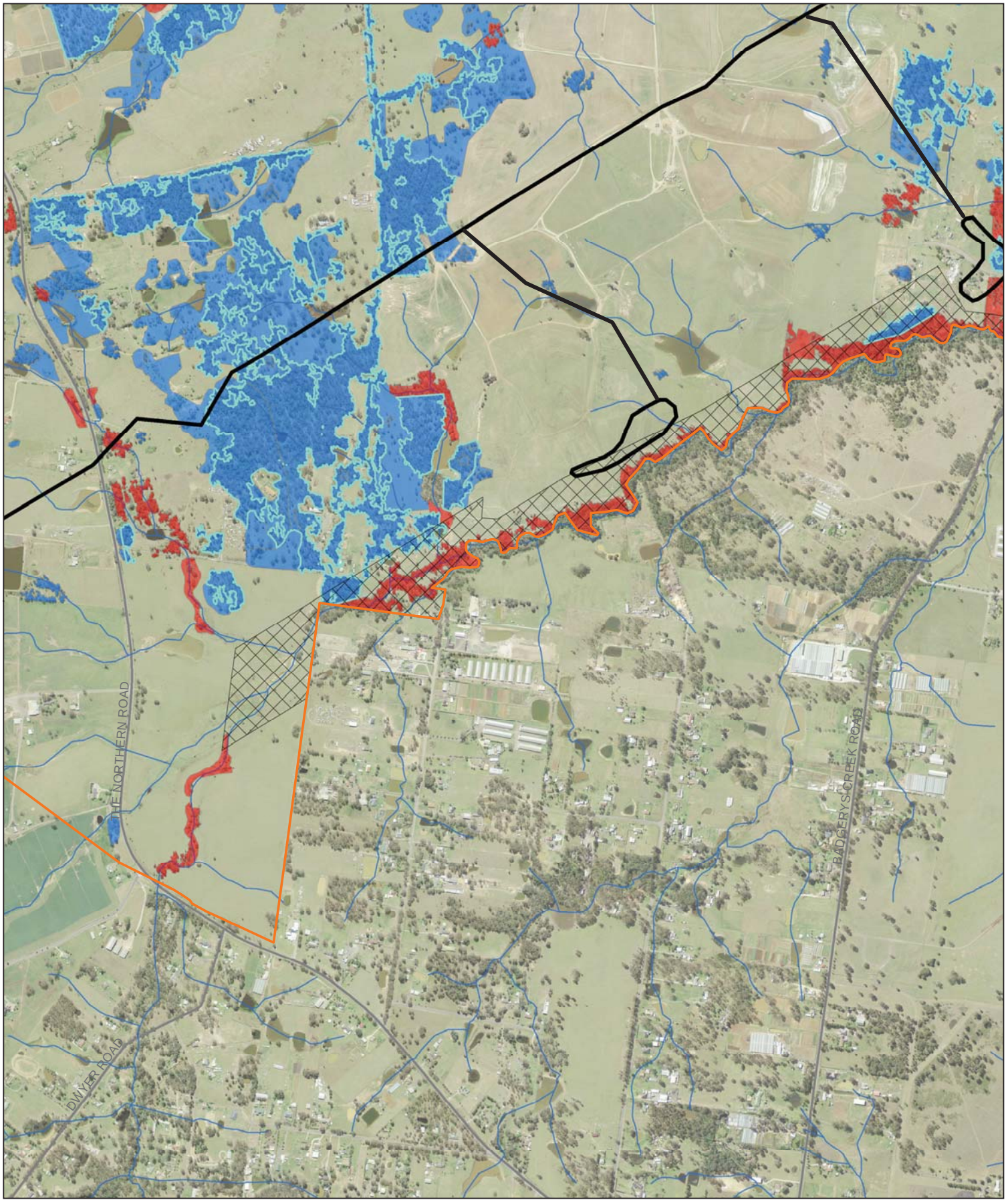


LEGEND

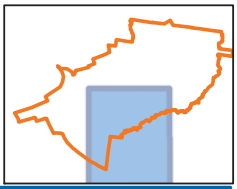
- The airport site
- Stage one construction impact zone
- Environmental conservation
- Swale_Lines_SYMBOLONLY
- Roads
- Watercourses

EPBC Act

- Cumberland Plain Shale Woodlands and Shale Gravel Transition Forest (CEEC under EPBC Act and TSC Act)
- *Pultenaea parviflora* (endangered species under the EPBC Act and TSC Act)

TSC Act

- Cumberland Plain Woodland (CEEC under the TSC Act)
- River Flat Eucalypt Forest (EEC under the TSC Act)
- Shale/gravel Transition Forest (EEC under the TSC Act)
- *Marsdenia viridiflora subsp. viridiflora* (endangered population under the TSC Act)



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Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Offset Package

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Threatened flora and ecological communities

Figure 2C

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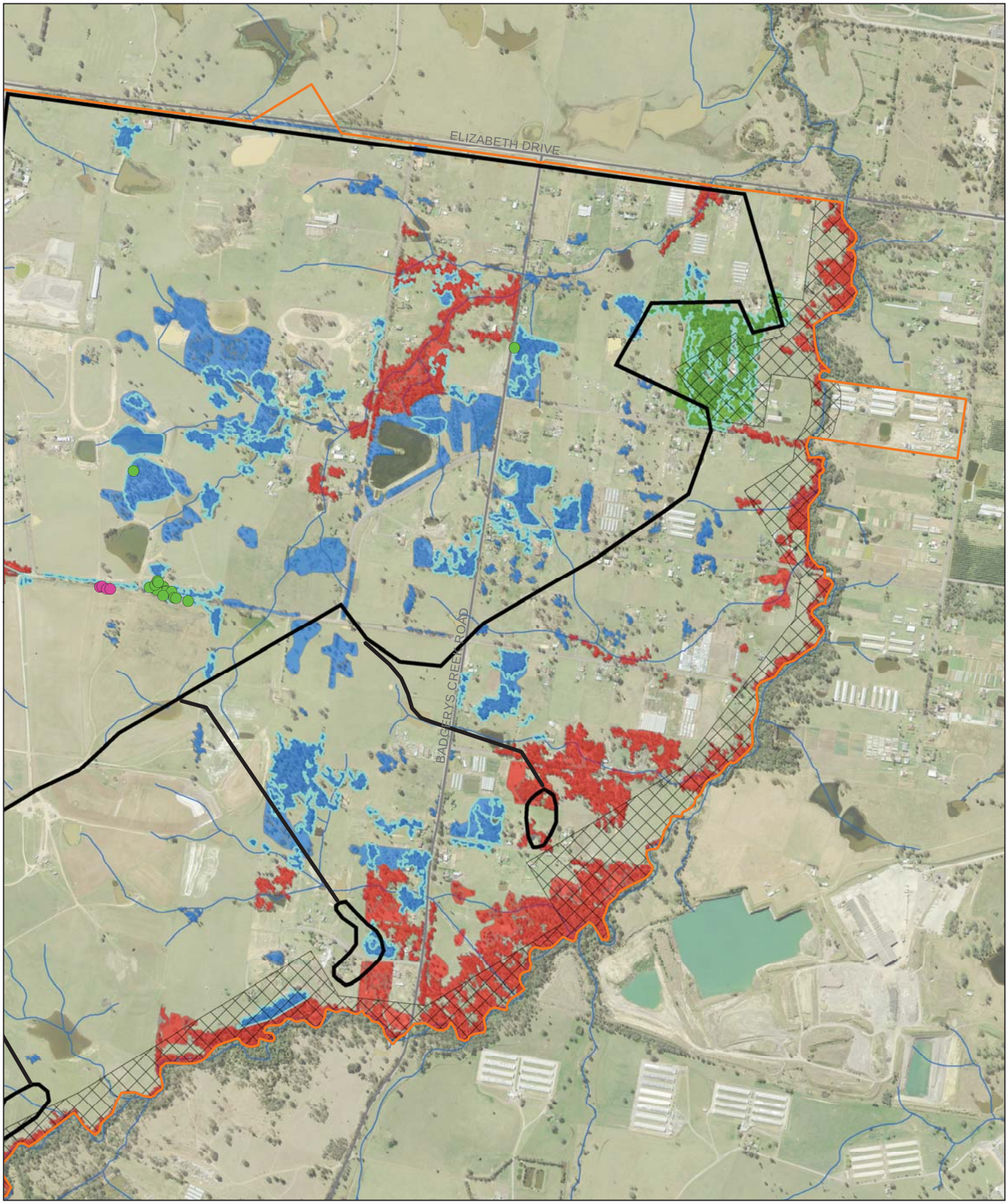

LEGEND

- The airport site
- Stage one construction impact zone
- Environmental conservation
- Swale_Lines_SYMBOLONLY
- Roads
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EPBC Act

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- *Pultenaea parviflora* (endangered species under the EPBC Act and TSC Act)

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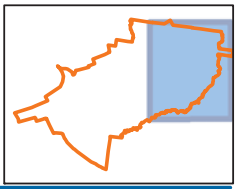

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Threatened flora and ecological communities

Figure 2D

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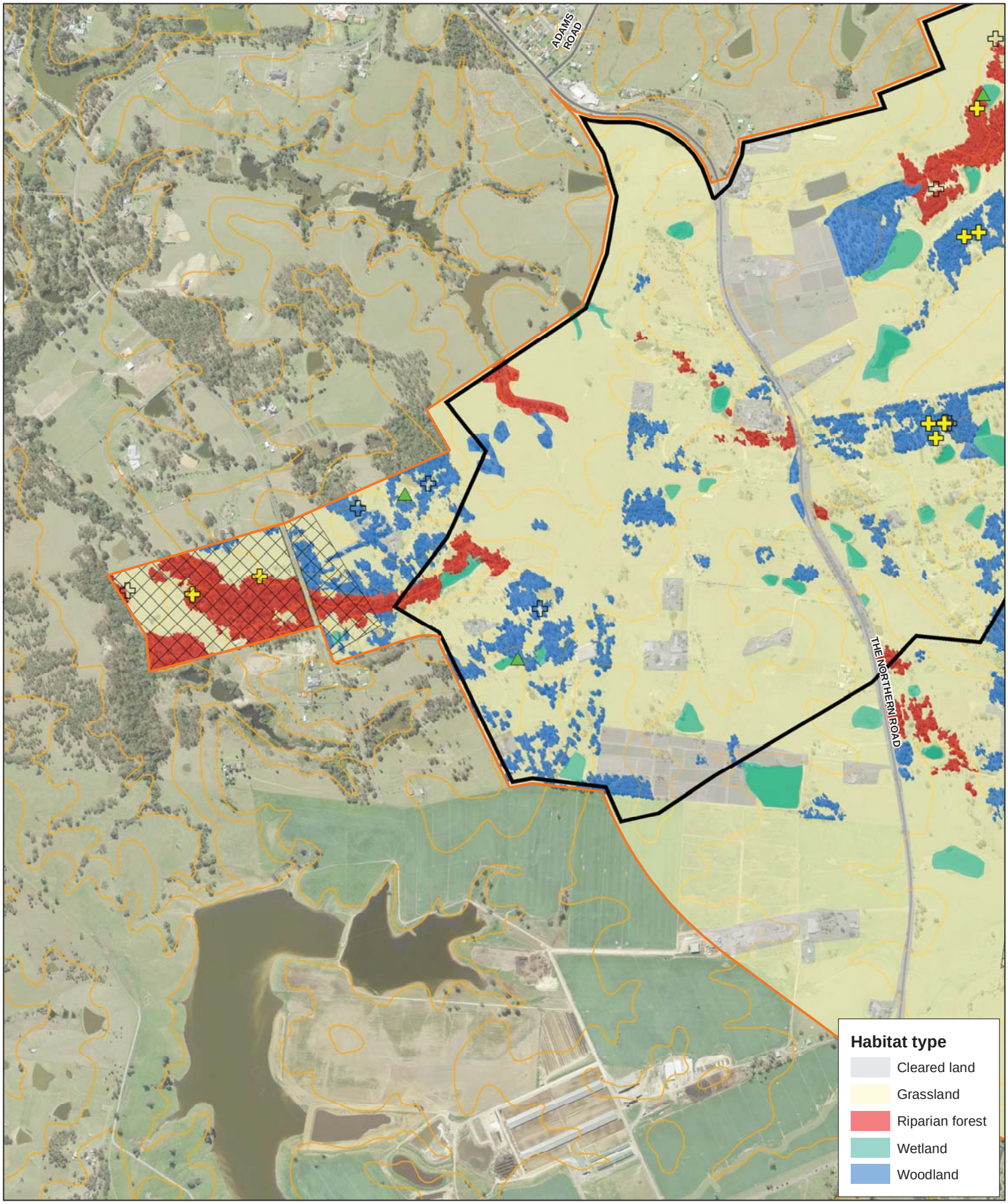

Legend

- The airport site
- Stage one construction impact zone
- Environmental conservation
- Contour
- Roads

Threatened species

- Black Bittern (V)
- Cumberland Plain Land Snail (E) (absent)
- Cumberland Plain Land Snail (E) (present)
- East Coast Freetail Bat (V)
- Large-footed Myotis (V)
- Little Eagle (V)
- Scarlet Robin (V)
- Varied Sittella (V)

Notes: V - vulnerable species under the TSC Act;
E - endangered species under the TSC Act;
M - migratory species under the EPBC Act.

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Western Sydney Airport
Biodiversity Offset Package

Job Number	21-24265
Revision	A
Date	06 Oct 2015

Threatened fauna and habitat features

Figure 3A

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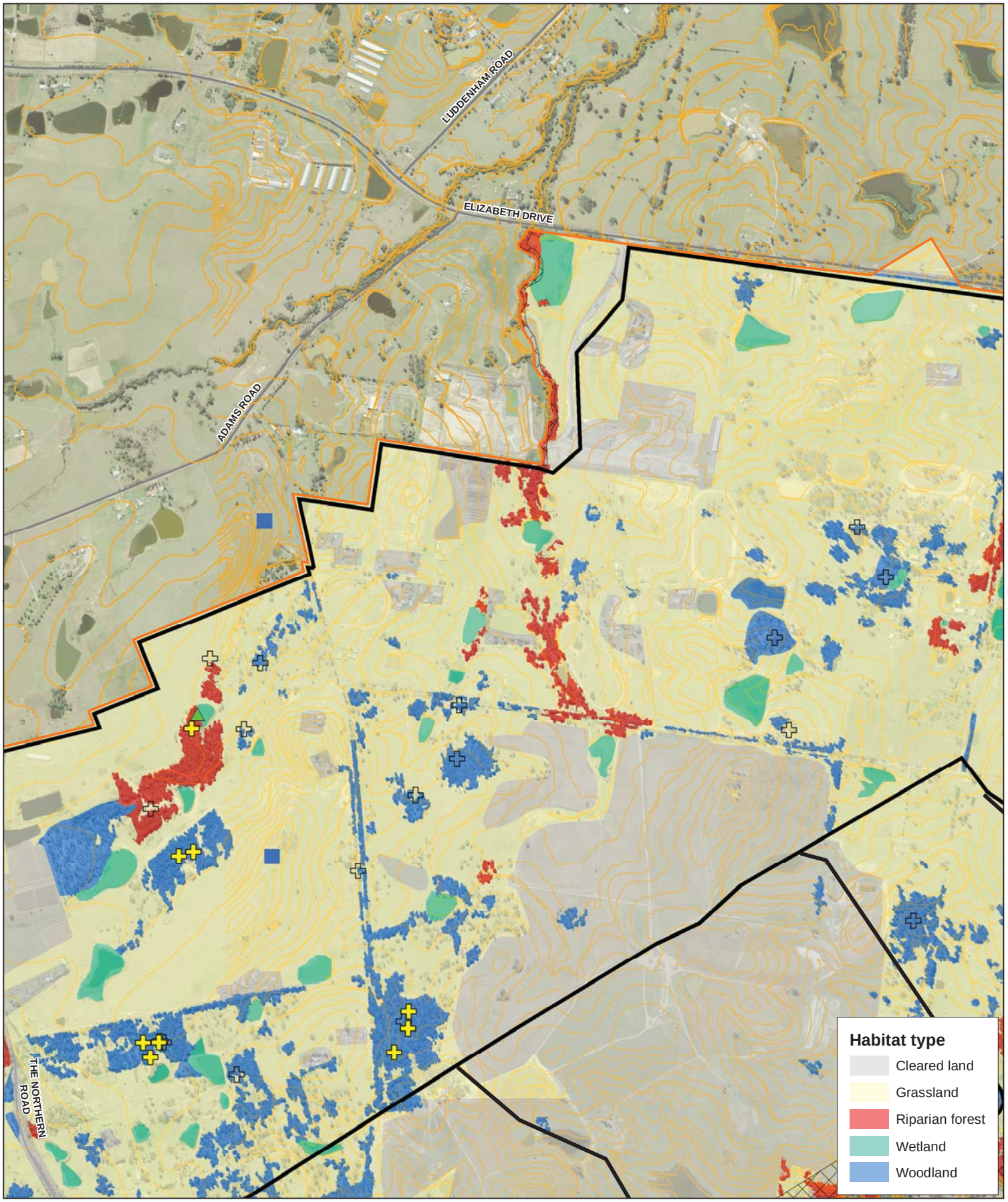

Legend

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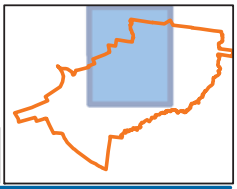

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Western Sydney Airport
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Revision	A
Date	06 Oct 2015

Threatened fauna and habitat features

Figure 3B

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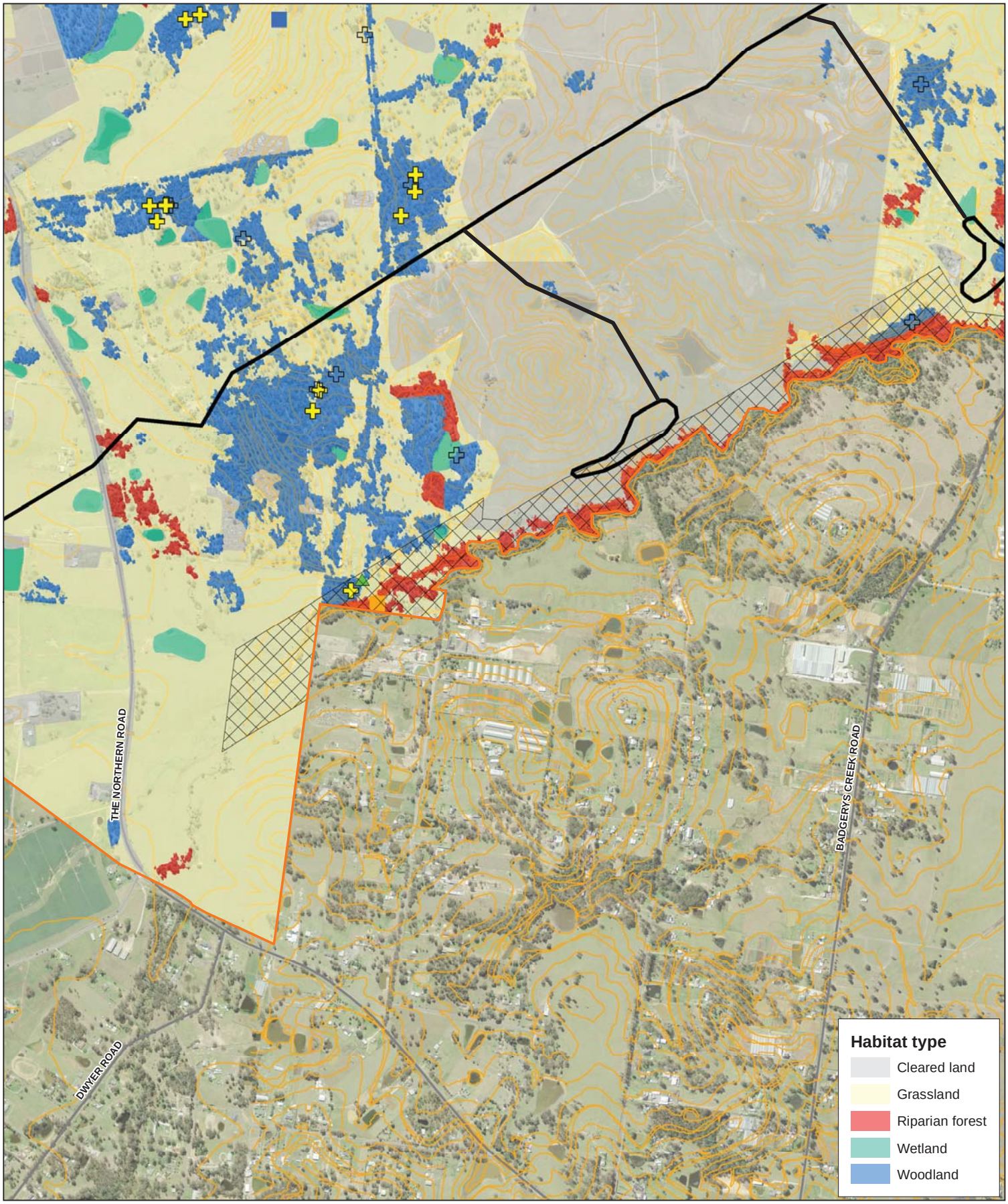

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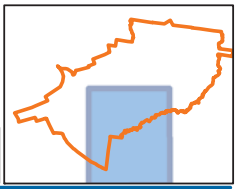

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Threatened fauna and habitat features

Figure 3C

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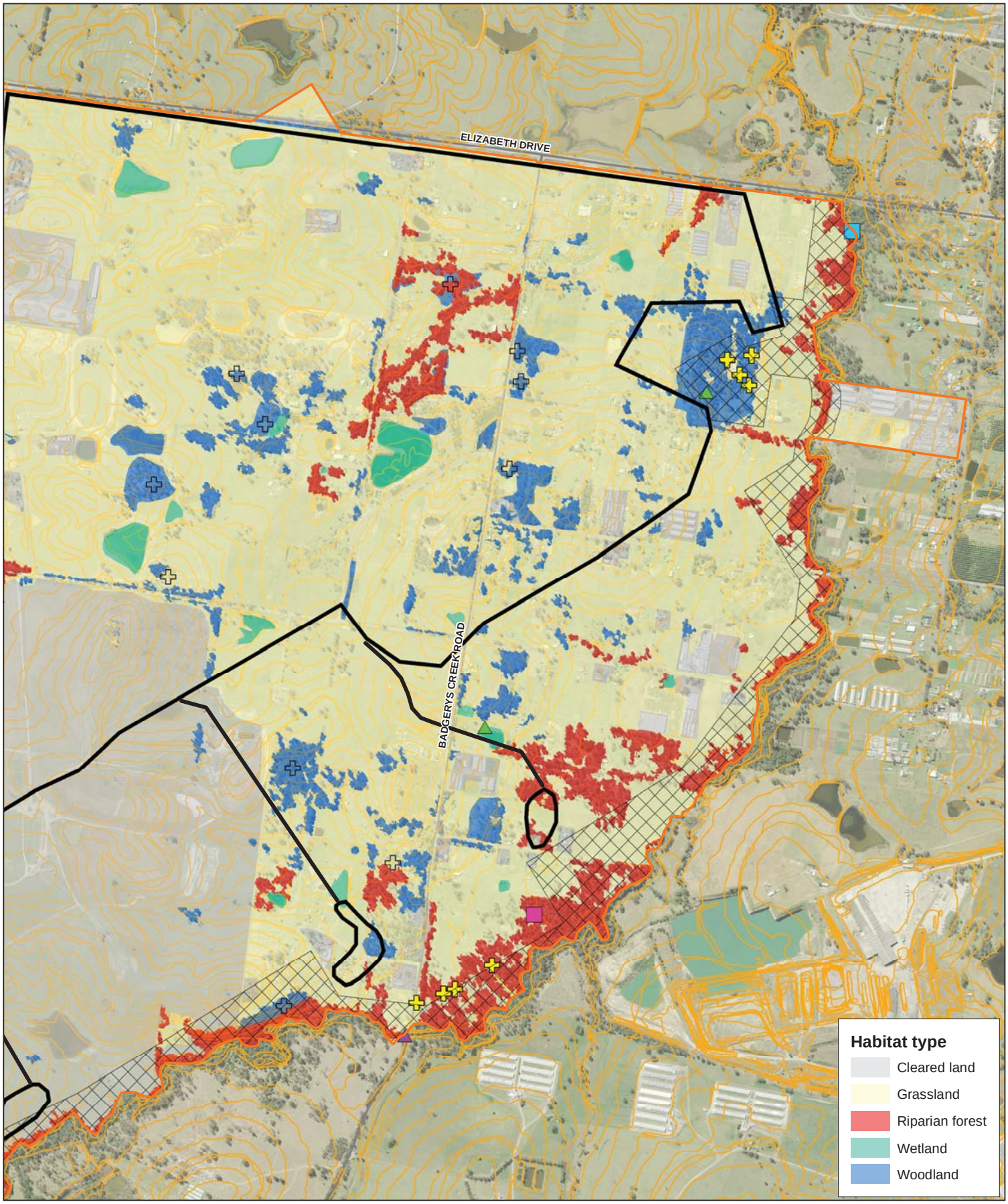

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Threatened fauna and habitat features

Figure 3D

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3. Offset Requirements for Impacts on the Environment

3.1 Overview

The Biodiversity Assessment assessed impacts on plants, animals and other features of the natural environment (GHD 2015a) as required by the EPBC Act significant impact guidelines 1.2 (OEH 2013b) for actions being undertaken by the Commonwealth. The Biodiversity Assessment concluded that the project would result in significant residual impacts on features of the natural environment including plant populations, fauna populations and several species and communities listed under NSW legislation (GHD 2015a). The offset assessment guide can only be used to calculate offsets for threatened biota listed under the EPBC Act and so an alternative approach is required for impacts on other protected matters. The EPBC Act offsets policy requires that the approach to calculating offsets must be in proportion to the level of statutory protection that applies to the protected matter, be of a size and scale proportionate to the residual impacts on the protected matter and be scientifically robust and reasonable (DSEWPaC 2013a). The BioBanking assessment methodology meets each of these criteria and is supported by DotE for this purpose.

BioBanking credit calculations using the assessment methodology for a major project in NSW have been used to estimate offsets for impacts on the environment, including species and communities listed under NSW legislation. The BioBanking credit calculations were performed by Ben Harrington (assessor accreditation number 0073) using credit calculator Version 4.0. The biodiversity credit report is included in Appendix B.

The data and assumptions used to perform the BioBanking credit calculations are summarised below.

3.2 Credit calculations

3.2.1 Landscape features

The BioBanking assessment methodology for a major project requires the assessment of landscape features to help describe the biodiversity values of the study area and assess the impacts of the project. The proposed airport is a site-based development (rather than linear infrastructure) and so the landscape value has been assessed according to the methodology for site-based major projects (OEH 2014b).Landscape features relevant to the credit calculations are shown on Figure 4 and summarised in Table 1.

Table 1 Summary of landscape features

Landscape feature	Stage 1 construction impact zone
Major Catchment	The stage 1 construction impact zone is located entirely within the Hawkesbury/Nepean major catchment.
Interim Biogeographic regionalisation of Australia (IBRA) bioregion and IBRA subregions	The stage 1 construction impact zone is located entirely within the 'Sydney Basin' IBRA bioregion and Cumberland – Hawkesbury/Nepean IBRA subregion.
Mitchell landscape	The stage 1 construction impact zone contains the Cumberland Plain Mitchell landscape (DECC 2008a).
% Native vegetation cover	The outer assessment circle is 4000 hectares in area and the inner assessment circle is 400 hectares.
	The current percent native vegetation cover in the outer assessment circle is 16-20% (around 795 hectares out of the 4000 hectare circle).
	The future percent native vegetation cover in the outer assessment circle is 11-15% (around 530 hectares out of the 4000 hectare circle, given the removal of around 265 hectares of native vegetation for the proposed airport).
	The current percent native vegetation cover in the inner assessment circle is 26-30% (around 110 hectares out of the 400 hectare circle).
	The future percent native vegetation cover in the inner assessment circle is 21-25% (around 88 hectares out of the 400 hectare circle, given the removal of 22 hectares of native vegetation for the proposed airport).
Connectivity value - class	The proposed airport would affect only a local area biodiversity link, because it would not affect the riparian corridor of any 4th order or greater streams, important wetlands, estuaries or state or regionally significant biodiversity links. The airport site contains multiple connecting links including the vegetated riparian corridors of Oaky Creek, Duncans Creek and Badgerys Creek.
Connectivity value - width	The current linkage width class of the narrowest point of each of these connecting links is 'Narrow' (>5-30m wide).
	The future linkage width class of the narrowest point of each of these connecting links is also 'Narrow' (>5-30m wide) because each connecting link would be maintained as at least this width after development.
Connectivity value - condition	The average projective foliage cover (PFC) of over storey and mid storey vegetation in the connecting link before development is at benchmark values.
	The average projective foliage cover (PFC) of over storey and mid storey vegetation in the connecting links after development would be at benchmark values because the connecting links extend outside of the airport site.
	A patch size polygon of around 670 hectares is shown on Figure 4 however the actual patch of connected native vegetation continues outside this area in the riparian corridors of Badgerys Creek to the north and Duncans Creek to the west. This is well above the patch size required to achieve the maximum patch size score for major projects (OEH, 2014b) (>100 ha, as the airport site is in the Cumberland Mitchell landscape, which is 89 % cleared (OEH 2015d).

3.2.2 Native vegetation

One vegetation zone was created for each NSW vegetation type and broad condition state in the stage 1 construction impact zone. The area of each zone was calculated using GIS. Vegetation zones within the stage 1 construction impact zone are summarised in Table 2.

Development impacts are likely to be restricted to the stage 1 construction impact zone. Given the mitigation measures specified in the biodiversity assessment (GHD 2015a) and EIS (GHD 2015b), adjoining land uses, and the extent of existing weed infestation and disturbance in the study area, the development would not result in any tangible secondary impacts.

Therefore no additional, secondary impacts have been included in the credit calculations.

Table 2 Vegetation zones

Veg Zone ID	Vegetation Zone	Condition	TSC Act Status	EPBC Act Status	Area	Plot/transects required	Plot/transects completed
1	Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	Moderate/good	CEEC	CEEC	71.3	14	Plot/transects 2, 5, 6, 7, 10, 11, 12, 16, 22, 23, 25, 31, 32, 35
2	Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	Moderate/good - poor	CEEC		107.8	7	Plot/transects 8, 19, 24, 28, 30, 37, 42
3	Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	Moderate/good	CEEC	CEEC	17.3	5	Plot/transects 20, 21, 36, 38, 40
4	Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	Moderate/good - poor	CEEC		22.3	4	Plot/transects 39, 41[1]
5	Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	Moderate/good	EEC		29.8	8	Plot/transects 9, 13, 15, 17, 18, 26, 29, 33
6	Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	Moderate/good - poor	EEC		4.2	3	Plot/transects 14, 27, 34
7	Good condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	Moderate/good	EEC	CEEC	2.2	2	Plot/transect 1[1]
8	Poor condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)	Moderate/good - poor	EEC		0.4	1	Plot/transect 43
9	Good condition artificial freshwater wetland on floodplain (HN630)	Moderate/good			25.4	4	Wetland assessment at targeted frog survey sites 2, 4, 5, 8, 9, 10, 11[2]

Notes: 1) less than the required number of plot/transects were sampled in the biodiversity assessment (GHD 2015a) and so available plot/transects were duplicated.

2) Wetland assessment data was used to extrapolate equivalent plot/transect data.

Site value data was collected using the BioBanking plot/transect methodology and was entered for each plot/transect field in each vegetation zone.

Changes in site biodiversity values through the development of a site is the basis for calculation of biodiversity credits required to offset impacts. Complete clearing of vegetation for a development reduces the site values to zero. There are certain circumstances where portions of a development are managed such that some site value is retained. These circumstances include asset protection zones (APZs) where only partial vegetation removal may be required. In such cases, vegetation zones

should be split into separate management zones to allow separate calculation of impacts of full vegetation removal versus partial vegetation removal.

All native vegetation and habitat within the stage 1 construction impact zone would be removed. The default decrease in site value was entered in the credit calculator for all management zones (i.e. the site values for all vegetation and habitat attributes were reduced to zero). Management zones in the stage 1 construction impact zone are summarised in Table 3.

Table 3 Management zones

Management Zone	Veg Zone ID	Vegetation Zone	Condition	Area (ha)	Management / Site Attribute Scores
MZ1	1	Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	Moderate/good	71.3	Full removal / Default decrease in site value.
MZ2	2	Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	Moderate/good - poor	107.8	Full removal / Default decrease in site value.
MZ3	3	Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	Moderate/good	17.3	Full removal / Default decrease in site value.
MZ4	4	Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	Moderate/good - poor	22.3	Full removal / Default decrease in site value.
MZ5	5	Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	Moderate/good	29.8	Full removal / Default decrease in site value.
MZ6	6	Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	Moderate/good - poor	4.2	Full removal / Default decrease in site value.
MZ7	7	Good condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	Moderate/good	2.2	Full removal / Default decrease in site value.
MZ8	8	Poor condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	Moderate/good - poor	0.4	Full removal / Default decrease in site value.
MZ9	9	Good condition artificial freshwater wetland on floodplain (HN630)	Moderate/good	25.4	Full removal / Default decrease in site value.

3.2.3 Threatened Species

Predicted threatened species

The credit calculator reports the suite of threatened fauna species that are predicted to be associated with ecosystem credits generated for the development. That is, the threatened fauna species that are predicted to use habitat within the vegetation types at the development site. Each of these species has a 'threatened species multiplier' that feeds into the ecosystem credit calculations. The species with the highest threatened species multiplier drives the credit calculations. If that fauna species or specific

habitat resources for that species are not present at the development site, then the threatened species multiplier score may be adjusted.

The suite of threatened species associated with ecosystem credits for the development is shown in Table 4. There is known or potential habit for each of these threatened species in the stage 1 construction impact zone and so the threatened species multipliers have not been adjusted.

Table 4 Predicted threatened species (ecosystem credit species)

Common name	*Scientific name*	Threatened species multiplier	On site [1]
Australian Painted Snipe	*Rostratula australis*	1.3	Yes
Barking Owl	*Ninox connivens*	3.0	Yes
Black-chinned Honeyeater (eastern subspecies)	*Melithreptus gularis* subsp. *gularis*	1.3	Yes
Black-tailed Godwit	*Limosa limosa*	2.6	Yes
Brown Treecreeper (eastern subspecies)	*Climacteris picumnus* subsp. *victoriae*	2.0	Yes
Bush Stone-curlew	*Burhinus grallarius*	2.6	Yes
Diamond Firetail	*Stagonopleura guttata*	1.3	Yes
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	2.2	Yes
Eastern Freetail-bat	*Mormopterus norfolkensis*	2.2	Yes
Flame Robin	*Petroica phoenicea*	1.3	Yes
Freckled Duck	*Stictonetta naevosa*	1.3	Yes
Gang-gang Cockatoo	*Callocephalon fimbriatum*	2.0	Yes
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	1.8	Yes
Greater Broad-nosed Bat	*Scoteanax rueppellii*	2.2	Yes
Hooded Robin (south-eastern form)	*Melanodryas cucullata* subsp. *cucullata*	1.7	Yes
Little Eagle	*Hieraaetus morphnoides*	1.4	Yes
Little Lorikeet	*Glossopsitta pusilla*	1.8	Yes
Masked Owl	*Tyto novaehollandiae*	3.0	Yes
Painted Honeyeater	*Grantiella picta*	1.3	Yes
Powerful Owl	*Ninox strenua*	3.0	Yes
Scarlet Robin	*Petroica boodang*	1.3	Yes
Speckled Warbler	*Chthonicola sagittata*	2.6	Yes
Spotted Harrier	*Circus assimilis*	1.4	Yes
Spotted-tailed Quoll	*Dasyurus maculatus*	2.6	No
Square-tailed Kite	*Lophoictinia isura*	1.4	Yes
Swift Parrot	*Lathamus discolor*	1.3	Yes
Turquoise Parrot	*Neophema pulchella*	1.8	Yes
Varied Sittella	*Daphoenositta chrysoptera*	1.3	Yes
White-fronted Chat	*Epthianura albifrons*	0.8	Yes
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*	2.2	Yes

Notes: 1) There are habitat resources for the species at the site that would be removed by the proposed development.

Species credits

The credit calculator references geographic, vegetation and habitat data for the project site to generate a list of the species credit-type threatened species predicted to occur and requiring targeted survey.

A table of 'Threatened species survey / time matrix and survey effort' in accordance with the BBAM is included in Appendix B. The majority of the species credit-type species predicted to occur has been reliably excluded from occurring at the airport site or being impacted by the proposed airport based on the field survey effort undertaken for the biodiversity assessment (GHD 2015a). A total of four species were not targeted by surveys at appropriate times of year according to the survey / time matrix. These species can be reliably excluded from occurring at the airport site or being impacted by the proposed airport based on the desktop assessment and habitat assessments undertaken for the biodiversity assessment (GHD 2015a) as summarised in Appendix B.

The species credit-type threatened species that are present at the airport site are summarised in Table 5 along with the extent of impacts. For plants, impacts were calculated based on the number of individuals in the stage 1 construction impact zone. For animals, impacts were calculated based on the extent of habitat for the species in the stage 1 construction impact zone as presented in the biodiversity assessment (GHD 2015a).

Table 5 Impacts on species credit-type species

Common name	Scientific name	TSC Act Status	Likelihood of occurrence	Quantum of impact
Pultenaea parviflora	*Pultenaea parviflora*	Endangered	Present. Four individuals were recorded at the airport site.	4 individuals
Marsdenia viridiflora subsp. *viridiflora*	*Marsdenia viridiflora* subsp. *viridiflora*	Endangered population	Present. 93 individuals were recorded at the airport site.	93 individuals
Southern Myotis roosting habitat	*Myotis macropus*	Vulnerable	Probably recorded (based on echo-location call analysis). Likely to forage along creeks and above dams. May roost under bridges and in tree hollows at the airport site.	29.8 hectares
Cumberland Plain Land Snail	*Meriodolum corneovirens*	Endangered	Present. Generally occurs in larger remnant patches of Cumberland Plain Woodland with deep leaf litter.	120.6 hectares
Black Bittern		Vulnerable	Present. Recorded in riparian vegetation along Badgerys Creek.	55.3 hectares

3.3 Biodiversity credits

The data summarised above was entered into Version 4.0 of the credit calculator to determine the number of biodiversity credits that would be required to offset the removal of vegetation and habitat in the stage 1 construction impact zone. The BioBanking Credit Report is included in Appendix B and summarised below.

3.3.1 Ecosystem credits

The ecosystem credits that would be required to offset the impacts of the proposed airport on the environment are shown in Table 6 along with potential offset options (i.e. the plant community types which can be used to offset these impacts according to the BioBanking credit trading rules).

Table 6 Ecosystem credits required to offset impacts of the proposed airport

Plant community type name	Condition	TSC Act Status	EPBC Act Status	Management zone area	Ecosystem credit requirement	Offset options – Plant community types
Good condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	Moderate/ Good	CEEC	CEEC	71.27	3,555	HN528, HH526[1]
Poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528)	Moderate/ Good_Poor	CEEC		107.79	3,208	HN528, HH526
Good condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	Moderate/ Good	CEEC	CEEC	17.32	751	HN529, HN528, HN526[1]
Poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529)	Moderate/ Good_Poor	CEEC		22.29	647	HN529, HN528, HN526
Good condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	Moderate/ Good	EEC		29.83	1,530	HN526, HN528
Poor condition Forest Red Gum - Rough-barked Apple grassy woodland (HN526)	Moderate/ Good_Poor	EEC		4.22	127	HN526, HN528
Good condition Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512)	Moderate/ Good	EEC	CEEC	2.19	161	HN512, HN513, HN604, HN556[1]
Poor condition Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (HN512)	Moderate/ Good_Poor	EEC		0.39	20	HN512, HN513, HN604, HN556
Good condition artificial freshwater wetland on floodplain (HN630)	Moderate/ Good			25.44	700	HN630, HN520

Notes: 1) Ecosystem credits that are used to offset impacts on EPBC Act Cumberland Plain Woodland would need to be plant community types HN528, HN529 or HN512 and associated with better quality vegetation in order to comply with the EPBC Act offset policy (DSEWPaC 2012).

3.3.2 Species credits

The species credits that would be required to offset the impacts of the proposed airport on the environment are shown in Table 7. The intent of this offset package is to offset impacts with matching species credits.

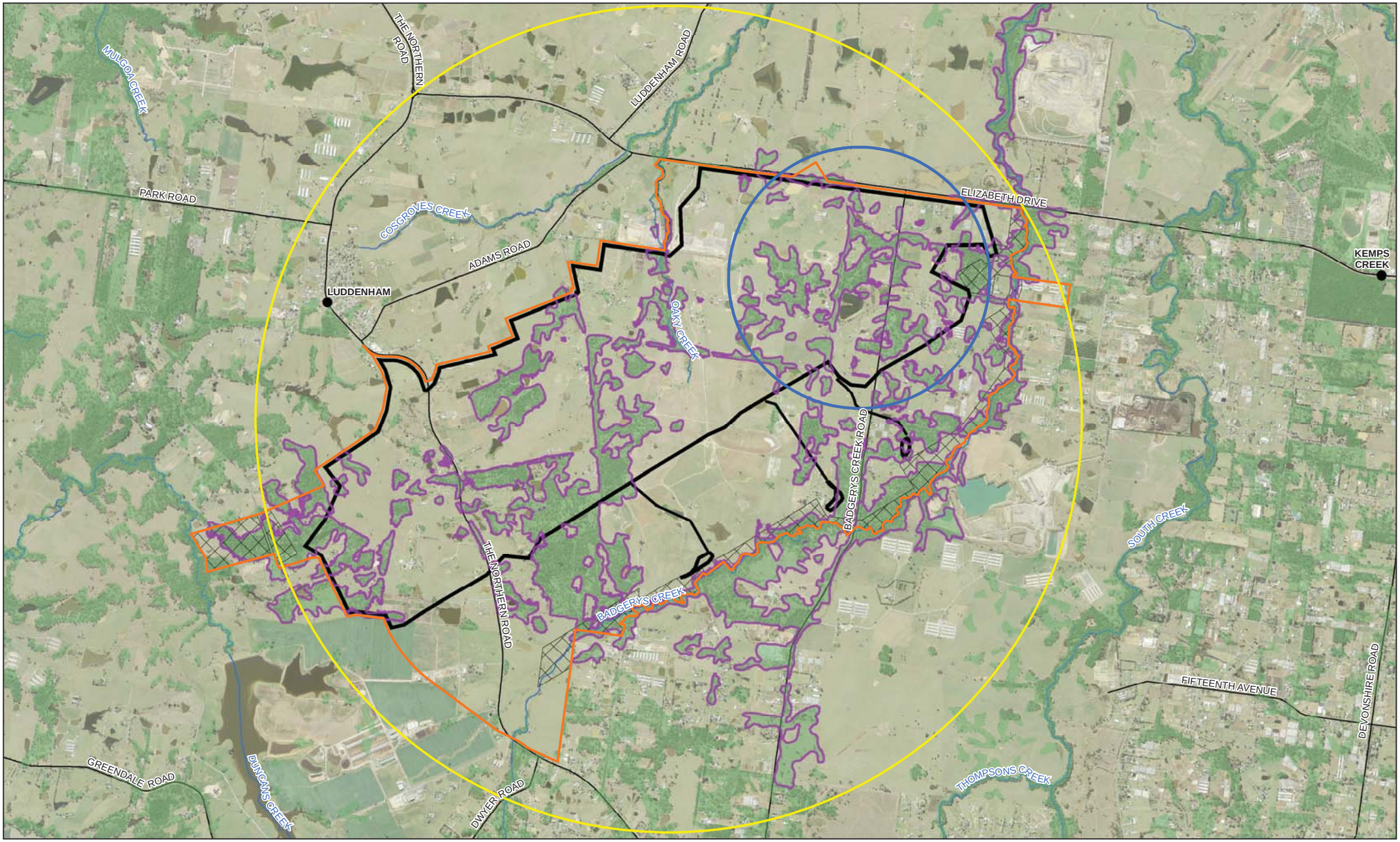
Table 7 Species credits required to offset impacts of the proposed airport

Common name	Scientific name	Threatened species multiplier	Species credits required
Black Bittern	*Ixobrychus flavicollis*	1.3	719
Cumberland Plain Land Snail	*Meridolum corneovirens*	1.3	1568
Marsdenia viridiflora subsp. *viridiflora* in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas	*Marsdenia viridiflora* subsp. *viridiflora* - endangered population	4.0	3720
Pultenaea parviflora	*Pultenaea parviflora*	1.5	60
Southern Myotis	*Myotis macropus*	2.2	656

3.4 Assumptions and amendments to the BioBanking methodology

The biodiversity offsets for impacts on the natural environment have been determined using the BioBanking credit calculator as it is applied to major projects as described above. Some data has been estimated or modified to enable BioBanking credit calculations based on the biodiversity assessment results (GHD 2015a). The assumptions and amendments to the BioBanking assessment methodology for major projects are listed below:

- BioBanking credit calculations have not been completed for proposed biobank sites (seeTable 8). A rate of seven ecosystem credits per hectare has been used to estimate the number of credits that would be generated at these sites, which is based on the results of BioBanking calculations from similar biobank sites.
- Wetlands were not sampled with plot/transects because of the inherent safety risk. Wetland vegetation was sampled by walking the margins of waterbodies and noting dominant plant species and percentage cover in each vegetation strata present (i.e. trees, shrubs, emergent, aquatic and fringing plants). These 'wetland survey' results were then used as surrogates for plot/transect data in credit calculations.
- Less than the minimum number of plot/transects required by the BioBanking assessment methodology for major projects were sampled in two out of the nine native vegetation zones at the airport site. In these instances the available plot/transect data for each vegetation zone were duplicated.
- It is assumed that all vegetation in the stage one construction impact zone would be completely removed for construction of the proposed airport. One management zone was created for each vegetation zone in the stage one construction impact zone and all site value scores were reduced to zero after the development.



Paper Size A3

0 10 20 40

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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LEGEND

- The airport site
- Stage one construction impact zone
- Environmental conservation
- Inner assessment circle (400 hectares)
- Outer assessment circle (4000 hectares)
- Patch size
- Native woodland and forest
- Watercourses
- Roads

Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Offset Package

Job Number	21-24265
Revision	A
Date	06 Oct 2015

Landscape assessment

Figure 4

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Data source: NSW LPI DTDB 2012, Inset - Geoscience Australia. Created by:jrichardson

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4. Proposed Offsets

4.1 Proposed offset strategy

The biodiversity offset strategy for the proposed airport is to conserve habitat for the affected threatened biota in suitable offset sites using BioBanking. The offsets would be secured by registration of a BioBanking agreement on title to the offset sites that would ensure that they would be securely titled and managed for conservation as a biobank in perpetuity.

The EPBC Act offset policy requires that a minimum of 90 per cent of the proposed airport's impacts must be directly offset as calculated with the offset assessment guide for listed threatened species and communities or as calculated with bioBanking or an alternative metric for other matters. The remaining offset requirement is able to be met by alternative contributions such as a financial contribution to research or conservation.

The specific components of this strategy that are included in the offset package are described below.

4.2 Identification of potential offset sites

A desktop assessment was performed to identify and describe potential offset sites for the proposed airport. Candidate sites would be secured under a BioBanking agreement that would ensure that the offset sites would be securely titled for conservation as a biobank in perpetuity.

The sources that were considered in the desktop assessment included:

- the 'biodiversity credits register' (OEH 2015b) which was used to identify existing biobank sites with biodiversity credits that would offset impacts on the affected threatened biota and that are available for sale;
- the BioBanking 'Expression of interest register' (OEH 2015c) which was used to identify potential biobank sites that could generate suitable biodiversity credits in the future;
- BioBanking assessment reports for existing and potential biobank sites, which were used to describe the biodiversity values of the sites and especially to confirm the extent and quality of habitat for the affected threatened biota; and
- consultation with private landowners and agencies such as OEH, the NSW Department of Planning and Environment (DPE) and the Western Sydney Parklands Trust to identify or to describe potential offset sites.

The following criteria were used to identify potential offset sites:

- presence of Cumberland Plain Woodland, comprising the NSW vegetation types HN528, HN529 and HN512 (OEH 2014);
  - that meets the condition criteria required to comprise the community as defined under the EPBC Act and associated policy (DEWHA 2010); or
  - is poorer quality Cumberland Plain Woodland that could be managed to achieve that condition and is connected to EPBC Act Cumberland Plain Woodland.
- presence of habitat for the Grey-headed Flying-fox based on the presence of known food tree species (Eby and Law 2008) and the critical habitat criteria listed in the Draft National Recovery Plan for the Grey-headed Flying-fox (DECCW 2009);

- land that is relatively close to the airport site, in order to more directly benefit the populations and communities affected by the proposed airport, and which as a minimum is located in the Cumberland IBRA sub-region; and
- land that is already set aside as a biobank and that has suitable biodiversity credits for sale, that is likely to be set aside as a biobank or otherwise protected under a conservation covenant, or that may be available for sale.

The offset package will include the conservation of core areas of Cumberland Plain Woodland in offset sites that already meet the condition criteria required to comprise the community as defined under the EPBC Act and associated policy (DEWHA 2010). The offset package will also include the conservation and management of poorer quality Cumberland Plain Woodland that could be managed to achieve that condition.

The guide to identifying and protecting EPBC Act Cumberland Plain Woodland notes that appropriate management of patches that do not meet the condition thresholds may still play an important ecological role, especially where they are linking native vegetation remnants in the landscape and contributing to the future viability of listed patches of the ecological community. Both patches that meet the condition thresholds and those that do not should be considered in recovery and other management actions (DEWHA 2010). This approach builds upon the information presented in the Commonwealth listing advice for Cumberland Plain Woodland which notes that if a patch does not meet the condition criteria, suitable recovery and management actions may improve it to the point that it can be regarded as part of the ecological community listed under the EPBC Act.

The listing advice also notes that derived grasslands and shrub lands can be quite easily recovered to meet the description and condition thresholds for the listed ecological community through planting of key canopy tree species and ongoing management actions, whereas loss of ground layer diversity is much more difficult to replace (TSSC 2008). In line with the listing advice, only derived native grassland and scrub with predominantly native groundcover and the capacity for natural regeneration will be included as poorer quality Cumberland Plain Woodland in the offset package.

4.3 Description of potential offset sites

The desktop assessment has revealed suitable offset sites that contain Cumberland Plain Woodland and/or Grey-headed Flying-fox habitat. The potential offset sites include established biobank sites with suitable biodiversity credits for sale and proposed biobank sites that are at various stages of the assessment and approval process for obtaining a BioBanking agreement.

Potential offset sites that contain habitat for the affected threatened biota and that could be included in this offset package are listed in Table 8. The locations of the potential offset sites relative to the airport site are shown on Figure 5. Portions of the Williamswood, Montpelier Stages 1 and 2 and Durham biobanks containing a total of 190 hectares of native vegetation and habitat are located in mapped Cumberland Plain Priority Conservation Lands that are identified in the recovery plan for Cumberland Plain Woodland (DECCW 2010, 2011). In addition, the Menangle Road and Dunheved biobank sites are connected to Cumberland Plain Priority Conservation Lands by remnant native vegetation (DECCW 2011).

A detailed description of each of the potential offset sites is provided in Appendix A, including their location, tenure, land uses, the vegetation types present, the extent and quality of habitat for the affected threatened biota, existing threats and recommended management actions. An overview of these sites is provided below.

The ‘Williamswood biobank’ and ‘The Oaks biobank’ offset sites are biobanks that have been subject to detailed field survey and BioBanking assessment and have already been set aside for conservation

under a BioBanking agreement. They are located within the Wollondilly Local Government Area (LGA) around 20 kilometres to the south of the airport site and feature a variety of grassy woodland vegetation types on shale and alluvial substrate. Both sites are currently zoned RU2 Rural Landscape under the *Wollondilly Local Environment Plan 2011* (LEP) and were grazed by cattle prior to being set aside as a biobank. Both sites contain Cumberland Plain Woodland that also comprises Grey-headed Flying-fox habitat as well as additional habitat associated with other vegetation types on shale or alluvium.

The 'Durham biobank', 'Mare biobank', Forrester biobank', 'Luddenham biobank', 'Caddens biobank' and 'Dunheved biobank' offset sites are proposed biobanks on land owned by the NSW DPE in the Ropes Creek and South Creek riparian corridors around 10-20 kilometres to the north of the airport site. These sites have been subject to a detailed field survey and a preliminary BioBanking assessment but have not yet been set aside for conservation under a BioBanking agreement. These offset sites each feature a variety of grassy woodland vegetation types on shale and alluvial substrate. These sites contain Cumberland Plain Woodland that also comprises Grey-headed Flying-fox habitat as well as additional habitat associated with other vegetation types.

The 'Stage 1 Montpelier Biobank', 'Stage 2 Montpelier biobank', 'Menangle Road biobank' and 'Bruelle biobank' offset sites are each proposed biobanks that have been subject to field surveys and BioBanking assessments prior to applications for BioBanking agreements from OEH (GHD, 2015d). Each of these biobanks is located within 20 kilometres of the airport site in the Wollondilly or Penrith LGAs. They are currently zoned RU2 Rural Landscape under applicable LEPs and are subject to cattle grazing. These sites each feature a variety of grassy woodland vegetation types on shale and alluvial substrate, including Cumberland Plain Woodland and Grey-headed Flying-fox habitat.

The 'Western Sydney Parklands biobank ID 120' and 'Western Sydney Parklands biobank ID 70' offset sites have already been set aside for conservation under a BioBanking agreement. They are located around 10 kilometres to the north-east of the airport site and feature a variety of grassy woodland vegetation types on shale and alluvial substrate. These sites contain Cumberland Plain Woodland that also comprises Grey-headed Flying-fox habitat.

Table 8 Potential offset sites

Potential Offset Site	Location	Total area (ha)	Status and ownership	Source
Williamswood biobank	Mount Hunter	104.4	Established biobank, private owner.	Williamswood Biobank BioBanking Assessment (GHD 2014a).
Durham biobank	Oxley Park (Ropes Creek riparian corridor)	46.85	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015c).
Mamre biobank	Mamre Park (South Creek riparian corridor)	98.1	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015c).
Luddenham biobank	Mamre Park (South Creek riparian corridor)	42	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015c).
Roper biobank	Minchinbury (Ropes Creek riparian corridor)	14.05	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015c).

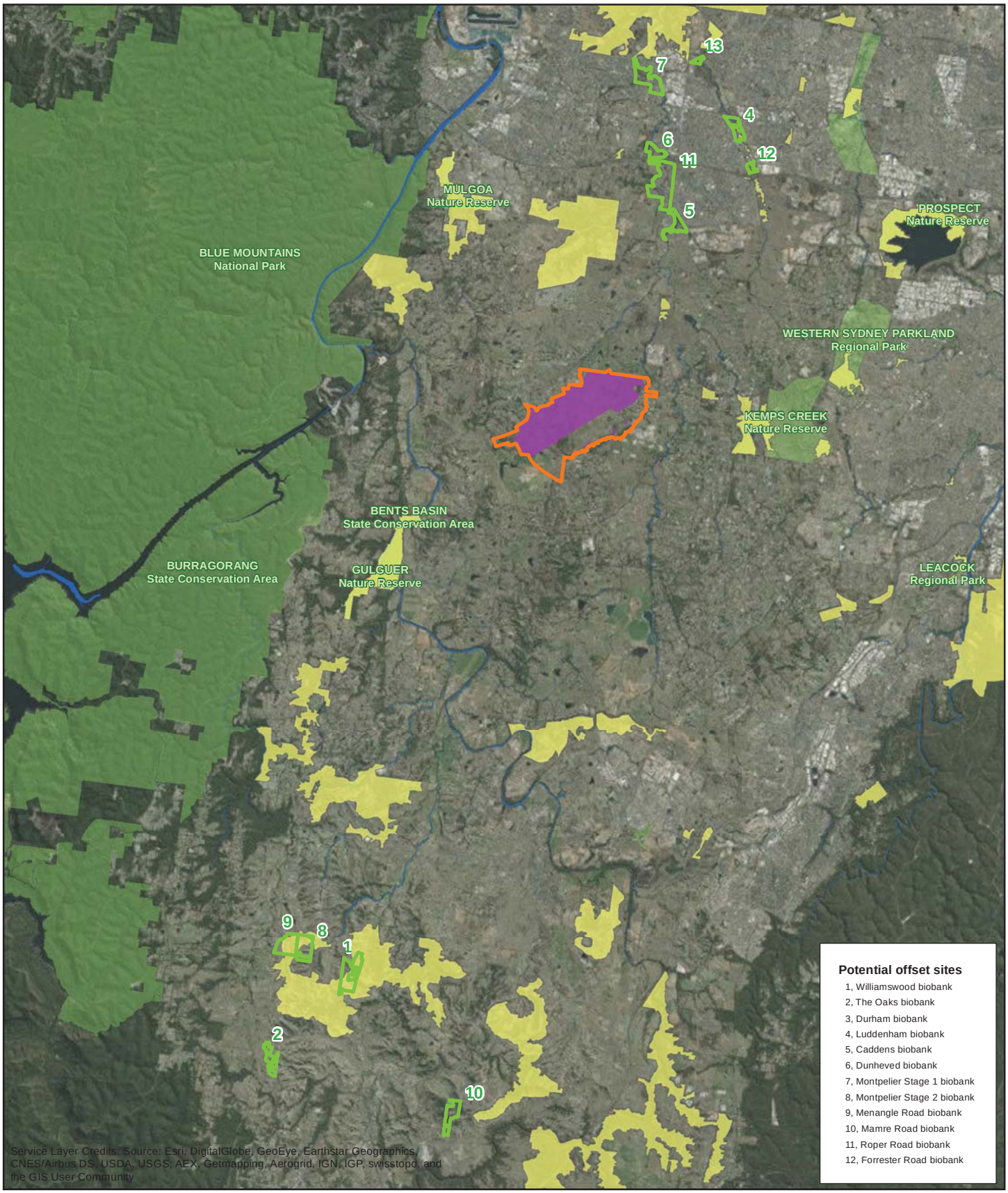
Potential Offset Site	Location	Total area (ha)	Status and ownership	Source
Caddens biobank	Claremont Meadows (South Creek riparian corridor)	36.08	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015c)
Dunheved biobank	Werrington County (South Creek riparian corridor)	90.17	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015c).
Forrester biobank	Tregear (Ropes Creek riparian corridor)	9.16	Potential biobank, DPE.	Ropes and South Creek Preliminary BioBanking Assessment Report (GHD 2015c).
Stage 1 Montpelier biobank	The Oaks	76.24	Potential biobank, private owner.	Stage 1 Montpelier Biobank BioBanking Assessment (GHD 2015d).
Stage 2 Montpelier biobank	The Oaks	79.5	Potential biobank, private owner	Stage 2 Montpelier Biobank BioBanking Assessment (GHD in prep).
Menangle Road biobank	The Oaks	57.07	Potential biobank, private owner	Menangle Road Biobank BioBanking Assessment (GHD 2015e).
Bruelle biobank	Mulgoa	27.5	Potential biobank, private owner	Bruelle biobank site Draft Biobank agreement assessment (GHD 2015f).
The Oaks	Mowbray Park	40	Established biobank, private owner	The Oaks Biobank BioBanking Assessment (GHD 2015g).
Western Sydney Parklands ID 120	Cecil Park	19.4	Established biobank, Western Sydney Parklands Trust	The biodiversity credits register (OEH 2015b).
Western Sydney Parklands ID 70	Cecil Park and Chandos West	40.5	Established biobank, Western Sydney Parklands Trust	The biodiversity credits register (OEH 2015b).

There are local occurrences of each of the TECs that would be removed for construction of the airport and known or potential habitat for many of the threatened species that would be affected at the offset sites (see Appendix A and Table 9).

Table 9 Threatened species recorded at the potential offset sites

Common name	Scientific name	TSC Act Status	EPBC Act Status	Sites recorded
Brown Treecreeper (eastern subspecies)	*Climacteris picumnus* subsp. *victoriae*	V		Dunheved[1]
Eastern Freetail-bat	*Mormopterus norfolkensis*	V		Mamre[2]
Little Eagle	*Hieraaetus morphnoides*	V		Roper, Luddenham, Montpelier Stage 1, Montpelier Stage 2, Williamswood[3]
Powerful Owl	*Ninox strenua*	V		Mamre[2]
Swift Parrot	*Lathamus discolor*	E	E	Dunheved[1]
Turquoise Parrot	*Neophema pulchella*	V		Luddenham[1]
Varied Sittella	*Daphoenositta chrysoptera*	V		Dunheved[1], Mamre[2]
Cumberland Plain Land Snail	*Meridolum corneovirens*	E		Forrester[1], Caddens[2]
Juniper-leaved Grevillea	*Grevillea juniperina* subsp. *juniperina*	V		Durham[3], Roper[3]
Dillwynia tenuifolia	*Dillwynia tenuifolia*	V		Roper[4]
Grey-headed Flying-fox	*Pteropus poliocephalus*	V	V	Caddens[2] and roost camp within 500 metres[4],
Large-footed Myotis	*Myotis macropus*	V		Mamre[2]
Pultenaea parviflora	*Pultenaea parviflora*	V	V	Dunheved[3]
Spiked Rice-flower	*Pimelea spicata*	E	E	Williamswood[3]

1 = Toolijooa (various dates); 2 = OEH (2015a); 3 = GHD (2014a,b; 2015a,b,c,d,e; in prep.); 4 = PB (2013).



LEGEND

- Airport site
- Potential offset sites
- Cumberland Plain Priority Conservation Lands
- Stage one construction impact zone
- Drainage lines
- Reserves

Paper Size A4

0 875 1,750 3,500 5,250 7,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Western Sydney Unit, Department of Infrastructure and Regional Development
Western Sydney Airport
Biodiversity Offset Package

The airport site and potential offset sites

Job Number 21-24265
Revision A
Date 27 Aug 2015

Figure 5

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Data source: Aerial Imagery: ESRI, 2015. Offset sites: GHD, 2015. Cumberland Plain Conservation: DECCW, 2011 Created by:Afoddy

4.4 Proposed offset areas

The potential offset sites described above contain some areas of native vegetation and habitat that is not an appropriate 'like for like' match for impacts on the EPBC Act-listed affected threatened biota or is associated with biodiversity credits that have already been sold. A subset of the habitat available at the potential offset sites has been selected on the basis that it would directly offset impacts on the affected threatened biota, and the biobanking credits which are generated to represent the offsets for that area are available for purchase. DotE will require these specific areas to be clearly documented and mapped in the final offset package.

The criteria for selecting the proposed offset areas are:

- areas that are linked to biodiversity credits that area available for sale at established biobanks or that would be available for sale at proposed biobanks;
- presence of EPBC Act Cumberland Plain Woodland;
- presence of habitat for the Grey-headed Flying-fox.

The 'proposed offset areas' (i.e. the specific areas of habitat at potential offset sites that would be included in the offset package to offset impacts on the affected threatened biota) are summarised in Table 10.

The area of Grey-headed Flying-fox habitat available in the proposed offset areas (around 401 hectares) is substantially greater than the estimated area required to meet this species' offset requirement. This area would also contribute offsets for impacts on the environment as estimated in Section 3 and so the full area has been included in the Offset assessment guide calculations in Section 5.2.3.

Table 10 Proposed offset areas

Potential Offset Site	Total area (ha)	Extent of available EPBC Act Cumberland Plain Woodland (ha)[1]	Extent of available poorer quality Cumberland Plain Woodland (ha)[2]	Grey-headed Flying fox habitat (ha) [3]	Notes
Williamswood biobank	104.5	31.9	28.0	50.4	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland.
The Oaks	40.0	10.0	3.0	10.4	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland.
Durham biobank	42.7	2.9	0.0	24.1	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional Grey-headed Flying-fox habitat associated with River Flat Eucalypt Forest and close to a known roost camp.
Mamre Biobank	98.1	0.0	0.0	52.5	Grey-headed Flying-fox habitat associated with River Flat Eucalypt Forest and linked to biodiversity credits that area available for sale.
Luddenham biobank	40.0	4.1	0.7	34.6	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional Grey-headed Flying-fox habitat associated with River Flat Eucalypt Forest. Additional poorer quality Cumberland Plain Woodland.
Roper biobank	13.3	3.0	1.7	6.7	EPBC Act Cumberland Plain Woodland and poorer quality Cumberland Plain Woodland linked to credits that are available for sale.

Potential Offset Site	Total area (ha)	Extent of available EPBC Act Cumberland Plain Woodland (ha)[1]	Extent of available poorer quality Cumberland Plain Woodland (ha)[2]	Grey-headed Flying fox habitat (ha) [3]	Notes
Caddens biobank	33.3	4.8	1.2	17.3	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland. Biodiversity credits for other impacts on the environment.
Dunheved biobank	65.0	3.8	8.7	23.0	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland. Biodiversity credits for other impacts on the environment.
Forrester biobank	9.2	0.0	0.0	5.9	Grey-headed Flying-fox habitat associated with River Flat Eucalypt Forest and linked to biodiversity credits that area available for sale.
Stage 1 Montpelier biobank	76.2	34.1	11.4	40.9	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland. Biodiversity credits for other impacts on the environment.
Stage 2 Montpelier biobank	79.5	20.9	9.2	48.5	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland. Biodiversity credits for other impacts on the environment.
Menangle Road biobank	57.1	27.0	21.1	36.0	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Additional poorer quality Cumberland Plain Woodland. Biodiversity credits for other impacts on the environment.
Bruelle biobank	26.8	14.4	0.0	27.5	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Biodiversity credits for other impacts on the environment.

Potential Offset Site	Total area (ha)	Extent of available EPBC Act Cumberland Plain Woodland (ha)[1]	Extent of available poorer quality Cumberland Plain Woodland (ha)[2]	Grey-headed Flying fox habitat (ha) [3]	Notes
Western Sydney Parklands ID 120	19.4	18.2	0.0	18.2	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Biodiversity credits for other impacts on the environment.
Western Sydney Parklands ID 70	40.5	5.2	0.0	5.2	EPBC Act Cumberland Plain Woodland linked to credits that are available for sale, which also comprises Grey-headed Flying-fox habitat. Biodiversity credits for other impacts on the environment.
	786.2	**180.3**	**78.6**	**401.2**	

Notes:

1- Vegetation types HN528, HN529 and HN512 that meet the condition criteria required to comprise Cumberland Plain Woodland as defined under the EPBC Act and associated policy (DEWHA 2010) and which are linked to biodiversity credits associated with an established biobank site that are currently available for sale and/or which are in a parcel of land that is likely to be set aside as a biobank.

2- Poorer condition patches of vegetation types HN528, HN529 and HN512 that do not meet the condition criteria required to comprise Cumberland Plain Woodland as listed under the EPBC Act (DEWHA 2010). Comprises derived native scrub or grassland with <10 per cent canopy cover.

3- Based on vegetation type descriptions in offset site assessment reports compared with the critical habitat criteria listed in the *Draft National Recovery Plan for the Grey-headed Flying-fox* (DECCW 2009).

The quality of habitat in the proposed offset areas is described further in Section 5.2. These data have been used to perform the preliminary offset assessment guide calculations included in Section 5. Based on these preliminary offset calculations the proposed offset areas could deliver 100 per cent of the required offsets for the Grey-headed Flying-fox as direct offsets but only around 74 per cent of the estimated requirement for Cumberland Plain Woodland. The process of identification of potential offset sites will continue until the required quantum of offsets can be delivered. As additional offset sites are identified the proposed offset areas would be reconsidered to ensure that the most suitable offset areas are included in the final offset package. Similarly, if some of the proposed areas are set aside as offsets for another project or otherwise become unavailable then alternative options would be considered.

4.5 Management of offset sites

4.5.1 Legal protection of offset sites

BioBanking agreements would be registered over each of the proposed offset sites that are included in the offset package. Several of the potential offset sites described above have already been set aside as biobanks.

A BioBanking agreement comprises a conservation covenant on the title of the lots within the biobank site. The covenant is the strongest available on private lands and extinguishes all land uses other than conservation unless the BioBanking agreement is varied or terminated by the NSW Minister for the Environment to permit alternative uses. Certain mining rights may be granted over a biobank site, and certain development can be carried out by public authorities on a biobank site, but any impacts from these activities must be offset again as an addition to any offsetting activities required by a given project in its own right.

Therefore the risk of loss of the offset sites with the BioBanking agreement in place has been assessed as 1 per cent for the purposes of the offset assessment guide calculations (see Section 5.4).

4.5.2 Management actions

A BioBanking agreement includes a binding requirement to perform management actions that will achieve improvements in biodiversity values at the biobank site (i.e. the offset sites). The following sections provide an outline of the actions that would be required for ongoing management of the offset sites and to achieve the proposed improvements in biodiversity values. A management action plan (MAP), detailing rehabilitation activities and a management program would be prepared for inclusion in the BioBanking agreement application. The MAP would include the costs and timeline for each proposed management action.

Management actions that would be performed at the offset sites may include:

- exclusion of domestic grazing;
- fencing;
- weed control;
- management of fire for conservation;
- management of human disturbance;
- retention of regrowth and remnant native vegetation;
- retention of dead timber;
- erosion control; and

- retention of rocks.

These management actions would improve the condition and viability of Cumberland Plain Woodland. Management would also improve the quality of habitat for the Grey-headed Flying-fox and especially the quality of foraging resources by increasing the extent, health and productivity of native vegetation containing food tree species.

Management actions would be specified in greater detail in the BioBanking assessments and/or MAPs for the offset sites as part of arrangements for protection of the sites in perpetuity. Additional site specific management actions may be required under the BioBanking methodology to alleviate specific threats for other species. Both threats and actions would be identified during field surveys conducted as part of the BioBanking assessment. Site specific management actions may include feral herbivore control or feral cat and/or fox control, in line with existing control programs in the locality, as required.

Based on an understanding of management measures which typically would be required for an offset site under a biobanking agreement, an increase in habitat quality score with offset has been entered in the offset assessment guide calculations (see Section 5.4). Table 11 provides the justification for the increase in habitat quality score with reference to conservation advice and recovery plans for the affected threatened biota as relevant.

Table 11 Effect of management actions on quality of habitat in the potential offset sites

Management action	Effect on Cumberland Plain Woodland	Effect on Grey-headed Flying-fox habitat
Retention of regrowth and remnant native vegetation.	Maintenance and improvement of the condition of the community. Improved viability of the populations of component species. Continued development of vegetation structure and habitat resources. Contributes to the following recovery objectives identified in the recovery plan for the community: Objective 1. To build a protected area network, comprising public and private lands, focused on the priority conservation lands (DECCW 2010). Five of the potential offset sites are located in mapped Cumberland Plain Priority Conservation Lands that are identified in the recovery plan for Cumberland Plain Woodland (DECCW 2010, 2011). BioBanking agreements are recognised as a preferred conservation mechanism (DECCW 2010).	Maintenance and improvement of shelter and foraging habitat. Regeneration and maturation of food tree species. Contributes to the following recovery objectives identified in the recovery plan for the species: Objective 1. To identify and protect foraging habitat critical to the survival of Grey-headed Flying-foxes throughout their range; and Objective 2. To protect and increase the extent of key winter and spring foraging habitat of Grey-headed Flying-foxes (DECCW 2009).
Regeneration of canopy vegetation in derived native grassland and scrub.	Increased extent of the EPBC Act community. Development of natural vegetation structure and microclimate and associated benefits for vegetation condition and species richness. Increased shelter and foraging habitat for component species. Improved connectivity of habitat. Improved quality and viability of the community through reduced edge effects.	Increased extent of shelter and foraging habitat. Improved connectivity of habitat resulting in reduced risk and energy costs of movement between patches of habitat. Improved quality and viability of retained habitat through reduced edge effects. Regeneration and maturation of food tree species. Contributes to objective 2 identified in the recovery plan for the species: to protect and increase the extent of key winter and spring foraging habitat of Grey-headed Flying-foxes (DECCW 2009).

Management action	Effect on Cumberland Plain Woodland	Effect on Grey-headed Flying-fox habitat
Weed control	Maintenance and improvement in the condition of the community by increasing the extent, health and productivity of native vegetation and restoring natural vegetation structure and microclimate. Reduced competition for component plant species. Consistent with one of main principles presented in the recovery plan for the community, which is that active management to best practice standards is needed to prevent the degradation of the remaining bushland in the fragmented landscape of Western Sydney (DECCW 2010).	Maintenance and improvement in quality of foraging habitat by increasing the extent, health and productivity of native vegetation containing food tree species.
Exclusion of domestic grazing and management of human disturbance.	Improved health and productivity of native vegetation. Reduced risk of secondary impacts such as erosion and sedimentation and transmission of weeds or disease.	Likely increase in the extent and quality of foraging habitat by increasing the extent, health and productivity of native vegetation containing food tree species.
Fire management (ecological burning and reduced risk of wildfire)	Maintenance of natural vegetation structure and microclimate and associated benefits for vegetation condition and species richness. Reduced risk of wildfire and associated erosion having an impact on the quality of the community.	Improvement in the health of vegetation and quality of foraging resources. Reduced risk of wildfire and associated risk of harm to individual animals and of erosion having an impact on the quality of the habitat.
Control of pest fauna (deer, rabbits, pigs, feral cattle).	Improved health and productivity of native vegetation. Reduced risk of secondary impacts such as erosion and sedimentation and transmission of weeds or disease.	Likely increase in the extent and quality of foraging habitat by increasing the extent, health and productivity of native vegetation containing food tree species.
Property maintenance (perimeter fencing, rubbish and barbed wire fence strand removal, erosion control etc.).	Increased condition of vegetation. Reduced risk and energy costs of movement between patches of habitat for component species. Reduced risk of uncontrolled access, erosion, rubbish dumping etc. having an impact on the quality of habitat.	Increased quality of shelter and foraging habitat. Reduced risk and energy costs of movement between patches of habitat. Reduced risk of adverse impacts on the quality of habitat. Contributes to objective 9 identified in the recovery plan for the species: To assess and reduce the impact on Grey-headed Flying-foxes of electrocution on power lines and entanglement in netting and on barbed-wire (DECCW 2009).

4.5.3 Funding of offset sites

The management of the offset sites would be funded through the purchase and retirement of biodiversity credits through BioBanking. The credits would be purchased from the biobank site owner at an agreed market rate.

The cost of biodiversity credits includes a minimum value set by the BioBanking methodology known as the 'total fund deposit'. This value is the minimum required to be paid into the BioBanking trust fund to ensure that adequate funds are available to perform the management actions specified in the MAP on an ongoing, annual basis, in perpetuity. BioBanking includes provision for annual monitoring of biobank sites and scope for OEH to enforce expenditure on management actions or acquire the property if management has not been performed satisfactorily (DECC, 2009). OEH provides a work

sheet as part of the BBAM: the ‘total fund deposit worksheet (Part A costs)’. This work sheet is used to determine the costs that are included in the MAP and is part of the BioBanking agreement application.

BioBanking provides certainty that the management of the offset site would be fully funded. The total cost of delivering the offset package will not be confirmed until agreements have been made to purchase enough biodiversity credits to deliver the offset package for the proposed airport.

5. Offset Assessment Guide Calculations

5.1 Overview

The EPBC Act policy requires a formal assessment of impacts and offset contributions for EPBC Act-listed species and communities using the 'offsets assessment guide'. The offsets assessment guide utilises a balance sheet approach to measure impacts and offsets. According to the EPBC Act Environmental Offsets Policy (DSEWPaC 2012a), controlled actions requiring offsets must achieve a minimum 90 per cent 'direct offset'. Direct offsets are defined as 'those actions that provide a measurable conservation gain for an impacted protected matter'. A conservation gain for the protected matter may be achieved by measures such as:

- improving existing habitat;
- creating new habitat;
- reducing threats; and/or
- averting the loss of a protected matter or its habitat that is under threat.

The offset package comprises the conservation and management of the affected threatened biota and their habitat in offset sites. This would achieve improvement in the condition of habitat, creation of new habitat and resources, mitigation of threats and averted risk of loss through development or agricultural activities. The quality of habitat in the proposed offset areas and the change in site quality with management is assessed in Section 5.2 below.

A single offset area can compensate for impacts on multiple threatened biota if they have common habitat requirements (DSEWPaC 2012b). EPBC Act Cumberland Plain Woodland at the airport site and in the proposed offset areas also comprises Grey-headed Flying-fox habitat.

Offset assessment guide calculations have been performed based on the significant residual impacts documented in the EIS (GHD 2015a, 2015b) and likely conservation and management of the potential offset sites. The output of this preliminary offset guide assessment is an estimate of the percentage of the proposed airport's impacts that would be 'directly offset' by the potential offset sites. The other data and assumptions that were used to perform the offset calculations are described in Table 12, Table 13 and Table 14.

Once the final offset sites have been identified, a 90 per cent direct offset would be acceptable under the DSEWPaC (2012a) policy with up to 10 per cent of the offset able to be achieved through 'other compensatory measures', which are 'those actions that … are anticipated to lead to benefits for the impacted protected matter, for example funding for research or educational programs'. The intent of the offset package is to secure 100 per cent direct offsets, through conservation of appropriate vegetation and habitat in offset sites, if possible.

5.2 Quality of offset sites

5.2.1 EPBC Act Cumberland Plain Woodland

Cumberland Plain Woodland in the proposed offset areas that already meets the condition criteria for the EPBC Act listed form of the community (hereafter referred to as 'EPBC Act Cumberland Plain Woodland') comprises remnant or regrowth native vegetation in moderate condition. The quality of a community is scored out of ten for offset assessment guide calculations. As described above, for the airport site there are three site characteristics that may contribute to quality: 'site condition', 'site context' and 'species stocking rate' that must be weighted according to their relative importance to the

offset calculations (DSEWPaC 2012b). The weighting of these three attributes for Cumberland Plain Woodland in the proposed offset areas was defined as site condition – 50 per cent, site context - 50 per cent and species stocking rate – 0 per cent, as for the airport site.

Each characteristic was scored based on the results of the various BioBanking assessments for the various offset sites, weighted according to the size of the area at each site that would be included in the offset package.

Site condition was scored as 5/10 based on the BioBanking plot/transects and other field survey data collected within the vegetation zones that comprise Cumberland Plain Woodland in the proposed offset areas. This score is based on the characteristics outlined below.

- Moderate/good - medium condition Grey Box - Forest Red Gum grassy woodland on hills (HN529) (around 140 hectares out of around 180 hectares of EPBC Act Cumberland Plain Woodland in the proposed offset areas). Remnant or regrowth native woodland at the Williamswood, The Oaks, Bruelle, Menangle Road and Stage 1 and 2 Montpelier biobanks. Vegetation zones at these biobanks have relatively similar characteristics comprising partially cleared grazing country on undulating shale hills. These vegetation zones feature near-intact over storey, moderate scores for native species richness and most vegetation cover attributes, occasional hollow-bearing trees and relatively little woody debris. There is frequently high exotic plant cover mainly consisting of woody weeds such as African Olive (*Olea europa* subsp. *cuspidata*) in the mid storey.
- Moderate/good - medium condition Grey Box - Forest Red Gum grassy woodland on flats (HN528) or Broad-leaved Ironbark –*Melaleuca decora* grassy open forest (HN512) (around 40 hectares out of around 180 hectares of EPBC Act Cumberland Plain in the proposed offset areas). Remnant or regrowth woodland at the Ropes and South Creek and Western Sydney Parklands biobanks. Vegetation zones at these biobanks have relatively similar characteristics comprising partially cleared grazing country or open space on lower slopes and flats near to major drainage lines. These vegetation zones feature near-intact over storey, moderate scores for native species richness and most vegetation cover attributes, occasional hollow-bearing trees and relatively little woody debris. There is frequently high exotic plant cover mainly consisting of perennial grasses such as Kikuyu (*Pennisetum clandestinum)* and herbs in the under storey or woody weeds such as Privet (*Ligustrum* species) in the mid storey.

A more detailed description of site condition at each of these offset sites is provided in Appendix A.

Site context was scored as 5/10, reflecting the position of each of the local occurrences of the community in highly fragmented, rural landscapes (the Wollondilly and Penrith LGA biobanks) or narrow bushland remnants surrounded by suburban development (the Ropes and South Creeks and Western Sydney Parklands biobanks). Fragmentation of native vegetation and associated fauna habitats in the locality of these offset sites has previously occurred through clearing for agriculture, residences and industry and construction of transmission lines, railways and roads. These land uses have created barriers to movement for many fauna species, particularly those that are limited by dispersal abilities and habitat preferences. The patches of Cumberland Plain Woodland that remain at the proposed offset sites have high edge to area ratios and are frequently dissected by tracks and fence lines. In this context, many of the species within Cumberland Plain Woodland at the proposed offset sites have limited opportunities for dispersal or recruitment and are subject to ongoing threats from human activities, grazing, exotic plants and pest fauna.

Based on the inputs described above, ‘offset calculator – start area and quality – quality’ (i.e. the current quality of the community in the proposed offset area) was scored as 5/10 overall. This is a slightly lower site quality score than the airport site, reflecting generally more severe weed infestation and generally smaller patches of vegetation, surrounded by more intensive development.

The EPBC Act Cumberland Plain Woodland in the proposed offset areas could be managed and improved to the same condition as the community at the airport site in the short to medium term, particularly through the intensive treatment of weed infestations. The 'time until ecological benefit' (i.e. the time period required to achieve the probable increase in site quality score and/or decline in site quality without management) was set as ten years. Ten years is the expected time it takes to establish a biobank, complete primary activities such as fencing and erosion control, complete the initial more, intensive weed control activities and achieve natural regeneration. The proposed management actions and the likely benefits to the community are described in greater detail in Section 4.5.2.

The 'offset calculator - future quality without offset' component for EPBC Act Cumberland Plain Woodland in the proposed offset areas (i.e. the likely decline in site condition if the site was not managed as a biodiversity offset) was scored as 4/10 reflecting a decline in the condition and possibly also extent of the community in the offset areas through an additional ten years of impacts arising from grazing, weed infestation, erosion, human activities and other threats.

The 'offset calculator - future quality with offset' component (i.e. the likely increase in site condition if the site is managed as a biodiversity offset) was scored as 8/10 reflecting a substantial improvement in the condition of the community through measures such as exclusion of grazing and unauthorised access, removal of rubbish, an ecological burn, treatment of erosion and especially treatment of weed infestations. After ten years the severe infestations of woody weeds through the mid storey in much of the proposed offset area would be substantially controlled and a natural vegetation structure would be restored. The management of additional poorer quality Cumberland Plain Woodland in offset areas (see Section 5.2.2) would improve the 'site context' component of the site quality score by increasing the extent of the community, removing threats associated with adjoining areas of exotic vegetation and connecting fragmented remnants.

The proposed offset area would be managed in perpetuity and additional gains in site quality would be achieved over the longer term through bush regeneration activities, continued development of species richness and vegetation structure, increased patch sizes, improved habitat connectivity and development of habitat resources such as woody debris and hollow-bearing trees.

These values have been entered in the offset assessment guide calculations that are presented in Section 5.4.

5.2.2 Poorer quality Cumberland Plain Woodland

Poorer quality Cumberland Plain Woodland in the proposed offset areas comprises derived native scrub or grassland. These patches of the community do not meet the condition criteria for the EPBC Act listed form of the community because the native over storey cover is less than 10 per cent (see DEWHA 2010). When purposefully managed for conservation in a biobank site suitable recovery and management actions may improve these patches to the point that they can be regarded as part of the ecological community listed under the EPBC Act (TSSC 2008).

The quality of a community is scored out of ten for offset assessment guide calculations. As described above there are three site characteristics that may contribute to quality: 'site condition', 'site context' and 'species stocking rate' that must be weighted according to their relative importance to the offset calculations (DSEWPaC 2012b). The weighting of these three attributes for Cumberland Plain Woodland in the proposed offset areas was defined as site condition – 50 per cent, site context – 50 per cent and species stocking rate – 0 per cent, as for the airport site.

Each characteristic was scored based on the results of the BioBanking assessments for the various offset sites, weighted according to the size of the area at each site that would be included in the offset package.

Site condition was scored as 3/10 based on the BioBanking plot/transects and other field survey data collected within the vegetation zones that comprise Cumberland Plain Woodland in the proposed offset areas. This score is based on the following characteristics.

- Moderate/good - poor condition Grey Box - Forest Red Gum grassy woodland on hills (HN529) (around 53 hectares out of around 78 hectares of poorer quality Cumberland Plain Woodland in the proposed offset areas). This comprises immature regrowth or derived native grassland or scrub at the Williamswood, The Oaks, Bruelle, Menangle Road and Stage 1 and 2 Montpelier biobanks. The relevant vegetation zones at these biobanks have relatively similar characteristics comprising partially cleared grazing country on undulating shale hills. These vegetation zones feature minimal over storey cover, moderate scores for native species richness, moderate to high cover of native mid storey, shrubs and/or grasses, very occasional hollow-bearing trees present as isolated paddock trees and relatively little woody debris. Canopy species were observed regenerating in these areas around paddock trees and adjoining patches of better condition vegetation. There is frequently high exotic plant cover mainly consisting of woody weeds such as African Olive or Lantana (*Lantana camara*) in the mid storey or exotic perennial grasses such as African Love Grass (*Eragrostis curvula)*.
- Moderate/good - poor condition Grey Box - Forest Red Gum grassy woodland on flats (HN528) (around 25 hectares out of around 78 hectares of poorer quality EPBC Act Cumberland Plain in the proposed offset areas). This comprises immature regrowth, immature planted vegetation or derived native grassland or scrub at the Ropes and South Creek and Western Sydney Parklands biobanks. Vegetation zones at these biobanks have relatively similar characteristics comprising partially cleared grazing country or open space on lower slopes and flats near to major drainage lines. These vegetation zones feature minimal over storey cover, moderate scores for native species richness, moderate to high cover of native mid storey, shrubs and/or grasses, very occasional hollow-bearing trees as isolated paddock trees and relatively little woody debris. Canopy species were observed regenerating in these areas, around paddock trees and adjoining patches of better condition vegetation. There is frequently high exotic plant cover mainly consisting of perennial grasses such as Kikuyu, African Love Grass and herbs in the under storey or woody weeds such as Privet and Lantana in the mid storey.

A more detailed description of site condition at each of the offset sites is provided in Appendix A.

Site context was scored as 3/10, reflecting the position of each of the local occurrences of the community in highly fragmented, rural landscapes or narrow bushland remnants surrounded by suburban development as described above for the EPBC Act Cumberland Plain Woodland at the same offset sites. The poorer quality patches of Cumberland Plain Woodland at the proposed offset sites actually comprise gaps in over storey vegetation and habitat in this context and make a minor contribution to the viability of the community.

Based on the inputs described above 'offset calculator – start area and quality – quality' (i.e. the current quality of the community in the proposed offset area) was scored as 3/10 overall.

The EPBC Act Cumberland Plain Woodland in the proposed offset areas could be managed and improved to the same condition as the community at the airport site in the medium to long term, through the intensive treatment of weed infestations and exclusion of grazing to permit regeneration of over storey vegetation. The 'time until ecological benefit' (i.e. the time period required to achieve the probable increase in site quality score and/or decline in site quality without management) was set as 20 years. Twenty years is the expected time it takes to establish a biobank, complete primary weed control and other management activities, achieve natural regeneration and for regenerating *Eucalyptus* to mature into over storey vegetation.

The proposed management actions and the likely benefits to the community are described in greater detail in Section 4.5.2. The aims of this management would be to achieve restoration of vegetation that comprises EPBC Act Cumberland Plain Woodland, specifically vegetation with >10 per cent canopy cover and >50 per cent native groundcover in accordance with the condition criteria specified in the conservation and listing advice for the community (TSSC 2008, DEWHA 2010).

The 'offset calculator - future quality with offset' component (i.e. the likely increase in site condition if the site is managed as a biodiversity offset) was scored as 6/10 reflecting a substantial improvement in the condition of the community through exclusion of grazing and unauthorised access, removal of rubbish, treatment of erosion, treatment of weed infestations and facilitated natural regeneration. After 20 years the severe infestations of woody weeds through the mid storey in much of the proposed offset area would be substantially controlled. Canopy species would have regenerated in areas of derived native grassland or scrub and a natural vegetation structure with >10 per cent canopy cover would be restored. Twenty years is likely to be sufficient to achieve natural regeneration over broad areas and for regenerating *Eucalyptus* to mature into over storey vegetation.

Monitoring of regeneration of poorer condition Cumberland Plain Woodland without a canopy at Mount Annan revealed:

- recovery of mid-storey plants (mainly Native Blackthorn) after 5-7 years in areas where they had been suppressed by grazing;
- significant declines in exotic groundcover after 15 years; and
- regeneration of canopy species and growth up to 8 metres after 17 years in areas of adequate water supply (Royal Botanic Gardens & Domain Trust undated). The Commonwealth listing advice notes that the canopy in regrowth stands of EPBC Act Cumberland Plain Woodland may be shorter than 10 metres tall (TSSC 2008).

The management of poorer quality Cumberland Plain Woodland in offset areas would also connect fragmented patches of vegetation and substantially improve the 'site context' component of the site quality score.

The 'offset calculator - future quality with offset' of 6/10 is the same site quality score as the airport site, as is required by the offset policy (DSEWPaC 2013). The proposed offset areas would not be of the same quality as the current condition of the airport site with regards to all condition attributes after 20 years. For instance, there would still be fewer hollow-bearing trees. However the offset areas would be in better condition with respect to some attributes such as native vegetation cover and especially the extent of weed infestation. For these reasons, an overall site quality of at least 6/10 could be achieved.

The 'offset calculator - future quality without offset' component for EPBC Act Cumberland Plain Woodland in the proposed offset areas (i.e. the likely decline in site condition if the site was not managed as a biodiversity offset) was scored as 2/10 reflecting a decline in the condition and possibly also extent of the community in the offset areas through an additional 20 years of impacts arising from grazing, weed infestation, erosion, human activities and other threats.

The proposed offset area would be managed in perpetuity and additional gains in site quality would be achieved over the longer term through bush regeneration activities, continued development of species richness and vegetation structure and development of habitat resources such as woody debris and hollow-bearing trees.

These values have been entered in the offset assessment guide calculations that are presented in Section 5.4.

5.2.3 Grey-headed Flying-fox

A Grey-headed Flying-fox roost camp has been recorded in the Ropes Creek riparian corridor less than 500 metres to the south of the Durham biobank (PB 2013). The species would be likely to occur at each of the proposed offset sites (noting that the ecological survey effort conducted at these sites to date has focussed on vegetation and habitat resources and has not included nocturnal fauna surveys).

The Department's instructions for the offset assessment guide state that the contribution of the three habitat attributes 'site condition', 'site context' and 'species stocking rate' to habitat quality must be weighted according to the ecology of the relevant species or community (DSEWPaC 2012b). The weighting of these three attributes for the Grey-headed Flying-fox population at the proposed offset sites was scored the same as for the airport site: site condition – 40 per cent; site context – 40 per cent; species stocking rate – 20 per cent.

Each characteristic was then scored based on the results of the BioBanking assessments for each of the offset sites (see Appendix A).

Site condition was scored as 8/10 based on the characteristics outlined below.

- The health and condition of the vegetation zones that comprise Grey-headed Flying-fox habitat based on BioBanking plot/transects and other field survey data. The habitat in the proposed offset areas is Cumberland Plain Woodland and River Flat Eucalypt Forest which is in moderate condition comprising remnant or regrowth native vegetation with near-intact over storey. .
- The presence of Forest Red Gum and Grey Box as dominant canopy species within Cumberland Plain Woodland and River Flat Eucalypt Forest in the proposed offset areas. As described above, these two tree species are recognised as 'significant species' in the blossom diet of the Grey-headed Flying-fox, are productive during food bottlenecks (Eby and Law 2008) and qualify as habitat critical to the survival of the species, as defined in the draft recovery plan (DECCW 2009)(GHD 2015a).

Site context was scored as 7/10 based on the characteristics outlined below.

- There are no camps located at the proposed offset sites, although there are multiple roost camps within 20 kilometres of each site and so they are appropriately located to provide foraging resources for individuals from those camps. A Grey-headed Flying-fox roost camp has been recorded in the Ropes Creek riparian corridor less than 500 metres to the south of the Durham biobank (PB 2013). Mother flying-foxes were recorded suckling young at this roost camp (PB 2013).
- Habitat at many of the proposed offset sites is in highly fragmented, rural landscapes or narrow bushland remnants surrounded by suburban development, as described above for the Cumberland Plain Woodland at the same offset sites.

Species stocking rate was scored as 7/10 comprising an area of productive foraging habitat within the broad range of this highly mobile species but which includes foraging and shelter habitat in the immediate vicinity of a roost camp at the Durham biobank.

Based on the inputs described above, the 'offset calculator – start area and quality – quality' (i.e. the current quality of the habitat in the proposed offset area) component was scored as 7/10 overall. This is a higher site quality score than the airport site, reflecting the fact that the majority of the habitat in the proposed offset area is of a similar quality to the airport site but that it also includes habitat in the immediate vicinity of a roost camp.

The Grey-headed Flying-fox habitat in the proposed offset areas would be managed to improve the health and productivity of food tree species and to reduce threats. The 'time until ecological benefit'

(i.e. the time period required to achieve the probable increase in site quality score and/or decline in site quality without management) was set as ten years. Ten years is the expected time it takes to establish a biobank, complete primary activities such as fencing and erosion control, complete the initial more intensive weed control activities and achieve natural regeneration. The proposed management actions and the likely benefits to Grey-headed Flying-fox habitat are described in greater detail in Section 4.5.2.

The 'offset calculator - future quality without offset' component for Grey-headed Flying-fox habitat in the proposed offset areas (i.e. the likely decline in site condition if the sites were not managed as biodiversity offsets) was scored as 6/10 reflecting a decline in the condition and possibly also extent of habitat in the offset areas through an additional ten years of impacts arising from grazing, weed infestation, human activities and other threats.

The 'offset calculator - future quality with offset' component (i.e. the likely increase in site condition if the site is managed as a biodiversity offset) was scored as 8/10 reflecting an improvement in the quality of habitat through exclusion of grazing and unauthorised access, treatment of weed infestations, regeneration and maturation of food tree species and development of habitat resources. After ten years the severe infestations of woody weeds through the mid storey in much of the proposed offset area would be substantially controlled and a natural vegetation structure and composition would be restored. This is likely to increase the health and productivity of food tree species. The management of additional poorer quality Cumberland Plain Woodland in offset areas (see Section 5.2.2) would improve the 'site context' component of the site quality score by increasing the extent of potential habitat, removing threats associated with adjoining areas of exotic vegetation and connecting fragmented remnants.

The proposed offset area would be managed in perpetuity and additional gains in site quality would be achieved over the longer term through continued development of vegetation structure and habitat resources and maturation of poorer quality Cumberland Plain Woodland to the extent that it would also comprise Grey-headed Flying-fox habitat.

These values have been entered in the offset assessment guide calculations that are presented in Section 5.4.

5.3 Alternative environmental contributions

There is a variety of alternative conservation mechanisms to BioBanking, including Voluntary Conservation Agreements or dedication of land to the National Parks estate. These alternative options may be more practical under certain circumstances such as if the Commonwealth, or another body has a specific parcel of land available for this purpose. Consultation with these agencies and bodies such as the Western Sydney Parklands Trust would be completed throughout the environmental assessment of the proposed airport and may identify more suitable options.

As described above the offset policy requires that a minimum of 90 per cent of the proposed airport's impacts must be directly offset and the remainder may be met by alternative contributions such as a financial contribution to research or conservation. The intent of the offset package is to secure 100 per cent of the offset requirement as direct offsets. Alternative contributions would be explored if there is a shortfall or if an appropriate contribution is identified by the Department or otherwise revealed by the environmental assessment and approvals process.

5.4 Preliminary offset assessment guide calculations

It is intended that the offset package would include the conservation and management of the proposed offset areas listed in Table 10 and based on the extent and quality of habitat for the affected MNES described in Section 5.2.

Preliminary offset assessment guide calculations were performed for the affected threatened biota based on the following:

- removal of approximately 88.9 hectares of EPBC Act Cumberland Plain Woodland with a site quality score of 6/10 (as described in Section 2.2.1);
- removal of approximately 120.4 hectares of habitat for the Grey-headed Flying-fox with a site quality score of 7/10 (as described in Section 2.2.2); and
- the conservation and management of offset sites to achieve increased site quality, containing:
  - EPBC Act Cumberland Plain Woodland (as described in Section 5.2.1);
  - poorer quality Cumberland Plain Woodland (as described in Section 5.2.2); and
  - Grey-headed Flying-fox habitat (as described in Section 5.2.3).

The outcome of these preliminary offset assessment guide calculations is that:

- the proposed offset areas containing around 180 hectares of EPBC Act Cumberland Plain Woodland would offset 59 per cent of the proposed airport's impacts on the ecological community;
- the proposed offset areas containing around 79 hectares of poorer condition Cumberland Plain Woodland would offset around 15 per cent of the proposed airport's impacts on the ecological community, resulting in a total offset contribution of 74 per cent of the proposed airport's impacts.
- The proposed offset areas containing up to 401 hectares of habitat for the Grey-headed Flying-fox would offset around 136 per cent of the proposed airport's impacts on this vulnerable species.

Based on these preliminary calculations, the proposed offset sites could not meet all of the proposed airport's EPBC Act offsetting requirements as direct offsets. Additional offset sites containing Cumberland Plain Woodland will be identified throughout the environmental assessment and approval process for the proposed airport and will be included in the final offset package.

The data that were entered in the preliminary offset assessment guide calculations are summarised in Table 12, Table 13 and Table 14 along with the justification for the attribute values that were entered and the estimated percentage of the direct offset requirement for each MNES that would be met by this Preliminary EPBC Act biodiversity offset proposal.

Table 12 Attribute values entered in the preliminary offset assessment guide calculations for EPBC Act Cumberland Plain Woodland

Offset assessment guide attribute	Value	Justification
Impact Calculator - Quantum of impact - Area	88.9 hectares	A direct reduction in extent of an occurrence of EPBC Act Cumberland Plain Woodland as documented in the Biodiversity Assessment (GHD 2015a) and Section 2.2.1 above.
Impact Calculator - Quantum of impact – Quality	6/10	Removal of moderate quality patches of the community as documented in the Biodiversity Assessment (GHD 2015a) and Section 2.2.1 above.
Offset calculator – Time horizon – Risk related time horizon	20 years	The offset sites would be protected and managed in perpetuity under a BioBanking agreement. Twenty years is the maximum timeframe for averting loss in the guide.
Offset calculator – Time horizon – Time until ecological benefit	10 years	The offset sites contain EPBC Act Cumberland Plain Woodland that would be managed through measures such as exclusion of stock, weed control and treatment of pest fauna. Ecological benefits in moderate condition vegetation can be achieved in the short to medium term. A tangible increase in site quality score with management or decrease because of ongoing threats would be expected after 10 years.
Offset calculator - Future area and quality without offset – Risk of loss without offset	15 per cent	The offset sites are located in partially cleared and developed parcels of land in western Sydney. The majority of the offset area is agricultural land that is zoned RU2 Rural Landscape. This zoning enables a range of industries and developments to occur while preserving the rural nature of a landscape. Should the site not be secured under a BioBanking agreement the impacts of existing agricultural use would continue and/or the land would be used for another purpose or development as long as it can be shown the rural nature of the site can be maintained. The locality surrounding the offset sites is moderately populated and is subject to potential impacts from housing development, agriculture and infrastructure construction. Western Sydney is, in general, experiencing some of the greatest development pressure and especially demand for housing, of any region in Australia. Under this scenario a risk of loss without offset of 15 per cent was considered appropriate.
Offset calculator - Future area and quality with offset – Risk of loss with offset	1 per cent	The offset sites would be protected and managed in perpetuity under a BioBanking agreement. This is the strongest conservation mechanism available on privately owned land in NSW. DSEWPaC (2013) guidance and recent determinations by the Department suggest that one per cent is a reasonable residual risk of loss for land protected under a BioBanking agreement.

Offset assessment guide attribute	Value	Justification
Confidence in result – averted loss of offset	95 per cent	DSEWPaC (2013) guidance and recent determinations by the Department suggest that 95% is a reasonable estimate of the confidence in the strength and effectiveness of a BioBanking agreement.
Offset calculator – Start area and quality – Area	180.3 hectares	There are 180.3 hectares of EPBC Act Cumberland Plain Woodland in the proposed offset areas (see Table 10).
Offset calculator – Start area and quality – Start quality	5/10	The proposed offset areas contain EPBC Act Cumberland Plain Woodland in moderate condition as described in Section 5.2.1.
Offset calculator - Future area and quality without offset – Future quality without offset (1-10)	4/10	EPBC Act Cumberland Plain Woodland would continue to deteriorate through impacts from grazing, weed infestation etc. in the proposed offset areas if they were not set aside for conservation as described in Section 5.2.1.
Offset calculator - Future area and quality with offset – Future quality with offset (1-10)	8/10	EPBC Act Cumberland Plain Woodland at the offset sites would be managed as described in Section 5.2.1 and would improve in quality and would exceed the condition of habitat at the airport site. The improvement in site quality of poorer condition Cumberland Plain Woodland would contribute to this increase in site quality by connecting remnant patches of EPBC Act Cumberland Plain Woodland. The DSEWPaC (2012a) offset policy requires that an offset site must reach the quality of vegetation in the impact footprint as a minimum.
Confidence in result – change in quality	85 per cent	DSEWPaC (2013) guidance and recent determinations by the Department suggest that 85% is a reasonable estimate of the effectiveness of standard environmental management and bush regeneration techniques.
Percentage of impact offset	**59.14 per cent**	

Table 13 Attribute values entered in the preliminary Offset assessment guide calculations for poorer quality Cumberland Plain Woodland

Offset assessment guide attribute	Value	Justification
Impact Calculator - Quantum of impact - Area	88.9 hectares	A direct reduction in extent of an occurrence of EPBC Act Cumberland Plain Woodland as documented in the Biodiversity Assessment (GHD 2015a) and Section 2.2.1 above.
Impact Calculator - Quantum of impact – Quality	6/10	Removal of moderate quality patches of the community as documented in the Biodiversity Assessment (GHD 2015a) and Section 2.2.1 above.
Offset calculator – Time horizon – Risk related time horizon	20 years	The offset sites would be protected and managed in perpetuity under a BioBanking agreement. Twenty years is the maximum timeframe for averting loss in the guide.

Offset assessment guide attribute	Value	Justification
Offset calculator – Time horizon – Time until ecological benefit	20 years	The offset sites contain poorer quality Cumberland Plain Woodland comprising derived native grassland and scrub. This vegetation would be managed through measures such as exclusion of stock, weed control and facilitated natural regeneration. Ecological benefits in poorer condition vegetation without a canopy can be achieved in the medium term. An increase in site quality score with management that is sufficient to achieve the restoration of the EPBC Act listed community would be expected after 20 years. Further justification for this time period is provided in 5.2.2.
Offset calculator - Future area and quality without offset – Risk of loss without offset	15 per cent	The offset sites are located in partially cleared and developed parcels of land in western Sydney. The majority of the offset area is agricultural land that is zoned RU2 Rural Landscape. This zoning enables a range of industries and developments to occur while preserving the rural nature of a landscape. Should the site not be secured under a BioBanking agreement the impacts of existing agricultural use would continue and/or the land would be used for another purpose or development as long as it can be shown the rural nature of the site can be maintained. The locality surrounding the offset sites is moderately populated and is subject to potential impacts from housing development, agriculture and infrastructure construction. Western Sydney is, in general, experiencing some of the greatest development pressure and especially demand for housing, of any region in Australia. Under this scenario a risk of loss without offset of 15% was considered appropriate.
Offset calculator - Future area and quality with offset – Risk of loss with offset	1 per cent	The offset sites would be protected and managed in perpetuity under a BioBanking agreement. This is the strongest conservation mechanism available on privately owned land in NSW. DSEWPaC (2013) guidance and recent determinations by the Department suggest that one per cent is a reasonable residual risk of loss for land protected under a BioBanking agreement.
Confidence in result – averted loss of offset	95 per cent	DSEWPaC (2013) guidance and recent determinations by the Department suggest that 95% is a reasonable estimate of the confidence in the strength and effectiveness of a BioBanking agreement.
Offset calculator – Start area and quality – Area	88 hectares	There are 88 hectares of poorer quality Cumberland Plain Woodland in the proposed offset areas (see Table 10).
Offset calculator – Start area and quality – Start quality	3/10	The proposed offset areas contain poorer quality Act Cumberland Plain Woodland that comprises derived native grassland or scrub as described in Section 5.2.2.

Offset assessment guide attribute	Value	Justification
Offset calculator - Future area and quality without offset – Future quality without offset (1-10)	2/10	Poorer quality Cumberland Plain Woodland would continue to deteriorate through impacts from grazing, weed infestation etc. in the proposed offset areas if they were not set aside for conservation as described in Section 5.2.2.
Offset calculator - Future area and quality with offset – Future quality with offset (1-10)	6/10	EPBC Act Cumberland Plain Woodland the offset sites would be managed as described in Section 5.2.2 and would improve in quality and would achieve the quality of habitat at the airport site and the restoration of vegetation that comprises EPBC Act Cumberland Plain Woodland. Further justification for increase in site quality score after 20 years is provided in 5.2.2.The improvement in site quality of EPBC Act Cumberland Plain Woodland at the offset sites would contribute to the site context component of this increase in site quality by improving the condition of connected vegetation. The DSEWPaC (2012a) offset policy requires that an offset site must reach the quality of vegetation in the impact footprint as a minimum.
Confidence in result – change in quality	85 per cent	DSEWPaC (2013) guidance and recent determinations by the Department suggest that 85 per cent is a reasonable estimate of the effectiveness of standard environmental management and bush regeneration techniques.
Percentage of impact offset	**16.32 per cent**	

Table 14 Attribute values entered in the preliminary Offset assessment guide calculations for the Grey-headed Flying-fox

Offset assessment guide attribute	Value	Justification
Impact Calculator - Quantum of impact - Area	120 hectares	Direct removal of 120.4 hectares of Grey-headed Flying-fox habitat as documented in the Biodiversity Assessment (GHD 2015a) and Section 2.2.2 above.
Impact Calculator - Quantum of impact – Quality	6/10	Removal of moderate quality Grey-headed Flying-fox habitat as documented in the Biodiversity Assessment (GHD 2015a) and Section 2.2.2 above.
Offset calculator – Time horizon – Risk related time horizon	20 years	The offset sites would be protected and managed in perpetuity under a BioBanking agreement. Twenty years is the maximum timeframe for averting loss in the guide.
Offset calculator – Time horizon – Time until ecological benefit	10 years	The offset sites contain occupied Grey-headed Flying-fox habitat that would be managed through measures such as exclusion of stock, weed control and treatment of pest fauna. Ecological benefits in moderate condition habitat can be achieved in the short to medium term. A tangible increase in site quality score with management or decrease because of ongoing threats would be expected after 10 years.

Offset assessment guide attribute	Value	Justification
Offset calculator - Future area and quality without offset – Risk of loss without offset	15 per cent	The offset sites are located in partially cleared and developed parcels of land in western Sydney. The majority of the offset area is agricultural land that is zoned RU2 Rural Landscape. This zoning enables a range of industries and developments to occur while preserving the rural nature of a landscape. Should the site not be secured under a BioBanking agreement the impacts of existing agricultural use would continue and/or the land would be used for another purpose or development as long as it can be shown the rural nature of the site can be maintained. The locality surrounding the offset sites is moderately populated and is subject to potential impacts from housing development, agriculture and infrastructure construction. Western Sydney is, in general, experiencing some of the greatest development pressure and especially demand for housing, of any region in Australia. Under this scenario a risk of loss without offset of 15% was considered appropriate.
Offset calculator - Future area and quality with offset – Risk of loss with offset	1 per cent	The offset sites would be protected and managed in perpetuity under a BioBanking agreement. This is the strongest conservation mechanism available on privately owned land in NSW. DSEWPaC (2013) guidance and recent determinations by the Department suggest that one per cent is a reasonable residual risk of loss for land protected under a BioBanking agreement.
Confidence in result – averted loss of offset	95 per cent	DSEWPaC (2013) guidance and recent determinations by the Department suggest that 95% is a reasonable estimate of the confidence in the strength and effectiveness of a BioBanking agreement.
Offset calculator – Start area and quality – Area	401 hectares	There are up to 401 hectares of Grey-headed Flying-fox habitat in the proposed offset areas (see Table 10).
Offset calculator – Start area and quality – Start quality	7/10	The proposed offset areas contain Grey-headed Flying-fox habitat in good condition as described in Section 5.2.3.
Offset calculator - Future area and quality without offset – Future quality without offset (1-10)	6/10	Grey-headed Flying-fox habitat would deteriorate through impacts from grazing, weed infestation etc. in the proposed offset areas if they were not set aside for conservation as described in Section 5.2.3.
Offset calculator - Future area and quality with offset – Future quality with offset (1-10)	8/10	Grey-headed Flying-fox habitat at the offset sites would be managed as described in Section 5.2.3 and would improve in quality and exceed the condition of habitat at the airport site. The improvement in site quality of poorer condition Cumberland Plain Woodland would contribute to this increase in site quality by connecting remnant patches and eventually also providing foraging resources. The DSEWPaC (2012a) offset policy requires that an offset site must reach the quality of vegetation in the impact footprint as a minimum.

Offset assessment guide attribute	Value	Justification
Confidence in result – change in quality	85 per cent	DSEWPaC (2013) guidance and recent determinations by the Department suggest that 85 per cent is a reasonable estimate of the effectiveness of standard environmental management and bush regeneration techniques.
Percentage of impact offset	**135.82 per cent**	

6. Delivery of Offsets

6.1 Purchase and retirement of biodiversity credits

Biodiversity credits would be purchased to secure the proposed offset areas for EPBC Act-listed biota. Subject to confirmation of the overall offset requirement for the proposed airport, additional biodiversity credits would be purchased to offset the proposal's impacts on the environment.

The EPBC Act offset policy and the BioBanking assessment methodology include different rules that govern the biodiversity offsets that can be delivered for a development's impacts. The EPBC Act offset policy requires 'like for like' biodiversity offsets and the offset site must be able to reach the same site quality score as the development site. Therefore only EPBC Act Cumberland Plain Woodland, poorer quality Cumberland Plain Woodland that could reach this standard and Grey-headed Flying Fox habitat have been included in the proposed offset areas (see Section 5.2). The suite of biodiversity credits that are associated with the proposed offset areas would be purchased and retired in order to secure the offsets for EPBC Act-listed biota.

The BioBanking assessment methodology includes greater flexibility with respect to some criteria. This flexibility allows trading of ecosystem credits for closely related vegetation types if they are in the same vegetation class and are at least as extensively cleared (i.e. have the same or greater conservation significance). BioBanking also allows trading of ecosystem credits associated with low condition vegetation at a biobank site, including vegetation that could not meet the standard of EPBC Act Cumberland Plain Woodland. This flexibility should be considered along with the fact that BioBanking requires the calculation of biodiversity offsets for poorer condition vegetation. A substantial area of poor condition vegetation at the airport site has contributed to the amount of offset required for residual significant impacts on the environment. Species credits should be traded on a like for like basis.

The number and type of biodiversity credits that would be required to offset the proposed airport's impacts on the environment are specified in the BioBanking credit report (see Appendix B). The suite of matching biodiversity credits that are available at the proposed offset sites to offset impacts on the environment are summarised in Table 15. Many of the offset sites included in Table 15 are proposed biobanks that have not yet been subject to detailed BioBanking credit calculations and so a rate of seven credits per hectare has been used to estimate the number of biodiversity credits available.

Table 15 includes a comparison of the credits available at the proposed offset sites and the ecosystem credit requirement to offset the proposed airport's impacts on the natural environment as estimated in Section 3. There would be sufficient ecosystem credits available to offset impacts on Grey Box - Forest Red Gum grassy woodland on shale (HN529) and Forest Red Gum - Rough-barked Apple grassy woodland (HN526). The 'Credit balance' in Table 15 shows that additional ecosystem credits would be required to offset impacts on other vegetation types and associated predicted threatened species. The credit shortfall for Grey Box - Forest Red Gum grassy woodland on flats (HN528) can be partially met by trading surplus HN526 credits, which is permitted by the BioBanking credit trading rules.

The credit shortfall for HN528 could also be partially met by up to 1365 ecosystem credits associated with HN529 and Grey Box - Forest Red Gum shrubby woodland (HN524). These are not matching credits according to the BioBanking credit trading rules but are associated with very closely related ecological communities with similarly high conservation significance. Both vegetation types are associated with EPBC Act-listed critically endangered ecological communities and HN528 and HN529 are both consistent with Cumberland Plain Woodland.

Table 15 Ecosystem credits for impacts on the natural environment

Potential Offset Site	Total area (hectares)	Available HN528 credits	Available HN529 credits	Available HN526 credits	Available HN512 credits	Available HN630 credits	Available HN524 credits
Williamswood biobank	104.5	0	694	280	0	0	38
Durham biobank	42.7	31	0	246	0	0	0
Mamre biobank	98.1	0	0	680	0	7	0
Luddenham biobank	40.0	34	0	246	0	0	0
Roper biobank	13.3	48	0	20	25	0	0
Caddens biobank	33.3	47	0	181	0	5	0
Dunheved biobank	65.0	93	0	362	0	0	0
Forrester biobank	9.2	0	0	56	0	0	0
Stage 1 Montpelier biobank	76.2	119	442	0	0	0	153
Stage 2 Montpelier biobank	79.5	0	363	0	0	0	118
Menangle Road biobank	57.1	0	454	36	0	0	29
Bruelle biobank	26.8	0	141	0	0	0	0
The Oaks	40.0	0	261	11	0	0	69
Western Sydney Parklands ID 120	19.4	120	0	61	0	0	0
Western Sydney Parklands ID 70	40.5	49	0	10	0	0	0
Total	**892.8**	**542**	**2355**	**2188**	**25**	**12**	**407**
Ecosystem credit requirement		**6763**	**1398**	**1657**	**181**	**700**	**0**
Credit balance		**-6221**	**957**	**531**	**-156**	**-688**	**407**
Total including trading of matching credits		**1074**[1]		**1657**			
Credit balance including trading of matching credits		**-5689**	**957**	**0**	**-156**	**-688**	**407**

Notes: 1) includes 531 HN526 credits which may be traded with HN528.

No species credits have been calculated at any of the existing or proposed biobank sites included in this offset package. Species credits may be generated once targeted surveys have been undertaken to confirm the presence of threatened species and the numbers of individuals of plants and area of habitat for fauna. Based on the assessments undertaken to date, the proposed offset sites contain known or potential habitat for each of the species credit-type threatened species affected by the proposed airport. Table 16 summarises the species credits required to offset the impacts of the proposed airport as calculated in Section 3.3.2, the equivalent area of fauna habitat or number of plants required to generate these credits at an offset site and a summary of the potential habitat available at offset sites.

Sufficient *Pultenaea parviflora* has already been recorded at the Dunheved biobank site to generate the required number of species credits (GHD 2014a). Based on the site surveys and habitat assessments undertaken it is likely that supplementary surveys would confirm the presence of the fauna species at these offset sites and allow the calculation of species credits. *Marsdenia viridiflora* subsp. *viridiflora* is very sparsely and sporadically distributed within its range and so it is likely to be difficult to locate a population of the required size at offset sites. The proposed translocation program will be important in avoiding or minimising impacts on this endangered population (GHD 2015a) and should be coordinated with the offset package.

Table 16 Species credits potentially available at offset sites

Common name	Scientific name	Species credits required	Individuals / area required in offset site	Individuals / area available in offset site(s
Black Bittern	*Ixobrychus flavicollis*	719	101	Up to around 314 hectares of potential habitat in Forest Red Gum - Rough-barked Apple grassy woodland (HN526) and Coastal freshwater wetland (HN630) at proposed off set sites.
Cumberland Plain Land Snail	*Meridolum corneovirens*	1568	221	Up to around 414 hectares of potential habitat in Grey Box - Forest Red Gum grassy woodland on shale (HN529) and Grey Box - Forest Red Gum grassy woodland on plains (HN528). The species has been recorded at the Forrester and Caddens biobank sites.
Marsdenia viridiflora subsp. *viridiflora* in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas	*Marsdenia viridiflora* subsp. *viridiflora* - endangered population	3720	524	Up to around 476 hectares of potential habitat in Grey Box - Forest Red Gum grassy woodland on shale (HN529), Grey Box - Forest Red Gum grassy woodland on plains (HN528) and Grey Box - Forest Red Gum shrubby woodland (HN524).
Pultenaea parviflora	*Pultenaea parviflora*	60	8	100 individuals recorded at the Dunheved biobank site.
Southern Myotis	*Myotis macropus*	656	92	Up to around 313 hectares of potential habitat in Forest Red Gum - Rough-barked Apple grassy woodland (HN526) at proposed off set sites. The species has been recorded at the Mamre biobank site.

6.2 Identification of additional offsets

Based on the preliminary offset assessment guide calculations and BioBanking calculations, the proposed offset sites could not meet all of the proposed airport's EPBC Act offsetting requirements as direct offsets. Additional offset sites containing Cumberland Plain Woodland and other additional offset contributions will be identified throughout the environmental assessment process for the proposed airport and will be included in the final offset package. Any additional offset sites would be identified according to the approach specified in Section 4.2 and the following specific criteria:

- areas that are linked to biodiversity credits that are available for sale at established biobanks, that would be available for sale at proposed biobanks or are in parcels of land that area available for sale and suitable for BioBanking;
- presence of EPBC Act Cumberland Plain Woodland;
- presence of habitat for the Grey-headed Flying-fox; and
- proximity to the airport site, in order to more directly benefit the populations and communities affected by the proposed airport.

These criteria will ensure that offset sites are an appropriate 'like for like' match for the proposed airport's impacts and meet the other requirements of the EPBC Act offset policy.

A similar approach would be taken in the event that any credits which have been identified for purchase from biobank sites identified in this EIS are sold to third parties before they can be secured as offsets for the proposed airport.

A number of potential offset sites have already been considered in the preparation of this offset package but could not be formally included at this stage because insufficient information was available about their biodiversity values and/or future ownership and management. These sites include:

- additional land in the Western Sydney Parklands that has not yet been set aside as a biobank; and
- the "Hardwicke" property, which is a 200 hectare site located in the Wollondilly LGA. There would be four separate biobank agreements across the site, each of which may contribute offsets for the proposal as follows:

  - Biobank 1 (56 hectares), issue of the BioBanking agreement is imminent and up to 87 HN529 ecosystem credits would be available to offset impacts on Cumberland Plain Woodland.

  - Biobank 2 (57 hectares), BioBanking assessment has been completed, OEH are undertaking a site audit in late 2015 and up to 550 HN529 ecosystem credits would potentially be available to offset impacts on Cumberland Plain Woodland.

  - Biobanks 3 and 4 (87 hectares), BioBanking assessment has not yet commenced but around 1000-1300 HN529 and HN528 ecosystem credits would potentially be available to offset impacts on Cumberland Plain Woodland.

Additional survey and assessment would be required to confirm that these potential offset sites would be suitable for inclusion in the offset package for the proposed airport. A particular focus would be to determine if they contain EPBC Act-listed Cumberland Plain Woodland, poorer quality Cumberland Plain Woodland and/or habitat suitable for offsetting impacts on other features of the natural environment.

6.3 Cost of delivery of offsets

Attachment 4 to the EIS guidelines for the proposed airport specifies that the offset package must include an assessment of the overall cost of the proposed offsets package; including costs associated with acquisition and transfer of land, implementation of all related management actions and monitoring, reporting and auditing of offset performance. The offset package is expected to be delivered using BioBanking and so each of these costs are included in the price of the biodiversity credits that would be purchased and retired to offset the impacts of the proposed airport.

BioBanking includes rules for determining the price of biodiversity credits. Notably these rules specify that the biodiversity credit sale price must be at least equal to the 'Total Fund Deposit' as calculated with the Biodiversity Credits Pricing Spreadsheet (also known as the 'Part A costs'). The Total Fund Deposit proportion of the total credit sale price is held in the BioBanking Trust Fund administered by the NSW Government to cover the costs of managing the biobank site in perpetuity. Payments are made from the Trust Fund to the biobank site owner annually to cover the cost of management actions. The BioBanking rules ensure that the cost of delivering the offset package will include appropriate funds to cover the implementation of all related management actions and monitoring, reporting and auditing of offset performance in perpetuity in accordance with the EIS guidelines. The remainder of the biodiversity credit price is set in negotiation between the landowner and the credit purchaser and reflects the original cost of the land, opportunity costs and a profit margin for the landowner.

As stated in Section 6.1 above, the precise number and type of biodiversity credits that would be purchased and retired to offset the impacts of the proposed airport would not be confirmed until detailed BioBanking assessments have been conducted at each of the offset sites that will be included in the final offset package. The same assessment would also need to be applied for additional offset sites identified in accordance with Section 6.2. The quantum of offsets required in the offset package may change based on the final offset assessment guide calculations. Further, the total biodiversity credit sale price would only be confirmed once sale terms have been finalised with individual offset site owners. Therefore it is not possible to accurately calculate the cost of delivery of biodiversity offsets at this stage of the assessment and approval process for the airport.

It is possible to broadly estimate the cost of delivering the offset package based on the BioBanking credit calculations included in Section 6.1 and recent biodiversity credit sales for equivalent vegetation types and species in the Western Sydney region. Based on these estimates it would cost between $100,000,000 and $140,000,000 to deliver the biodiversity offset package for the Stage 1 development. As stated above, the cost would vary depending on the outcome of supplementary BioBanking assessments at offset sites and negotiations with landowners. The total cost of delivering direct offsets would be confirmed once the biodiversity offset package is finalised after approval of the proposed airport.

The total cost of delivering direct offsets would be used by DotE to calculate the cost of delivering up to 10% indirect offsets for the proposed airport (if required). The aim of the offset package is to meet 100% of the proposed airport's offset requirements as direct offsets, subject to the identification and assessment of suitable offset sites within the timeframe for delivery of offsets that would be nominated in the conditions of approval.

6.4 Finalisation of the offset package

The Minister for the Environment would advise the final quantum of biodiversity offsets required for the proposed airport based on the information presented in this offset package, technical review by DotE and consultation with DIRD. The requirement for biodiversity offsets would be provided as part of the process of obtaining the Minister's advice that the airport plan may be determined.

Additional information required to support EPBC Act offset calculations may include the requirement for additional site specific information such as proposed management, current risk of development and the security of title proposed for individual offset sites. These additional data would be entered in the offset assessment guide and the final calculations and details regarding data and assumptions underlying the results would be compiled and collectively comprise the EPBC Act offset package for the airport.

Additional information required to finalise offset calculations for impacts on the environment would include an approved BioBanking assessment and final credit calculations for each proposed biobank site. Unless alternative matching biodiversity credits become available on the open market this would include plot/transect surveys to accurately calculate ecosystem credits and targeted surveys to calculate species credits.

Based on the approach outlined in this offset package, the next steps involved in finalising the delivery of offsets for the proposed airport would be to:

- identify additional offset areas to address the shortfall in the offset areas for EPBC Act Cumberland Plain Woodland, biodiversity credits for impacts on the environment and/or any additional offset requirements required by the Minister for the Environment;
- compile any additional information required to finalise offset assessment guide and/or BioBanking credit calculations;
- agree on the number and type of biodiversity credits to be purchased to finalise the offset package;
- purchase the number and type of biodiversity credits required to finalise the offset package from the biobank site owners; and
- retire to the NSW OEH the biodiversity credits that are included in the offset package.

There are a variety of alternative conservation mechanisms to BioBanking, including Voluntary Conservation Agreements or dedication of land to the National Parks estate. These alternative options may be appropriate under certain circumstances such as if DotE, , NSW OEH or other body has a specific parcel of land available for this purpose. Consultation with these agencies and bodies such as the Western Sydney Parklands Trust would continue and may identify more effective options.

Any alternative options would be presented in accordance with the EPBC Act offset policy and would be supported by offset assessment guide calculations. Alternative options would need to meet the criteria specified in Section 4.2 to ensure that they are an appropriate ‘like for like’ match for the proposed airport’s impacts. As described above, in reviewing the EIS the Minister for the Environment is expected to specify the quantum of offsets required and the steps involved in their delivery.

6.5 Consistency with EPBC Act offset policy

The EIS guidleines for the proposed airport require an analysis of how the offset package meets the requirements of the EPBC Act Offsets Policy. Table 17 provides a summary of how this offset package meets each of the overarching principles included in the EPBC Act Offsets Policy that are applied in determining the suitability of offsets.

Table 17 Consistency with the EPBC Act offset principals

Offset principals (DSEWPaC 2012, box 1)	Western Sydney Airport offset package
Suitable offsets must:	
1. deliver an overall conservation outcome that improves or maintains the viability of the aspect of the environment that is protected by national environment law and affected by the proposed action	This offset package has been developed in accordance with biodiversity offset assessment methodologies that have been developed by Government Agencies in order to ensure that appropriate biodiversity offsets would improve or maintain the viability of the affected protected matters. The conservation outcomes that would be delivered by this offset package are based on: • an estimate of the quantum of biodiversity offsets required for affected threatened biota listed under the EPBC Act as calculated with the offset assessment guide; and • an estimate of the quantum of biodiversity offsets required for residual impacts on the environment as calculated using the BioBanking assessment methodology (BBAM) for a major project.
2. be built around direct offsets but may include other compensatory measures	The offset package is based on direct offsets for each of the protected matters affected by the proposal. Direct biodiversity offsets would be delivered through conservation of suitable offset sites. The offset sites will be secured by registration of a BioBanking agreement on title to the sites. This approach would require the purchase of the number and type of biodiversity credits that match: • the offset area which is required to offset the proposal's impacts on specific EPBC Act-listed biota and deliver appropriate direct offsets as calculated in accordance with the EPBC Act offsets policy. • the ecosystem and species credits which are required to offset the proposal's impacts on the environment (including NSW-listed biota) and deliver appropriate direct offsets as calculated using the BioBanking assessment methodology for a major project.
3. be in proportion to the level of statutory protection that applies to the protected matter	Offsets for impacts on EPBC Act-listed biota have been calculated using the offset assessment guide which includes International Union for Conservation of Nature data on the probability of annual extinction for different categories of threatened species as a multiplier in the offset calculations (DSEWPaC 2012). The higher the level of statutory protection and associated probability of annual extinction the greater the quantum of biodiversity offset required. Offsets for impacts on the environment have been calculated using the BBAM which includes a 'threatened species offset multiplier' that feeds into the biodiversity credit calculations. The level of statutory protection of threatened biota as well as the expected response of threatened biota to management actions at a biobank site determine the multiplier that applies to credit calculations.
4. be of a size and scale proportionate to the residual impacts on the protected matter	This offset package has been developed in accordance with biodiversity offset assessment methodologies that have been developed by Government Agencies in order to ensure that biodiversity offsets are of a size and scale proportionate to the residual impacts on the protected matter. The quantum of biodiversity offsets required for affected threatened biota listed under the EPBC Act has been calculated with the offset assessment guide, which includes factors for the: area and quality of the impact area; area and improvement in quality of the offset site; averted risk of loss of the offset site; the time it will take for conservation gains to be achieved; and risk of the offset not succeeding (DSEWPaC 2012). The quantum of biodiversity offsets required for residual impacts on the environment has been calculated using the BBAM, which includes factors for for the extent and condition of the impact area; landscape-scale impacts on habitat connectivity; extent and improvement in condition of the offset; and averted risk of loss of the offset (OEH 2014a).
5. effectively account for and manage	Offset sites will be secured by registration of a BioBanking agreement on title to

Offset principals (DSEWPaC 2012, box 1)	Western Sydney Airport offset package
the risks of the offset not succeeding	the sites. A BioBanking agreeement is the strongest conservation covenant available on private land in NSW and extinguishes all land uses other than conservation unless the BioBanking agreement is varied or terminated by the NSW Minister for the Environment to permit alternative uses. Certain mining rights may be granted over a biobank site, and certain development can be carried out by public authorities on a biobank site, but any impacts from these activities must be offset again as an addition to any offsetting activities required by a given project in its own right. A BioBanking agreement confers an obligation on the landowner to conserve and manage the biodiversity values of the biobank site in order to ensure that the offsets would improve or maintain the viability of the affected protected matters. The BioBanking Trust Fund ensures that sufficient funds are available to perform the required management actions in perpetuity. BioBanking requires preparation of an annual monitoring report to ensure compliance with the requirements of the agreement and the effectiveness of management actions. BioBanking also includes periodic inspections by OEH to ensure compliance and enforcement measures up to and including compulsory acquisition of the biobank by OEH. The security of titling and management and monitoring framework afforded by BioBanking effectively account for and substantially reduce the risks of the offset not succeeding.
6. be additional to what is already required, determined by law or planning regulations or agreed to under other schemes or programs (this does not preclude the recognition of state or territory offsets that may be suitable as offsets under the EPBC Act for the same action)	The biodiversity offsets presented in this offset package are the sole requirement of the EIS and are not the result of any other legal requirement that applies to the proposed airport. The offset areas and associated biodiversity credits included in this offset package are not linked to any other conservation covenant or set aside as an offset for another development. Some of the biobank sites included in this offset package are associated with biodiversity credits that have been used to offset the impacts of another development. These credits and associated areas of land at the biobank sites have been excluded from this offset package.
7. be efficient, effective, timely, transparent, scientifically robust and reasonable	As stated above, this offset package has been developed in accordance with biodiversity offset assessment methodologies that have been developed by Government Agencies in order to ensure that biodiversity offsets are efficient, effective, transparent, scientifically robust and reasonable. This offset package includes direct offsets for the majority of protected matters affected by the proposal at the time of public exhibition of the EIS. Direct biodiversity offsets would continue to be identified and secured according to the criteria and process outlined in this offset package. Direct offsets would be delivered prior to the impact occurring as far as is possible (subject to the availability of suitable 'like for like' offset sites). This approach is likely to ensure the timely delivery of offsets for the majority of the protected matters affected by the proposal.
8. have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced.	Offset sites will be secured by registration of a BioBanking agreement on title to the sites. A BioBanking agreement confers an obligation on the landowner to conserve and manage the biodiversity values of the biobank site in order to ensure that the offsets would improve or maintain the viability of the affected protected matters. BioBanking requires preparation of an annual monitoring report to ensure compliance with the requirements of the agreement and the effectiveness of management actions. BioBanking also includes periodic inspections by OEH to ensure compliance and enforcement measures up to and including compulsory acquisition of the biobank by OEH. These governance arrangements are transparent, in that they are specified in the BBAM and the individual BioBanking agreements which will be available on the the biodiversity credits and BioBanking agreements register (OEH 2015b).

7. Conclusions

The Biodiversity Assessment for the airport has concluded that biodiversity offsets would be required to compensate for significant residual impacts on Cumberland Plain Woodland, the Grey-headed Flying-fox and the environment in accordance with the EPBC Act offset policy (DSEWPaC 2012a). The offset policy requires offsets for significant impacts on threatened species and communities listed under the EPBC Act, calculated using the 'offset assessment guide' spreadsheet. Consultation with DotE has confirmed that BioBanking is their preferred approach for estimating offsets for the significant residual impacts on the environment. The proposed biodiversity offset package for the proposed airport has been prepared in accordance with the offset policy and will conserve habitat for the affected threatened biota, threatened species and communities listed under NSW legislation and other and other features of the environment in suitable offset sites.

The biodiversity offsets for the project would be secured by registration of a BioBanking agreement on the title of offset sites that would ensure they would be securely titled and managed for conservation as a biobank in perpetuity. The number and type of biodiversity credits would be purchased and retired from offset sites to match the proposed airport's impacts as calculated by the offset assessment guide. Additional biodiversity credits would be purchased to offset impacts on the natural environment. This would secure the conservation covenant over the area of land that is linked to the biodiversity credits and provide funds for management in perpetuity.

Suitable offset sites have been identified that contain Cumberland Plain Woodland and/or Grey-headed Flying-fox habitat and biodiversity credits appropriate to match the proposed airport's impacts on the natural environment. The potential offset sites include established biobank sites with suitable biodiversity credits for sale and proposed biobank sites that are at various stages of the assessment and approval process for obtaining a BioBanking agreement. Portions of four of these potential offset sites are located in Cumberland Plain Priority Conservation Lands identified in the recovery plan for Cumberland Plain Woodland (DECCW 2010, 2011).

Offset assessment guide calculations were performed for the affected threatened biota based on the following:

- removal of 88.9 hectares of Cumberland Plain Woodland;
- removal of 120.4 hectares of habitat for the Grey-headed Flying-fox;
- the conservation and management of proposed offset sites to achieve increased site quality, containing:
  - 180 hectares Cumberland Plain Woodland that is in moderate condition and comprises the EPBC Act-listed form of the community;
  - 79 hectares of poorer quality Cumberland Plain Woodland that would be actively managed so that it would reach the same site quality as the airport site and comprise a functioning occurrence of the EPBC Act-listed form of the community over the medium-term; and
  - Up to 401 hectares of Grey-headed Flying-fox habitat.

The outcome of these offset assessment guide calculations is that:

- the proposed offset areas containing around 180 hectares of EPBC Act Cumberland Plain Woodland would offset 59 per cent of the airport's impacts on the community;

- the proposed offset areas containing around 79 hectares of poorer condition Cumberland Plain Woodland would offset around 15 per cent of the proposed airport's impacts on the ecological community, resulting in a total offset contribution of 74 per cent of the proposed airport's impacts; and
- the proposed offset areas containing up to 401 hectares of habitat for the Grey-headed Flying-fox would offset around 136 per cent of the proposal's impacts on habitat for this vulnerable species.

Based on these preliminary calculations, the proposed offset sites could not meet all of the proposed airport's EPBC Act offsetting requirements as direct offsets. Additional offset sites containing Cumberland Plain Woodland will be identified throughout the environmental assessment process for the proposed airport and will be included in the final delivery of offsets.

BioBanking credit calculations using the assessment methodology for a major project in NSW have been used to estimate offsets for impacts on the environment, including species and communities listed under NSW legislation. The estimated offset requirement for impacts on the natural environment substantially overlaps with that required for EPBC Act-listed biota but involves a considerably greater quantum because of the inclusion of additional matters that are not protected under the EPBC Act. Notably, offsets would be required for poorer condition vegetation that does not comprise EPBC Act-listed Cumberland Plain Woodland.

DotE is expected to confirm the specific offset requirements for residual impacts arising from the proposed airport. Offset calculations would be finalised with additional site specific information such as proposed management, current risk of development and the security of title proposed for individual offset sites. These additional data would be entered in the offset assessment guide by specialists within DotE to confirm the quantum of offsets that would be delivered for threatened biota listed under the EPBC Act. The quantum of offsets required for impacts on the environment would be determined by DotE based on the Biobanking calculations included in this offset package.

This offset package satisfies the EIS guidelines for biodiversity offsets including: an estimate of the quantum of offsets that may be required for the significant residual impacts on Cumberland Plain Woodland, the Grey-headed Flying-fox and the environment that are likely to arise from the proposed airport; evidence that access is possible to offset sites that could substantially meet this offsetting requirement; and an approach to delivering the remaining offset requirement. When implemented the offset package would improve or maintain the viability of the protected matters that would be affected by the proposed airport.

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Appendices

Appendix A – Potential offset sites

Williamswood biobank

The ‘Williamswood biobank’ offset site is a biobank that has been subject to a detailed field survey and BioBanking assessment and has already been set aside for conservation under a BioBanking agreement. The description of the site presented below is based on the information presented in the BioBanking assessment report for the site (GHD 2014a).

The Williamswood biobank includes 104.4 hectares of land and is located at Mount Hunter within the Wollondilly Local Government Area (LGA). It falls within the Cumberland subregion of the Hawkesbury Nepean Catchment Management Authority (CMA), and within the Sydney Basin Bioregion. The biobank is currently zoned RU2 Rural Landscape under the *Wollondilly Local Environment Plan 2011* and was grazed by cattle prior to being set aside as a biobank.

There are three NSW vegetation types at the biobank. Each of these vegetation types have been cleared, grazed and subject to weed infestation to varying degrees with areas of Moderate/good-medium, Moderate/good – poor and Low condition vegetation. Vegetation types were split into broad condition classes yielding six vegetation zones. The distribution of vegetation zones at the biobank is closely tied to soil type, underlying geology and geomorphic position. The biobank site includes vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland, and Grey-headed Flying-fox habitat (specifically vegetation zones with native over storey cover greater than 10 per cent). There are also areas of poorer quality Cumberland Plain Woodland that comprises derived grassland or scrub which could be managed to improve in quality and become EPBC Act Cumberland Plain Woodland. These areas have minimal canopy cover and contain minimal foraging resources for the Grey-headed Flying Fox. Only vegetation zones in Moderate/good- medium condition comprise Grey-headed Flying-fox habitat. The extent of available habitat for the affected threatened biota has been further refined based on the number of biodiversity credits currently available for sale (see Table 18). Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment.

More exposed slopes and ridges on shale support Grey Box – Forest Red Gum grassy woodland (HN529). This vegetation zone comprises an occurrence of the EPBC Act listed form of Cumberland Plain Woodland.

Grey Box – Forest Red Gum grassy woodland grades into Moderate/good condition Forest Red Gum – Grey Box shrubby woodland (HN524) on sheltered slopes with a fine grained volcanic substrate, which is distinguished from adjoining grassy woodlands on shale by the presence of mesic small trees, a denser shrub layer and mesic understorey species. These vegetation types give way to Forest Red Gum – Rough-barked Apple grassy woodland (HN526) in riparian areas and adjoining alluvial flats.

There are moderate to severe infestations of noxious weeds, such as Lantana (*Lantana camara*), Blackberry (*Rubus fruticosus* spp. agg.) and especially African Olive (*Olea europea* subsp. *cuspidata*) at the site. These weeds are most prevalent on the cleared low lying areas and on more sheltered slopes.

Much of the site has been grazed and canopy vegetation has been extensively cleared or thinned historically. Mid storey vegetation has since re-established across the majority of the biobank though there are very few over storey species in areas of poor or low condition vegetation. There are mature hollow-bearing trees in moderate densities throughout areas of Moderate/good – medium condition vegetation at the biobank.

One threatened fauna species was recorded at the biobank site during field surveys: the Little Eagle (*Hieraaetus morphnoides*) which is listed as a vulnerable species under the TSC Act. One threatened plant has been recorded at the site: Spiked Rice-flower (*Pimelea spicata)* which is listed as an endangered species under the EPBC Act and the TSC Act. A single Spiked Rice-flower was recorded

at the site during field surveys by GHD ecologists and a number of other individuals were observed by OEH staff during a site inspection. This species has not been formally included in the BioBanking assessment and no species credits have been created. Systematic targeted surveys for the Spiked Rice-flower will be conducted and species credits will be created based on the results of that survey.

Table 18 Vegetation zones, habitat for the affected threatened biota and available biodiversity credits at the Williamswood biobank (GHD 2014a)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland[2] (ha)	Area of Habitat for Grey-headed Flying fox[3] (ha)	Available biodiversity credits
1 -Grey Box - Forest Red Gum grassy woodland on hills (Moderate/good - medium)	HN529	Moderate/ good - medium	31.9	CEEC	CEEC	31.9		31.9	367
2 -Grey Box - Forest Red Gum grassy woodland on hills (Moderate/good - poor)	HN529	Moderate/ good - poor	28		CEEC	0	28	0	322
3 -Grey Box - Forest Red Gum grassy woodland on hills (Low)	HN529	Low	12.6			0		0	5
4 -Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good - medium)	HN526	Moderate/ good - medium	14.3		EEC	0		14.3	144
5 -Forest Red Gum - Rough-barked Apple grassy woodland (Low)	HN526	Low	13.5			0		0	136
6 - Forest Red Gum - Grey Box shrubby woodland (Moderate/good - high)	HN524	Moderate/ good - high	4.2	CEEC	EEC	0		4.2	38
		Total	**104.5**			**31.9**	**28**	**50.4**	**1012**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010) and is linked to biodiversity credits that are available for sale. 2) Derived native scrub or grassland with <10 per cent native canopy cover and predominantly native understorey that does not comprise EPBC Act Cumberland Plain Woodland in accordance with the conservation advice for the community (DEWHA 2010) and that is linked to biodiversity credits that are available for sale. 3) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009) and is linked to biodiversity credits that are available for sale.

The Oaks Biobank

The ‘Oaks biobank’ offset site is a biobank that has been subject to a detailed field survey and BioBanking assessment and has already been set aside for conservation under a BioBanking agreement. The description of the site presented below is based on the information presented in the BioBanking assessment report for the site (GHD 2014g).

The Oaks biobank includes 40 hectares of land and is located at Mowbray Park within the Wollondilly Local Government Area (LGA). It falls within the Cumberland subregion of the Hawkesbury Nepean Catchment Management Authority (CMA), and within the Sydney Basin Bioregion. The biobank is currently zoned RU2 Rural Landscape under the *Wollondilly Local Environment Plan 2011* and was grazed by cattle prior to being set aside as a biobank.

There are four NSW vegetation types at the biobank. The stands of these vegetation types are in varying condition (according to the BBAM) and were split into broad condition classes yielding six vegetation zones. The distribution of vegetation zones at the biobank is closely tied to soil type, underlying geology and geomorphic position.

The biobank site includes vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland and/or Grey-headed Flying-fox habitat (specifically only vegetation zones with native over storey cover greater than 10 per cent). There are also areas of poorer quality Cumberland Plain Woodland that comprises derived grassland or scrub which could be managed to improve in quality and become EPBC Act Cumberland Plain Woodland. These areas have minimal canopy cover and contain minimal foraging resources for the Grey-headed Flying Fox. Available habitat for these affected threatened biota has been calculated based on the number of biodiversity credits currently available for sale (see Table 19). Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment.

More exposed slopes and ridges on shale support Grey Box – Forest Red Gum grassy woodland (HN529). Moderate/good-medium condition patches of this vegetation type comprise an occurrence of the EPBC Act listed form of Cumberland Plain Woodland.

Grey Box – Forest Red Gum grassy woodland grades into Moderate/good condition Forest Red Gum – Grey Box shrubby woodland (HN524) on sheltered slopes with a fine grained volcanic substrate, which is distinguished from adjoining grassy woodlands on shale by the presence of a mid-storey of mesic small trees, a denser shrub layer and mesic understorey species. These vegetation types give way to Forest Red Gum – Rough-barked Apple grassy woodland (HN526) in riparian areas and adjoining alluvial flats. Each of these vegetation types have been cleared, grazed and subject to weed infestation to varying degrees with areas of Moderate/good- medium, Moderate/good – poor and Low condition vegetation. Moderate/good- medium condition vegetation zones comprise Grey-headed Flying-fox habitat.

There are moderate to severe infestations of noxious weeds, such as Lantana (*Lantana camara*), Blackberry (*Rubus fruticosus* spp. agg.) and especially African Olive (*Olea europea* subsp. *cuspidata*) at the site. These weeds are most prevalent on the cleared low lying areas and on more sheltered slopes.

Much of the site has been grazed and canopy vegetation has been extensively cleared or thinned historically. Mid storey vegetation has since re-established across the majority of the biobank though there are very few over storey species in areas of poor or low condition vegetation. There are mature hollow-bearing trees in moderate densities throughout areas of Moderate/good – medium condition vegetation at the biobank.

Table 19 Vegetation zones, habitat for the affected threatened biota and available biodiversity credits at the Oaks biobank (GHD 2014g)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland[2] (ha)	Area of Habitat for Grey-headed Flying fox[3] (ha)	Available biodiversity credits
Forest Red Gum - Grey Box shrubby woodland (Low)	HN524	Low	8.2		EEC				69
Grey Box - Forest Red Gum grassy woodland (medium)	HN529	Moderate/good - medium	13.9	CEEC	CEEC	10		10	121
Grey Box - Forest Red Gum grassy woodland (poor)	HN529	Moderate/good - poor	5.5	CEEC	EEC		3		48
Grey Box - Forest Red Gum grassy woodland (Low)	HN529	Low	10.7		EEC				93
Grey Myrtle dry rainforest (poor)	HN538	Moderate/good - poor	0.4	CEEC	EEC			0.4	5
Forest Red Gum - Rough-barked Apple grassy woodland (Low)	HN526	Low	1.3		EEC				11
		Total	**40**			**10**	**3**	**10.4**	**346**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010) and is linked to biodiversity credits that are available for sale.

2) Derived native scrub or grassland with <10 per cent native canopy cover and predominantly native understorey that does not comprise EPBC Act Cumberland Plain Woodland in accordance with the conservation advice for the community (DEWHA 2010) and that is linked to biodiversity credits that are available for sale.

3) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009) and is linked to biodiversity credits that are available for sale.

Durham biobank

The ‘Durham biobank’ offset site is a proposed biobank on land owned by the NSW Department of Planning and Environment (DPE) at Oxley Park in the Ropes Creek riparian corridor. The site has been subject to a detailed field survey and a preliminary BioBanking assessment but has not yet been set aside for conservation under a BioBanking agreement. The remaining steps involved with finalising the BioBanking assessment include definition of site boundaries, BioBanking credit calculations and preparation of a management actions plan (MAP). The description of the site presented below is based on the information presented in the preliminary BioBanking assessment report for the site (GHD 2015c). The description of the biodiversity values at the site that is included below is unlikely to substantially change as a result of later stages of the BioBanking assessment. The area of habitat for the affected MNES that is present at the site will be reassessed based on any additional information obtained prior to the final delivery of the offset package for the proposed airport and the total quantum of offset will be adjusted if required.

The Durham biobank includes 46.85 hectares of land and is located along the riparian corridor of Ropes Creek within the Hawkesbury Nepean CMA, and within the Sydney Basin Bioregion. The Durham biobank is located within the Penrith and Blacktown LGAs.

The site is dominated by Forest Red Gum - Rough-barked Apple grassy woodland (HN526) in varying conditions, which intergrades with Swamp Oak - Prickly Tea-tree - Swamp Paperbark swamp forest (HN594) in several locations along Ropes Creek, presumably where soil salt content is greater. There is a small section of Grey Box - Forest Red Gum grassy woodland on shale (HN528) in the south east corner of the site, associated with a slight increase in topography. There are relatively abundant populations of the threatened plant Juniper-leaved Grevillea (*Grevillea juniperina* subsp. *juniperina*) at the site. A Grey-headed Flying-fox roost camp has been recorded in the Ropes Creek riparian corridor less than 500 metres to the south of the Durham biobank (PB 2013). Mother flying-foxes were recorded suckling young at this roost camp (PB 2013).

The biobank includes vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland, and Grey-headed Flying-fox habitat (specifically only vegetation zones with native over storey cover greater than 10 per cent). At this site ‘Moderate/good – poor’ condition vegetation comprises regrowth vegetation with moderate native over storey cover that would qualify as Cumberland Plain Woodland and that does contain foraging resources for the Grey-headed Flying Fox. The Commonwealth listing advice for Cumberland Plain Woodland notes that the canopy in regrowth stands of EPBC Act Cumberland Plain Woodland may be shorter than 10 m tall (TSSC 2008). Vegetation zones and habitat for the affected threatened biota at the Durham biobank site are presented inTable 20. Additional bodiversity credits associated with Low condition vegetation would be available to offset impacts on the environment..

There is considerable scope to improve the biodiversity values of the site if it is included in a biobank through treatment of weed infestations, removal of rubbish from drainage lines and development of vegetation structure and habitat resources.

Table 20 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Durham biobank (GHD 2014a)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland (ha)	Area of Habitat for Grey-headed Flying fox[2] (ha)	Estimated biodiversity credits[3]
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good – medium)	HN526	Moderate/ good – medium	10.42		EEC	0		10.42	73
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good – poor)	HN526	Moderate/ good – poor	7.8		EEC	0		7.8	55
Forest Red Gum - Rough-barked Apple grassy woodland (Low)	HN526	Low	16.95			0		0	119
Swamp Oak - Prickly Tea-tree - Swamp Paperbark swamp forest (Moderate/good)	HN594	Moderate/ good	3.01		EEC	0		3.01	21
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – high)	HN528	Moderate /good – high	1.55	CEEC	CEEC	1.55		1.55	11
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – poor)	HN528	Moderate/ good – poor	1.3	CEEC	CEEC	1.3		1.3	9
Grey Box - Forest Red Gum grassy woodland on shale (Low)	HN528	Low	1.63			0		0	11
		Total	**42.66**			**2.85**		**24.08**	**299**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010).

2) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009).

3) Estimate based on a credit generation rate of seven credits per hectare.

8.1.1 Mamre biobank

The ‘Mamre biobank’ offset site is a proposed biobank on a 172 hectare parcel of land owned by DPE at Mamre Park connected to the South Creek riparian corridor. The site has been subject to a detailed field survey and a preliminary BioBanking assessment but has not yet been set aside for conservation under a BioBanking agreement. The description of the site presented below is based on the information presented in the preliminary BioBanking assessment report for the site (GHD 2015c). As noted for the Durham biobank above, the description of the biodiversity values at the site is unlikely to substantially change but prior to the final delivery of the offset package for the airport the total quantum of offset will be reassessed and adjusted if required.

Forest Red Gum - Rough-barked Apple grassy woodland (HN526) occupies the majority of the site, in varying condition. There are several areas that have been revegetated along the boundary of the site, typically mapped as Moderate/good – poor condition vegetation.

Vegetation closest to areas of disturbance (e.g. in areas close to cleared land or land used for horse agistment) is dominated by exotic species. There are several informal tracks throughout vegetated areas of the site that appear to be used on a regular basis as horse trails, despite the presence of fences and gates. There are low to moderate densities of exotic herbaceous and grass species along many of these tracks.

There are extensive planted areas around the site, most of which have been mapped as Moderate/good – poor condition. These areas typically lack a midstorey, having been primarily revegetated with canopy species. There are low to moderate infestations of exotic species in the understorey, and some areas also support moderate to severe infestations of woody weeds and climbers in the midstorey.

Only vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland and/or Grey-headed Flying-fox habitat would be included in this offset package (specifically only vegetation zones with native over storey cover greater than 10%). At this site ‘Moderate/good – poor’ condition vegetation comprises planted or regrowth vegetation with moderate native over storey cover that contains foraging resources for the Grey-headed Flying Fox. Vegetation zones and habitat for the affected threatened biota at the Mamre biobank site are presented in Table 21. Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment..

There is considerable scope to improve the biodiversity values of the site through treatment of weed infestations, removal of rubbish from drainage lines and development of vegetation structure and habitat resources. Preventing use of bushland areas as horse trails would assist in improving the condition of vegetation on site, through a reduction in the spread of weed species seeds, as well as halting the spread of nutrients into bushland areas.

Table 21 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Mamre biobank (GHD 2014a)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of Cumberland Plain Woodland1 (ha)	Area of Habitat for Grey-headed Flying fox2 (ha)	Estimated biodiversity credits[3]
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good – medium)	HN526	Moderate/good – medium	26.86		EEC		26.86	188
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good – poor)	HN526	Moderate/good – poor	25.61		EEC		25.61	179
Forest Red Gum - Rough-barked Apple grassy woodland (Low)	HN526	Low	44.62					312
Phragmites australis and Typha orientalis coastal freshwater wetlands (Moderate/good)	HN630	Moderate/good	1.04		EEC			7
		Total	**98.13**			**0**	**52.47**	**687**

Notes: 1) Features >10% native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010).

2) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009).

3) Estimate based on a credit generation rate of seven credits per hectare.

Forrester biobank

The ‘Forrester biobank’ offset site is a proposed biobank on a 9 hectare parcel of land owned by DPE at Tregear, connected to the Ropes Creek riparian corridor. The site has been subject to a detailed field survey and a preliminary BioBanking assessment but has not yet been set aside for conservation under a BioBanking agreement. The description of the site presented below is based on the information presented in the preliminary BioBanking assessment report for the site (GHD 2015c). As noted for the Durham biobank above, the description of the biodiversity values at the site is unlikely to substantially change but prior to the final delivery of the offset package for the airport the total quantum of offset will be reassessed and adjusted if required.

The majority of the site contains Forest Red Gum - Rough-barked Apple grassy woodland (HN526) on alluvial flats. There is a narrow linear corridor of Swamp Oak - Prickly Tea-tree - Swamp Paperbark swamp forest (HN594) along Ropes Creek.

Only vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland and/or Grey-headed Flying-fox habitat would be included in this offset package (specifically only vegetation zones with native over storey cover greater than 10%). At this site ‘Moderate/good – poor’ or ‘Low’ condition vegetation comprises derived native grassland or sub-mature planted vegetation and does not contain foraging resources for the Grey-headed Flying Fox. Vegetation zones and habitat for the affected threatened biota at the Forrester biobank site are presented in Table 22. Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment..

There are severe infestations of exotic woody weed and vine species along the riparian strip of Ropes Creek in the north east of the site, as well as infestations of invasive grass species along an electricity easement in the east.

There is considerable scope to improve the biodiversity values of the site if it included in a biobank through treatment of weed infestations, removal of rubbish from drainage lines and accessible portions of the site, securing the site to prevent access by recreational vehicles including 4WD vehicles, dirt bikes and mountain bikes and development of vegetation structure and habitat resources.

Table 22 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Forrester biobank (GHD 2014a)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of Cumberland Plain Woodland1 (ha)	Area of Habitat for Grey-headed Flying fox2 (ha)	Estimated biodiversity credits[3]
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/ good – medium)	HN526	Moderate/ good – medium	4.74		EEC		4.74	33
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/ good – poor)	HN526	Moderate/ good – poor	1.96		EEC			14
Forest Red Gum - Rough-barked Apple grassy woodland (Low)	HN526	Low	1.31					9
Swamp Oak - Prickly Tea-tree - Swamp Paperbark swamp forest (HN594)	HN594	Moderate/good condition	1.16		EEC		1.16	8
		Total	**9.17**				**5.9**	64

Notes: 1) Features >10% native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010).

2) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009).

3) Estimate based on a credit generation rate of seven credits per hectare.

Luddenham biobank

The ‘Luddenham biobank’ offset site is a proposed biobank on a 42 hectare parcel of land owned by DPE at Mamre Park, connected to the South Creek riparian corridor. The site has been subject to a detailed field survey and a preliminary BioBanking assessment but has not yet been set aside for conservation under a BioBanking agreement. The description of the site presented below is based on the information presented in the preliminary BioBanking assessment report for the site (GHD 2015c). As noted for the Durham biobank above, the description of the biodiversity values at the site is unlikely to substantially change but prior to the final delivery of the offset package for the proposed airport the total quantum of offset will be reassessed and adjusted if required.

Forest Red Gum - Rough-barked Apple grassy woodland (HN526) occupies the majority of the site, in varying condition. There are several areas that have been revegetated along the boundary of the site, typically mapped as Moderate/good – poor condition vegetation and some low condition vegetation with immature regrowth. There is a small portion of cleared land in the south of the site within an electricity easement.

There is around five hectares of Grey Box - Forest Red Gum grassy woodland on shale (HN528) on higher ground.

Revegetated portions of the site appear to have been planted with a mixture of canopy, midstorey and understorey species. The understorey in these areas is typically dominated by exotic herbaceous and grass species, with several small and localised exceptions. Several areas that have been revegetated have moderate to high levels of woody weed infestation as well as low to moderate infestations with Blackberry (*Rubus fruiticosis* sp. agg.)

The biobank includes vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland, and Grey-headed Flying-fox habitat (specifically only vegetation zones with native over storey cover greater than 10 per cent). There are also areas of poorer quality Cumberland Plain Woodland that comprises planted or regrowth vegetation which could be managed to improve in quality and become EPBC Act Cumberland Plain Woodland. These areas have moderate native over storey cover and contain foraging resources for the Grey-headed Flying Fox. Vegetation zones and habitat for the affected threatened biota at the Luddenham biobank site are presented in Table 23. Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment..

There is considerable scope to improve the biodiversity values of the site through treatment of weed infestations, removal of rubbish from drainage lines and development of vegetation structure and habitat resources. Preventing use of bushland areas as horse trails would assist in improving the condition of vegetation on site, through a reduction in the spread of weed species seeds, as well as halting the spread of nutrients into bushland areas.

One threatened fauna species was recorded at the biobank site during field surveys: the Little Eagle.

There is considerable scope to improve the biodiversity values of the site if it is included in a biobank through treatment of weed infestations, removal of rubbish from drainage lines and accessible portions of the site and development of vegetation structure and habitat resources.

Table 23 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Luddenham biobank (GHD 2014a)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland (ha)[2]	Area of Habitat for Grey-headed Flying fox[3] (ha)	Estimated biodiversity credits[4]
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good – medium)	HN526	Moderate/good – medium	20.46		EEC	0		20.46	143
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good – poor)	HN526	Moderate/good – poor	9.26		EEC	0		9.26	65
Forest Red Gum - Rough-barked Apple grassy woodland (Low)	HN526	Low	5.38			0		0	38
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – high)	HN528	Moderate/good – high	4.14	CEEC	CEEC	4.14		4.14	29
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – poor)	HN528	Moderate/good – poor	0.73		CEEC	0	0.73	0.73	5
		Total	**39.97**			**4.14**	**0.73**	**34.59**	**280**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010).

2) Derived native scrub or grassland with <10 per cent native canopy cover and predominantly native understorey that does not comprise EPBC Act Cumberland Plain Woodland in accordance with the conservation advice for the community (DEWHA 2010) and that is linked to biodiversity credits that are available for sale.

3) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009).

4) Estimate based on a credit generation rate of seven credits per hectare.

Roper biobank

The ‘Roper biobank’ offset site is a proposed biobank on a 14 hectare parcel of land owned by DPE at Minchinbury, connected to the Ropes Creek riparian corridor. The site has been subject to a detailed field survey and a preliminary BioBanking assessment but has not yet been set aside for conservation under a BioBanking agreement. The description of the site presented below is based on the information presented in the preliminary BioBanking assessment report for the site (GHD 2015c). As noted for the Durham biobank above, the description of the biodiversity values at the site is unlikely to substantially change but prior to the final delivery of the offset package for the proposed airport the total quantum of offset will be reassessed and adjusted if required.

Close to Ropes Creek, the vegetation is made up of Forest Red Gum - Rough-barked Apple grassy woodland (HN526) in varying condition, including some areas of planted vegetation. Further away from the creek line, the site features Grey Box - Forest Red Gum grassy woodland on shale (HN28). There is a patch of Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (HN512) associated with an area of shale/gravel soil on slightly higher ground.

Only vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland and/or Grey-headed Flying-fox habitat would be included in this offset package (specifically only vegetation zones with native over storey cover greater than 10 per cent). At this site ‘Moderate/good – poor’ condition vegetation comprises planted or regrowth vegetation with moderate native over storey cover that contains foraging resources for the Grey-headed Flying Fox as well as comprising poorer quality Cumberland Plain Woodland. Vegetation zones and habitat for the affected threatened biota at the Roper biobank site are presented in Table 15. Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment..

One threatened fauna species was recorded at the biobank site during field surveys: the Little Eagle. Two threatened flora species are present at the site: *Grevillea juniperina* subsp. *juniperina* and *Dilwynia tenuifolia*.

There are several cleared areas within the site with abandoned buildings and exotic gardens and farm infrastructure. There are also several paddocks that appear to have been used for intensive grazing in the past within these cleared areas.

There is evidence of bush regeneration activities across the site, with some areas of revegetation as well as the presence of silt fences that appear to have been placed in an attempt to protect revegetated areas from grazing by feral herbivores such as rabbits.

There is considerable scope to improve the biodiversity values of the site if it is included in a biobank through treatment of weed infestations, removal of rubbish from drainage lines and unsecured parts of the site (i.e. in areas that are accessible by members of the public such as those lacking secured gates or fences) and development of vegetation structure and habitat resources.

Table 24 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Roper biobank (GHD 2014a)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland (ha)	Area of Habitat for Grey-headed Flying fox[2] (ha)	Estimated biodiversity credits[4]
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good – medium)	HN526	Moderate/ good – medium	0.98		EEC	0		0.98	7
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good – poor)	HN526	Moderate/ good – poor	1.05		EEC	0		1.05	7
Forest Red Gum - Rough-barked Apple grassy woodland (Low)	HN526	Low	0.87			0		0	6
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – poor)	HN528	Moderate/ good – poor	1.65		CEEC	0	1.65	1.65	12
Grey Box - Forest Red Gum grassy woodland on shale (Low)	HN528	Low	5.22		CEEC	0		0	37
Broad-leaved Ironbark - Grey Box - *Melaleuca decora* grassy open forest (Moderate/good – medium)	HN512	Moderate/ good – medium	3.04	CEEC	CEEC	3.04		3.04	21
Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest (Low)	HN512	Low	0.47		CEEC	0		0	3
		Total	**13.28**			**3.04**	**1.65**	**6.72**	**93**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010). 2) Derived native scrub or grassland with <10 per cent native canopy cover and predominantly native understorey that does not comprise EPBC Act Cumberland Plain Woodland in accordance with the conservation advice for the community (DEWHA 2010) and that is linked to biodiversity credits that are available for sale. 3) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009). 4) Estimate based on a credit generation rate of seven credits per hectare.

Caddens biobank

The ‘Caddens biobank’ offset site is a proposed biobank on a 36 hectare parcel of land owned by DPE at Claremont Meadows, connected to the South Creek riparian corridor. The site has been subject to a detailed field survey and a preliminary BioBanking assessment but has not yet been set aside for conservation under a BioBanking agreement. The description of the site presented below is based on the information presented in the preliminary BioBanking assessment report for the site (GHD 2015c). As noted for the Durham biobank above, the description of the biodiversity values at the site is unlikely to substantially change but prior to the final delivery of the offset package for the proposed airport the total quantum of offset will be reassessed and adjusted if required.

The site includes Grey Box - Forest Red Gum grassy woodland on shale (HN528) in varying conditions on higher ground and Forest Red Gum - Rough-barked Apple grassy woodland (HN526) on alluvial flats. Much of the Forest Red Gum - Rough-barked Apple grassy woodland is subject to very severe Privet (*Ligustrum* species) infestation and would require relatively intense and expensive management.

The biobank site includes vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland and Grey-headed Flying-fox habitat (specifically only vegetation zones with native over storey cover greater than 10 per cent). There are also areas of poorer quality Cumberland Plain Woodland vegetation that comprises derived native grassland or planted or regrowth vegetation which could be managed to improve in quality and become EPBC Act Cumberland Plain Woodland. These areas of planted or regrowth vegetation have moderate mid and over storey cover that contains contain foraging resources for the Grey-headed Flying Fox. Vegetation zones and habitat for the affected threatened biota at the Caddens biobank site are presented in Table 25. Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment..

There are also substantial freshwater wetlands in the site that would have considerable fauna habitat value, including for a potential population of the Green and Golden Bell Frog (*Litoria aurea)*. The Green and Golden Bell Frog has been recorded in the vicinity of the site (OEH 2015d).

There is considerable scope to improve the biodiversity values of the site if it is included in a biobank through treatment of weed infestations, removal of rubbish from drainage lines and development of vegetation structure and habitat resources.

Table 25 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Caddens biobank (GHD 2014a)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland (ha)[2]	Area of Habitat for Grey-headed Flying fox[3] (ha)	Estimated biodiversity credits[4]
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good – medium)	HN526	Moderate/good – medium	6.35		EEC	0		6.35	44
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/good – poor)	HN526	Moderate/good – poor	6.19		EEC	0		6.19	43
Forest Red Gum - Rough-barked Apple grassy woodland (Low)	HN526	Low	13.28			0		0	93
Phragmites australis and *Typha orientalis* coastal freshwater wetlands (Moderate/good condition)	HN630	Moderate/good condition	0.71			0		0	5
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – high)	HN528	Moderate/good – high	4.75	CEEC	CEEC	4.75		4.75	33
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – poor)	HN528	Moderate/good – poor	1.17		CEEC	0	1.17	0	8
Grey Box - Forest Red Gum grassy woodland on shale (Low)	HN528	Low	0.85			0		0	6
		Total	**33.3**			**4.75**	**1.17**	**17.29**	**233**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010).

2) Derived native scrub or grassland with <10 per cent native canopy cover and predominantly native understorey that does not comprise EPBC Act Cumberland Plain Woodland in accordance with the conservation advice for the community (DEWHA 2010) and that is linked to biodiversity credits that are available for sale.

3) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009).

4) Estimate based on a credit generation rate of seven credits per hectare.

Dunheved biobank

The ‘Dunheved biobank’ offset site is a proposed biobank on a 90 hectare parcel of land owned by DPE at Werrington County, connected to the South Creek riparian corridor. The site has been subject to a detailed field survey and a preliminary BioBanking assessment but has not yet been set aside for conservation under a BioBanking agreement. The description of the site presented below is based on the information presented in the preliminary BioBanking assessment report for the site (GHD 2015c). As noted for the Durham biobank above, the description of the biodiversity values at the site is unlikely to substantially change but prior to the final delivery of the offset package for the proposed airport the total quantum of offset will be reassessed and adjusted if required.

The majority of the site contains Forest Red Gum - Rough-barked Apple grassy woodland (HN526) on alluvial flats. There are some patches of Grey Box - Forest Red Gum grassy woodland on shale (HN528) along the western boundary and in the central portion of the site.

The biobank site includes vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland, and Grey-headed Flying-fox habitat (specifically only vegetation zones with native over storey cover greater than 10 per cent). There are also areas of poorer quality Cumberland Plain Woodland that comprises derived native grassland or scrub which could be managed to improve in quality and become EPBC Act Cumberland Plain Woodland. These areas do not contain foraging resources for the Grey-headed Flying Fox. Vegetation zones and habitat for the affected threatened biota at the Dunheved biobank site are presented in Table 26. Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment..

Around 100 individual *Pultenaea parviflora* were recorded at the site (GHD 2014a). These could generate species credits that would offset the proposed airport’s impacts on this species as calculated with the BioBanking methodology for major projects (see Section 3.3)

There are substantial freshwater wetlands in the site that would have considerable fauna habitat value, including for a potential population of the Green and Golden Bell Frog (*Litoria aurea)*. The Green and Golden Bell Frog has been recorded in the vicinity of the site (OEH 2015a).

There is considerable scope to improve the biodiversity values of the site if it is included in a biobank through treatment of weed infestations, removal of rubbish from drainage lines and development of vegetation structure and habitat resources.

Table 26 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Dunheved biobank (GHD 2014a)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland[2] (ha)	Area of Habitat for Grey-headed Flying fox[3] (ha)	Estimated biodiversity credits[4]
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/ good – medium)	HN526	Moderate/ good – medium	19.18		EEC	0		19.18	134
Forest Red Gum - Rough-barked Apple grassy woodland (Moderate/ good – poor)	HN526	Moderate/ good – poor	6.84		EEC	0	0	0	48
Forest Red Gum - Rough-barked Apple grassy woodland (Low)	HN526	Low	25.64			0		0	179
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/ good – high)	HN528	Moderate/ good – high	3.82	CEEC	CEEC	3.82		3.82	27
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/ good – poor)	HN528	Moderate/ good – poor	8.67		CEEC	0	8.67	0	61
Grey Box - Forest Red Gum grassy woodland on shale (Low)	HN528	Low	0.86		CEEC	0		0	6
		Total	**65.01**			**3.82**	**8.67**	**23**	**455**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010).

2) Derived native scrub or grassland with <10 per cent native canopy cover and predominantly native understorey that does not comprise EPBC Act Cumberland Plain Woodland in accordance with the conservation advice for the community (DEWHA 2010) and that is linked to biodiversity credits that are available for sale.

3) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009).

4) Estimate based on a credit generation rate of seven credits per hectare.

Stage 1 Montpelier Biobank

The ‘Stage 1 Montpelier Biobank’ offset site is a proposed biobank that has been subject to a detailed field survey and BioBanking assessment and is currently awaiting issue of a BioBanking agreement from OEH (GHD, 2015d).

The proposed biobank is located around five kilometres south of village of The Oaks within the Wollondilly LGA. It falls within the Hawkesbury Nepean Catchment Management Authority CMA region, and within the Sydney Basin Bioregion. The biobank is currently zoned RU2 Rural Landscape under the *Wollondilly Local Environment Plan 2011*.

Field surveys confirmed the presence and distribution of four NSW vegetation types at the biobank. The stands of these vegetation types are in varying condition (according to the BBAM) and were split into broad condition classes yielding six vegetation zones.

The distribution of vegetation zones at the biobank is mainly tied to geomorphic position. More exposed slopes and ridges support Grey Box – Forest Red Gum grassy woodland (HN529). There are occurrences of Grey Box – Forest Red Gum grassy woodland on shale (HN528) on lower undulating slopes and flatter areas of the site. Moderate/good- medium condition patches of these vegetation types comprise an occurrence of the EPBC Act form of Cumberland Plain Woodland.

This vegetation type grades into Forest Red Gum – Grey Box shrubby woodland (HN524) in steeper or more sheltered areas, which is distinguished from adjoining grassy woodlands on shale by the presence of a denser shrub layer and mesic understorey species. These vegetation types give way to Grey Myrtle dry rainforest (HN538) on sheltered alluvial flats and in narrow gullies. Each of these vegetation types have been cleared, grazed and subject to weed infestation to varying degrees with areas of Moderate/good- medium, Moderate/good – poor and low condition vegetation. Moderate/good- medium condition patches of all vegetation types at the site contain a canopy of *Eucalyptus* and other species in the blossom diet of the Grey-headed Flying-fox (Eby and Law 2008) and comprise critical habitat for the species (DEWHA 2010).

There are moderate to severe infestations of noxious weeds, such as Lantana (*Lantana camara*) and Blackberry (*Rubus fruticosus* spp. agg.) across much of the site. These two species form a dense midstorey in many parts of the site. Other noxious weeds present on site in lower numbers include African Olive (*Olea europea* subsp. *cuspidata*), Small-leaved Privet (*Ligustrum* sinense), Fireweed (*Senecio madagascariensis*), African Boxthorn (*Lycium ferocissimum*), Bridal Creeper (*Asparagus asparagoides*), Green Cestrum (*Cestrum parqui*), Moth Vine (*Araujia sericifera*) and Prickly Pear (*Opuntia stricta*).

The biobank site includes vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland, and Grey-headed Flying-fox habitat (specifically only vegetation zones with native over storey cover greater than 10 per cent). There are also areas of poorer quality Cumberland Plain Woodland that comprises derived grassland or scrub which could be managed to improve in quality and become EPBC Act Cumberland Plain Woodland. These areas have minimal canopy cover and contain minimal foraging resources for the Grey-headed Flying Fox. Vegetation zones and habitat for the affected threatened biota at the Stage 1 Montpelier biobank site are presented in Table 27. Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment..

Much of the site has been grazed and canopy vegetation has been extensively cleared or thinned historically. Mid-storey vegetation has since re-established across the majority of the biobank though there are very few over storey species in areas of poor or low condition vegetation. There are mature hollow-bearing trees in low to moderate densities throughout areas of Moderate/good – medium condition vegetation at the biobank. There are no hollow-bearing trees within areas of poor or low

condition vegetation. There is considerable scope to improve the biodiversity values of the site through treatment of weed infestations and development of vegetation structure and habitat resources.

One threatened fauna species was recorded at the biobank site during field surveys: the Little Eagle.

Table 27 Vegetation zones, habitat for the affected threatened biota and available biodiversity credits at the Stage 1 Montpelier biobank (GHD 2015d)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland[2] (ha)	Area of Habitat for Grey-headed Flying fox[3] (ha)	Available biodiversity credits
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – medium)	HN529	Moderate/good - medium	16.83	CEEC	CEEC	16.83		16.83	191
Grey Box - Forest Red Gum grassy woodland on shale (Low)	HN529	Low	10.67			0		0	121
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – poor)	HN529	Moderate/good - poor	11.38		CEEC	0	11.38	0	129
Forest Red Gum - Grey Box shrubby woodland (Moderate/good – medium)	HN524	Moderate/good - medium	17.27	CEEC	EEC	17.27		17.27	153
Grey Myrtle dry rainforest	HN538	Moderate/good	6.78	CEEC	EEC	0		6.78	73
Grey Box - Forest Red Gum grassy woodland on flats (Low)	HN528	Low	13.31			0		0	119
		Total	**76.24**			**34.1**	**11.38**	**40.88**	**787**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010).

2) Derived native scrub or grassland with <10 per cent native canopy cover and predominantly native understorey that does not comprise EPBC Act Cumberland Plain Woodland in accordance with the conservation advice for the community (DEWHA 2010) and that is linked to biodiversity credits that are available for sale.

3) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009).

Stage 2 Montpelier Biobank

The ‘Stage 2 Montpelier Biobank’ offset site is a proposed biobank that has been subject to a preliminary field survey and BioBanking assessment and will be subject to a detailed BioBanking assessment as part of an application to OEH for a Biobanking agreement (GHD in prep.). The description of the site presented below is based on the information presented in the preliminary BioBanking assessment report for the site (GHD in prep.). As noted for similar sites above, the description of the biodiversity values at the site is unlikely to substantially change but prior to the final delivery of the offset package for the proposed airport the total quantum of offset will be reassessed and adjusted if required.

The proposed biobank is located immediately adjacent to the stage 1 Montpelier biobank described above. The biobank is currently zoned RU2 Rural Landscape under the *Wollondilly Local Environment Plan 2011*.

Field surveys confirmed the presence and distribution of three NSW vegetation types at the biobank. The stands of these vegetation types are in varying condition (according to the BBAM) and were split into broad condition classes yielding five vegetation zones.

The distribution of vegetation zones at the biobank is mainly tied to geomorphic position. More exposed slopes and ridges support Grey Box – Forest Red Gum grassy woodland (HN529). Moderate/good- medium condition patches of this vegetation type comprise an occurrence of the EPBC Act form of Cumberland Plain Woodland. This vegetation type grades into Forest Red Gum – Grey Box shrubby woodland (HN524) in steeper or more sheltered areas. These vegetation types give way to Grey Myrtle dry rainforest (HN538) in narrow gullies. Each of these vegetation types have been cleared, grazed and subject to weed infestation to varying degrees with areas of Moderate/good-medium, Moderate/good – poor and Low condition vegetation. Moderate/good- medium condition patches of all vegetation types at the site contain a canopy of *Eucalyptus* and other species in the blossom diet of the Grey-headed Flying-fox (Eby and Law 2008) and comprise critical habitat for the species (DEWHA 2010).

There are moderate to severe infestations of noxious weeds, such as Lantana, Blackberry and especially African Olive which form a dense mid storey in many parts of the site. Other noxious weeds present on site include Privet (*Ligustrum* species), Fireweed (*Senecio madagascariensis*), Bridal Creeper (*Asparagus asparagoides*), Green Cestrum (*Cestrum parqui*) and Moth Vine (*Araujia sericifera*).

The biobank site includes vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland, and Grey-headed Flying-fox habitat (specifically only vegetation zones with native over storey cover greater than 10 per cent). There are also areas of poorer quality Cumberland Plain Woodland that comprises derived grassland or scrub with minimal canopy cover that does not qualify as Cumberland Plain Woodland but which could be managed to improve in quality and become EPBC Act Cumberland Plain Woodland. These areas contain minimal foraging resources for the Grey-headed Flying Fox. Vegetation zones and habitat for the affected threatened biota at the Stage 2 Montpelier biobank site are presented in

Table 28. Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment..

There is considerable scope to improve the biodiversity values of the site through treatment of weed infestations and development of vegetation structure and habitat resources.

One threatened fauna species was recorded at the biobank site during field surveys: the Little Eagle.

Table 28 Vegetation zones, habitat for the affected threatened biota and estimated biodiversity credits at the Stage 2 Montpelier biobank (GHD in prep.)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland (ha)[2]	Area of Habitat for Grey-headed Flying fox[3] (ha)	Estimated biodiversity credits[4]
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – medium)	HN529	Moderate/good - medium	20.9	CEEC	CEEC	20.9		20.9	146
Grey Box - Forest Red Gum grassy woodland on shale (Low)	HN529	Low	21.8						153
Grey Box - Forest Red Gum grassy woodland on shale (Moderate/good – poor)	HN529	Moderate/good - poor	9.2		CEEC		9.2		64
Forest Red Gum - Grey Box shrubby woodland (Moderate/good – medium)	HN524	Moderate/good - medium	16.9	CEEC	EEC			16.9	118
Grey Myrtle dry rainforest	HN538	Moderate/good	10.7	CEEC	EEC			10.7	75
		Total	**79.5**			**20.9**	**9.2**	**48.5**	**557**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010).

2) Derived native scrub or grassland with <10 per cent native canopy cover and predominantly native understorey that does not comprise EPBC Act Cumberland Plain Woodland in accordance with the conservation advice for the community (DEWHA 2010) and that is linked to biodiversity credits that are available for sale.

3) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009).

4) Estimate based on a credit generation rate of seven credits per hectare.

Menangle Road Biobank

The ‘Menangle Road biobank’ offset site is a proposed biobank on privately owned land that has been subject to a detailed field survey and BioBanking assessment will be included in an application for a BioBanking agreement from OEH. The site has been subject to a detailed field survey and a preliminary BioBanking assessment but has not yet been set aside for conservation under a BioBanking agreement. The description of the site presented below is based on the information presented in the BioBanking assessment report for the site (GHD 2015e).

The remaining steps involved with finalising the BioBanking assessment include definition of site boundaries, BioBanking credit calculations and preparation of a MAP. As discussed for similar proposed biobanks above, the description of the biodiversity values at the site that is included below is unlikely to substantially change but will be reassessed prior to the final delivery of the offset package for the proposed airport and the total quantum of offset will be adjusted if required.

The proposed biobank is located on around 57 hectares of land about 3.6 kilometres south-east of Picton within the Wollondilly LGA. It falls within the Hawkesbury Nepean CMA region, and within the Sydney Basin Bioregion. The biobank is currently zoned RU2 Rural Landscape under the *Wollondilly Local Environment Plan 2011*.

Field surveys confirmed the presence and distribution of four NSW vegetation types at the biobank. The stands of these vegetation types are in varying condition (according to the BBAM) and were split into broad condition classes yielding eight vegetation zones.

The distribution of vegetation zones at the biobank is mainly tied to geomorphic position. More exposed slopes and ridges support Grey Box – Forest Red Gum grassy woodland (HN529). This vegetation type grades into Forest Red Gum – Grey Box shrubby woodland (HN524) in steeper, south facing and more sheltered areas, which is distinguished from adjoining grassy woodlands on shale by the presence of a denser shrub layer and mesic understorey species. There is a small isolated patch of Grey Myrtle dry rainforest (HN538) on a sheltered alluvial slope and linear strips of Forest Red Gum - Rough-barked Apple grassy woodland (HN526) associated with drainage lines. Each of these vegetation types have been cleared, grazed and subject to weed infestation to varying degrees with areas of moderate/good and moderate/good – poor condition vegetation.

There are moderate infestations of noxious weeds, such as African Olive (*Olea europea* subsp. *cuspidata*) and Blackberry (*Rubus fruticosus* spp. agg.) across sections of the site. Other weeds present on site in lower numbers include Lantana (*Lantana camara*), Small-leaved Privet (*Ligustrum* sinense), Fireweed (*Senecio madagascariensis*), African Boxthorn (*Lycium ferocissimum*), Bridal Creeper (*Asparagus asparagoides*), Green Cestrum (*Cestrum parqui*), Moth Vine (*Araujia sericifera*) and Prickly Pear (*Opuntia stricta*).

Portions of the site have been grazed and canopy vegetation has been extensively cleared or thinned historically. Much of the biobank is now covered with native vegetation, with areas of ‘low’ condition (namely those that lack a native understorey, midstorey or canopy) being excluded from the site. Mid-storey vegetation has established across the majority of the biobank though there are very few over storey species in areas of poor condition vegetation. There are mature hollow-bearing trees in low densities throughout areas of moderate/good condition vegetation at the biobank. There are no hollow-bearing trees within areas of poor condition vegetation.

The biobank site includes vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland, and Grey-headed Flying-fox habitat (specifically only vegetation zones with native over storey cover greater than 10 per cent). There are also areas of poorer quality Cumberland Plain Woodland that comprises derived grassland but which could be managed to improve in quality and become EPBC Act Cumberland Plain Woodland. These areas have minimal canopy cover and do not

contain foraging resources for the Grey-headed Flying Fox. Vegetation zones and habitat for the affected threatened biota at the Stage 1 Montpelier biobank site are presented in Table 29. Matching biodiversity credits from all vegetation zones, including Low condition vegetation, would be suitable for offsetting impacts on the environment.

Table 29 Vegetation zones, habitat for the affected threatened biota and available biodiversity credits at the Menangle Road biobank (GHD 2015e)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland (ha)[2]	Area of Habitat for Grey-headed Flying fox[3] (ha)	Available biodiversity credits
Forest Red Gum - Grey Box shrubby woodland	HN524	Moderate/good	3.44	CEEC	EEC	0		3.44	29
Forest Red Gum - Rough-barked Apple grassy woodland	HN526	Moderate/good	5.01		EEC	0		5.01	36
Grey Box - Forest Red Gum grassy woodland on shale	HN529	Moderate/good	26.96	CEEC	CEEC	26.96		26.96	255
Grey Box - Forest Red Gum grassy woodland on shale (poor)	HN529	Moderate/good - poor	21.08		CEEC	0	21.08	0	199
Grey Myrtle dry rainforest	HN538	Moderate/good	0.58	CEEC	EEC	0		0.58	6
		Total	**57.07**			**26.96**	**21.08**	**35.99**	**525**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010).

2) Derived native scrub or grassland with <10 per cent native canopy cover and predominantly native understorey that does not comprise EPBC Act Cumberland Plain Woodland in accordance with the conservation advice for the community (DEWHA 2010) and that is linked to biodiversity credits that are available for sale.

3) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009).

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Bruelle biobank

The ‘Bruelle biobank’ offset site is a proposed biobank on privately owned land that has been subject to a detailed field survey and BioBanking assessment and has already been set aside for conservation under a BioBanking agreement. The site has been subject to a detailed field survey and a preliminary BioBanking assessment but has not yet been set aside for conservation under a BioBanking agreement. The description of the site presented below is based on the information presented in the BioBanking assessment report for the site (GHD 2015f). The remaining steps involved with finalising the BioBanking assessment include definition of site boundaries, BioBanking credit calculations and preparation of a MAP. As discussed for similar proposed biobanks above, the description of the biodiversity values at the site that is included below is unlikely to substantially change but will be reassessed prior to the final delivery of the offset package for the proposed airport and the total quantum of offset will be adjusted if required.

The Bruelle biobank includes 28 hectares of land and is located at Mulgoa within Penrith LGA. It falls within the Hawkesbury Nepean CMA region and within the Sydney Basin Bioregion. The biobank is currently zoned E2 Environmental Conservation under the *Penrith City Council Local Environment Plan 2010* and was grazed by cattle prior to being set aside as a biobank.

The Bruelle biobank is bound to the west by the Notre Dame estate and to the north, east and south by rural residential adjoining properties. The biobank site is approximately 1 km to the east of the Nepean River and lies on the northern edge of the village of Mulgoa and approximately 10 km south of Penrith town centre.

There are four NSW vegetation types at the biobank. The biobank site comprises undulating hills on shale substrate which are dissected by a deeply incised gully that exposes the underlying lithic sandstone substrate. The ridge and upper slopes of this gully support Red Bloodwood - Grey Gum woodland (HN564), which is dominated by Grey Gum (*Eucalyptus punctata)* and Smooth-barked Apple (*Angophora costata*)*.* HN564 transitions into Grey Myrtle dry rainforest (HN538) at lower elevations, where the gully becomes steeper and more sheltered. HN538 is dominated by Grey Myrtle (*Backhousia myrtifolia*) and Rusty Fig (*Ficus rubiginosa*)*.*

The slopes of the north east and southern extents of the site feature Grey Box - Forest Red Gum grassy woodland (HN529), which comprises an occurrence of Cumberland Plain Woodland. HN529 features a canopy of Forest Red Gum) and Narrow-leaved Ironbark. The mid-slopes that occupy the central region of the site are influenced by the shale derived soils above the lithic sandstone substrate. Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest (HN556) dominates this area and displays a canopy of Narrow-leaved Ironbark, Grey Gum and Forest Red Gum. This vegetation type is an occurrence of Shale/Sandstone Transition Forest, which is listed as an EEC under the TSC Act and EPBC Act.

The biobank site includes vegetation zones which qualify as the EPBC Act listed form of Cumberland Plain Woodland, and Grey-headed Flying-fox habitat (specifically only vegetation zones with native over storey cover greater than 10 per cent). Vegetation zones and habitat for the affected threatened biota at the Stage 1 Bruelle biobank site are presented in Table 30. Matching biodiversity credits from all vegetation zones would be suitable for offsetting impacts on the environment.

Table 30 Vegetation zones, habitat for the affected threatened biota and available biodiversity credits at the Bruelle biobank (GHD 2015f)

Vegetation Zone	Veg Type ID	Condition	Area (ha)	EPBC Act Status	TSC Act Status	Area of EPBC Act Cumberland Plain Woodland[1] (ha)	Area of poorer quality Cumberland Plain Woodland (ha)	Area of Habitat for Grey-headed Flying fox[2] (ha)	Available biodiversity credits
Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest	HN556	Moderate/ good	11.6	CEEC	EEC	0	0	11.6	129
Grey Box - Forest Red Gum grassy woodland on shale	HN529	Moderate/ good	14.4	CEEC	CEEC	14.4	0	14.4	141
Red Bloodwood - Grey Gum woodland	HN564	Moderate/ good	1.2			0	0	1.2	10
Grey Myrtle dry rainforest	HN538	Moderate/ good	0.3			0	0	0.3	3
		Total	**27.5**			**14.4**	**0**	**27.5**	**283**

Notes: 1) Features >10 per cent native canopy cover and predominantly native understorey in accordance with the conservation advice for the community (DEWHA 2010).

2) Comprises critical foraging habitat as defined in the recovery plan for the species (DECCW 2009).

Appendix B – BioBanking Credit Calculations

Assessment of geographic / habitat features

Impact?[1]	Common name	Scientific name	Feature
☑ ☑ ☑	Cumberland Plain Land Snail	*Meridolum corneovirens*	land containing bark or leaf litter accumulation
☐ ☐ ☐	Large-eared Pied Bat	*Chalinolobus dwyeri*	land containing escarpments, cliffs, caves, deep crevices, old mine shafts or tunnels
☐ ☐ ☐	Matted Bush-pea	*Pultenaea pedunculata*	land within 5 km of coast in South East Coastal Plains CMA subregion
☑ ☑ ☑	Camden White Gum	*Eucalyptus benthamii*	alluvial soils
☑ ☑ ☑	Green and Golden Bell Frog	*Litoria aurea*	land within 100 m of emergent aquatic or riparian vegetation
☑ ☑ ☑	*Hypsela sessiliflora*	*Hypsela sessiliflora*	Wet and damp areas only.
☑ ☑ ☑	*Wahlenbergia multicaulis* (Tadgells Bluebell) population, Auburn, Bankstown, Baulkham Hills, Canterbury, Hornsby, Parramatta and Strathfield local government areas	*Wahlenbergia multicaulis - endangered population*	land situated in damp, disturbed sites
☑ ☑ ☑	Black Bittern	*Ixobrychus flavicollis*	land within 40 m of freshwater and estuarine wetlands, in areas of permanent water and dense vegetation or emergent aquatic vegetation
☐ ☐ ☐	Eastern Osprey	*Pandion cristatus*	land within 40 m of fresh/brackish/saline waters of larger rivers or creeks; estuaries, coastal lagoons, lakes and/or inshore marine waters
☑ ☑ ☑	Austral Pillwort	*Pilularia novae-hollandiae*	periodically waterlogged sites (including table drains and farm dams)
☑ ☑ ☑	Rosenbergs Goanna	*Varanus rosenbergi*	land within 250 m of termite mounds or rock outcrops
☑ ☑ ☑	Giant Burrowing Frog	*Heleioporus australiacus*	land within 40 m of heath, woodland or forest
☑ ☑ ☑	Comb-crested Jacana	*Irediparra gallinacea*	land within 40 m of permanent wetlands with a good surface cover of floating vegetation
☑ ☑ ☑	Australasian Bittern	*Botaurus poiciloptilus*	land containing brackish or freshwater wetlands

Note: 1) The habitat features are present at the site and would be removed by the proposed development.

Survey-time matrix for threatened species

Common name	Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Allocasuarina glareicola	*Allocasuarina glareicola*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Austral Pillwort	*Pilularia novae-hollandiae*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Australasian Bittern	*Botaurus poiciloptilus*	Yes	Yes	**Yes**	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes
Bargo Geebung	*Persoonia bargoensis*	Yes	Yes	**Yes**	**Yes**	**Yes**							Yes
Black Bittern	*Ixobrychus flavicollis*	Yes	Yes	**Yes**	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes
Brown Pomaderris	*Pomaderris brunnea*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bynoes Wattle	*Acacia bynoeana*	Yes	Yes	**Yes**						Yes	Yes	Yes	Yes
Camden White Gum	*Eucalyptus benthamii*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Comb-crested Jacana	*Irediparra gallinacea*	Yes	Yes	**Yes**	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes
Cumberland Plain Land Snail	*Meridolum corneovirens*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dillwynia tenuifolia	*Dillwynia tenuifolia*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dillwynia tenuifolia (a shrub) population, Kemps Creek	*Dillwynia tenuifolia - endangered population Kemps Creek*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Downy Wattle	*Acacia pubescens*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dwarf Kerrawang	*Rulingia prostrata*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Eastern Pygmy-possum	*Cercartetus nanus*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Gang-gang Cockatoo population, Hornsby and Ku-ring-gai Local Government Areas	*Callocephalon fimbriatum population in the Hornsby and Ku-ring-gai Local Government Areas*	Yes	Yes	**Yes**	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes
Giant Burrowing Frog	*Heleioporus australiacus*	Yes	Yes	**Yes**	**Yes**	**Yes**				Yes	Yes	Yes	Yes
Green and Golden Bell Frog	*Litoria aurea*	Yes	Yes	**Yes**					Yes	Yes	Yes	Yes	Yes
Gyrostemon thesioides	*Gyrostemon thesioides*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hibbertia sp. Bankstown	*Hibbertia sp. Bankstown*									Yes	Yes	Yes	Yes
Hypsela sessiliflora	*Hypsela sessiliflora*									Yes	Yes	Yes	
Juniper-leaved Grevillea	*Grevillea juniperina subsp. juniperina*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Koala	*Phascolarctos cinereus*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marsdenia viridiflora subsp. viridiflora in the Bankstown, Blacktown,	*Marsdenia viridiflora subsp. viridiflora - endangered population*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Common name	Scientific name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas													
Micromyrtus minutiflora	*Micromyrtus minutiflora*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Nodding Geebung	*Persoonia nutans*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pimelea curviflora subsp. curviflora	*Pimelea curviflora subsp. curviflora*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pultenaea parviflora	*Pultenaea parviflora*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Regent Honeyeater	*Anthochaera phrygia*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rosenbergs Goanna	*Varanus rosenbergi*	Yes	Yes									Yes	Yes
Small-flower Grevillea	*Grevillea parviflora subsp. parviflora*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spiked Rice-flower	*Pimelea spicata*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Squirrel Glider	*Petaurus norfolcensis*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sydney Plains Greenhood	*Pterostylis saxicola*									Yes	Yes	Yes	
Tall Knotweed	*Persicaria elatior*	Yes	Yes	**Yes**	**Yes**	**Yes**							Yes
Wahlenbergia multicaulis (Tadgells Bluebell) population, Auburn, Bankstown, Baulkham Hills, Canterbury, Hornsby, Parramatta and Strathfield local government areas	*Wahlenbergia multicaulis - endangered population*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes
White-flowered Wax Plant	*Cynanchum elegans*	Yes	Yes	**Yes**	**Yes**	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: 'Yes' indicates that targeted surveys for the individual species can be conducted in that month; '**Yes**' (i.e. bold type) indicates that targeted surveys for the individual species were conducted in that month as part of the biodiversity assessment.

Likelihood of occurrence of species credit-type species not targeted by seasonal surveys

Scientific name	Common name	TSC Status	EPBC Status	Habitat association	Desktop assessment results	Habitat present in the study area	Likelihood of occurrence in the airport site	Risk of impact
Hypsela sessiliflora syn. Isotoma sessiliflora		E	X	Currently known from a single location less than 10x15m on the Cumberland Plain in western Sydney. Known to grow in damp places, on the Cumberland Plain, including freshwater wetland, grassland/alluvial woodland and an alluvial woodland/shale plains woodland (Cumberland Plain Woodland) ecotone. May be an early successional species that benefits from some disturbance. Possibly out competed when overgrown by some species such as *Cynodon dactylon*. Considered extinct under the EPBC Act and may not be a valid taxon (Leonard, G. pers. comm.).	7 records within 10km (OEH 2015a)	Potential habitat present in wetlands and adjoining moist grassland.	Unlikely	Low. Outside of the species known, limited distribution.
Pterostylis saxicola	Sydney Plains Greenhood	E	E	Occurs in western Sydney between Picton and Freemans Reach. Grows in small pockets of shallow soil in depressions on sandstone rock shelves above cliff lines. Associated vegetation above these rock shelves is sclerophyll forest or woodland on shale or shale/sandstone transition soils.	Species or species' habitat likely to occur within 10km (DotE 2015a)	Marginal habitat present. Not previously recorded in the locality.	Unlikely	Low
Varanus rosenbergi	Rosenberg's Goanna	V	-	In NSW mainly occurs on the mid coast region from Wollemi NP to Nowra; the ACT and Goulburn regions and the South-west Slopes. Inhabits coastal heathlands, wet and dry sclerophyll forests, woodlands and mallee communities. Termite mounds are an important habitat feature: eggs are laid in the mounds in summer and incubate till spring, when the young dig themselves out. Young may return to the mound as a refuge for some months, while adults shelter in burrows dug under rocks or logs, or in rock crevices, hollow logs or even rabbit burrows (Sass 2008).	No records within 10km (OEH 2015a)	Broadly suitable habitat present. Not previously recorded in the locality.	Unlikely	Low
Hibbertia sp. Bankstown		CE	CE	Known only from Bankstown airport. Habitat is very heavily modified, lacks canopy species and is currently a low grass/shrub association with many pasture grasses and other introduced herbaceous weeds. Soil at the site is a sandy (Tertiary) alluvium with a high silt content.	No records within 10km (OEH 2015a)	No sandy alluvial soils present. Not previously recorded in the locality.	Unlikely	Low. Outside of the species known, limited distribution.

Biodiversity credit report

This report identifies the number and type of biodiversity credits required for a major project.

Date of report: 21/08/2015 Time: 5:38:33PM Calculator version: v4.0

Major Project details

Proposal ID:	073/2015/2144MP
Proposal name:	Western Sydney Airport
Proposal address:	The airport site Badgerys Creek NSW 2555
Proponent name:	Western Sydney Unit Department of Infrastructure and Regional Development
Proponent address:	GPO Box 594 Canberra ACT 2601
Proponent phone:	02 6210 6089
Assessor name:	Ben Harrington
Assessor address:	Level 15 133 Castlereagh Street Sydney NSW 2000
Assessor phone:	02 9239 7189
Assessor accreditation:	073

Summary of ecosystem credits required

Plant Community type	Area (ha)	Credits created
Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion	2.58	181.21
Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion	34.05	1,657.41
Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion	179.06	6,763.37
Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion	39.61	1,398.41
Phragmites australis and Typha orientalis coastal freshwater wetlands of the Sydney Basin Bioregion	25.44	700.00
Total	280.74	10,700

Credit profiles

1. Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion, (HN526)

Number of ecosystem credits created	1,657
IBRA sub-region	Cumberland - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion, (HN526) Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion, (HN528)	Cumberland - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

2. Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion, (HN528)

Number of ecosystem credits created	6,763
IBRA sub-region	Cumberland - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion, (HN528) Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion, (HN526)	Cumberland - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

3. Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion, (HN529)

Number of ecosystem credits created	1,398
IBRA sub-region	Cumberland - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Grey Box - Forest Red Gum grassy woodland on shale of the southern Cumberland Plain, Sydney Basin Bioregion, (HN529) Forest Red Gum - Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Basin Bioregion, (HN526) Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion, (HN528)	Cumberland - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

4. Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion, (HN512)

Number of ecosystem credits created	181
IBRA sub-region	Cumberland - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Broad-leaved Ironbark - Grey Box - Melaleuca decora grassy open forest on clay/gravel soils of the Cumberland Plain, Sydney Basin Bioregion, (HN512) Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion, (HN513) Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion, (HN604) Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain, Sydney Basin Bioregion, (HN556)	Cumberland - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

5. Phragmites australis and Typha orientalis coastal freshwater wetlands of the Sydney Basin Bioregion, (HN630)

Number of ecosystem credits created	700
IBRA sub-region	Cumberland - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Phragmites australis and Typha orientalis coastal freshwater wetlands of the Sydney Basin Bioregion, (HN630) Coastal freshwater lagoons of the Sydney Basin Bioregion and South East Corner Bioregion, (HN520)	Cumberland - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

Summary of species credits required

Common name	Scientific name	Extent of impact Ha or individuals	Number of species credits created
Pultenaea parviflora	Pultenaea parviflora	4.00	60
Marsdenia viridiflora subsp. viridiflora in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith local government areas	Marsdenia viridiflora subsp. viridiflora - endangered population	93.00	3,720
Cumberland Plain Land Snail	Meridolum corneovirens	120.60	1,568
Black Bittern	Ixobrychus flavicollis	55.30	719
Southern Myotis	Myotis macropus	29.80	656

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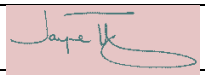
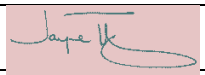
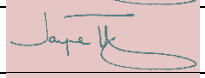
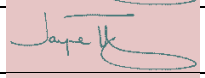
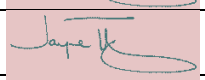
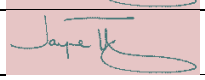
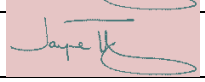
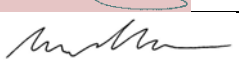
0	B Harrington	J Tipping		J Tipping		23/7/15
1	B Harrington	J Tipping		J Tipping		28/8/15
2	B Harrington	J Tipping		J Tipping		4/9/15
3	B Harrington	J Tipping		B Harrington		6/10/15

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Appendix L1
Surface water hydrology and geomorphology



Department of Infrastructure and Regional Development

Western Sydney Airport EIS

Surface Water Hydrology and Geomorphology

October 2015

Limitations

GHD has prepared this report pursuant to the conditions in the Department of Infrastructure and Regional Development Deed of Standing Quotation (SON2030181), the Commonwealth RFQTS Number 2014/7540/001, the subsequent response accepted and referenced in the relevant Official Order (collectively the “Contract”):

In particular, this report has been prepared by GHD for the Commonwealth (and to the extent expressly stated in the Contract (and for the purposes stated therein) the parties referred to in the Contract (“Other Parties”) and may only be used and relied on by the Commonwealth and the Other Parties in accordance with the Contract for the purpose agreed between GHD and the Commonwealth as set out in the Contract.

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Executive summary

This report presents an assessment of the impacts of the proposed Western Sydney Airport (proposed airport) on surface hydrology and geomorphology during construction, operation of the Stage 1 Development, and operation of the longer term development. The assessment includes definition of the existing environment both on and off the site with respect to watercourse type, quantities of estimated surface water and potential flooding. The assessment was carried out through desktop analysis, site inspections and hydrologic and hydraulic modelling of the site and related catchments. An assessment was also made of the sensitivity of the watercourses downstream of the site to changes in flow hydraulics. Nearby flood-affected residences were also identified in the review of flood impacts.

The indicative Stage 1 and longer term airport layouts and specifications were reviewed and an assessment was made of the potential for impacts on surface water sources. The impact analysis includes consideration of the sensitivity of the existing creeks and surrounding environment to change, together with the results of predictive modelling of surface water hydrology and hydraulics for Stage 1 and for the longer term airport.

Specific indicators of impact include changes in discharge from the site, changes in watercourse bed shear stress and changes in downstream water level. Consideration was also given to biodiversity that could be affected by changes to surface water flows, based on the findings of the biodiversity assessment carried out for this environmental impact statement (EIS). Potential groundwater changes are also considered for their impact on surface water sources.

The study finds that construction of the proposed airport would result in a major modification of the site in terms of land use characteristics and surface water runoff generated. It would also result in removal of a large number of watercourses and farm dams. The effects of these changes is mitigated by the inclusion in the design of a number of detention basins, though the strategy does not eliminate impacts altogether.

During construction, a detailed surface water management plan would be developed and would need to consider the impacts of flooding on-site over the course of the construction period.

Downstream of the site, the assessment finds that the detention basin strategy would be effective at limiting the downstream impact such that any increases in flood level would not worsen flooding to surrounding roads and dwellings. The risk to changes in creek geomorphology would be low, other than for a short reach of Oaky Creek and a tributary of Badgerys Creek.

Some localised increases and decreases in water level are predicted downstream of the site.

The assessment considers the potential for the cumulative impacts of climate change to exacerbate the environmental impacts of the proposed airport and also to increase susceptibility of the airport infrastructure to flooding. Aspects of climate change science, particularly as they relate to flooding, are still developing and the effect of climate change on the proposed airport cannot be determined with certainty. It is concluded that current and emerging advice should be considered as the airport design is finalised.

The cumulative impact of potential future development surrounding the airport was also considered.

The assessment finds that there is a need to further develop the detention basin strategy during design development, such that the basins would be effective at mimicking natural flows as closely as possible across a range of storm durations and magnitudes, including low and high flows. Consideration would need to be given to providing a basin or other form of water quantity detention on a tributary of Duncans Creek prior to discharge from the site.

Another mitigation requirement would be to ensure that any future development in the vicinity of Badgerys Creek where it passes through the site would be appropriate for a third order creek. This would involve protecting and preserving the habitat and riparian corridor and ensuring no worsening of flooding downstream.

During construction, demands on potable water would be high and there would be a need to develop a strategy for water supply to the airport site to meet the construction requirements as well as the ongoing operational water requirements. During operation, use of potable water on site would be supplemented with recycled water to reduce demand on potable water.

The effects of the proposed airport on surface water quality and groundwater are discussed in separate reports.

Glossary and abbreviations

Term	Definition
Annual exceedance probability (AEP)	The annual exceedance probability is a measure of the frequency of a rainfall event. It is the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. A one per cent event is a rainfall event with a one per cent chance of being exceeded in magnitude in any year. The current Australian Rainfall and Runoff recommendations (Institute of Engineers, Australia, 1987) are for use of AEP terminology rather than Average Recurrence Interval (ARI) terminology (refer below). However, for consistency with the hydrological modelling undertaken, Average Recurrence Interval terminology is used in this report.
Afflux	With reference to flooding, afflux refers to the predicted change, usually in flood levels, between two scenarios. It is frequently used as a measure of the change in flood levels between an existing scenario and a proposed scenario.
Airport	Western Sydney Airport
Airport site	The airport site is the total of all properties that may become part of Western Sydney Airport. The airport site includes existing Commonwealth land and land to be acquired by the Commonwealth, such as The Northern Road.
Airport features	Specific features of the proposed airport, such as runways, taxiways, terminal buildings or hangars.
Alluvium	Unconsolidated deposit of gravel, sand or mud formed by water flowing in identifiable channels. Commonly well sorted and stratified.
Australian Height Datum (AHD)	A common reference level used in Australia which is approximately equivalent to the height above sea level.
Average recurrence interval (ARI)	The average recurrence interval, like the annual exceedance probability, is a measure of the frequency of a rainfall event. The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. For example, a 100-year average recurrence interval event occurs or is exceeded on average once every 100 years. It is important to note that the ARI is an average period and it is implicit in the definition of the ARI that the periods between exceedances are generally random. Average recurrence intervals of greater than ten years are closely approximate to the reciprocal of the annual exceedance probability. A 100-year average recurrence interval is therefore approximately equivalent to a 1 per cent annual exceedance probability event. See also annual exceedance probability.

Term	Definition
Badgerys Creek	Badgerys Creek is a suburb in western Sydney and the general locality of the proposed airport, which is about 50 kilometres west of the Sydney central business district. Badgerys Creek is also the name of a watercourse which is referred to in this report.
Catchment	The area drained by a stream or body of water or the area of land from which water is collected.
Consent	Approval to undertake a development received from the consent authority.
Datum	A level surface used as a reference in measuring elevations.
DEM	Digital elevation model
Discharge	Quantity of water per unit of time flowing in a stream, for example cubic meters per second or megalitres per day.
DRAINS modelling	DRAINS is a multi-purpose software program for designing and analysing urban stormwater drainage systems and catchments.
Ephemeral	A stream that is usually dry, but may contain water for rare or irregular periods, usually after significant rainfall.
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
Flood	For the purposes of this report, a flood is defined as the inundation of normally dry land by water which escapes from, is released from, is unable to enter, or overflows from the normal confines of a natural body of water or watercourse such as rivers, creeks or lakes, or any altered or modified body of water, including dams, canals, reservoirs and stormwater channels.
Flood liable land	Land which is within the extent of the probable maximum flood and therefore prone to flooding.
Floodplain	The area of land subject to inundation by floods up to and including the probable maximum flood.
Floodway	The area of the floodplain where a significant portion of flow is conveyed during floods. Usually aligned with naturally defined channels.
Formation	A fundamental unit used in the classification of rock or soil sequences, generally comprising a body with distinctive physical and chemical features.
Geomorphology	Scientific study of landforms, their evolution and the processes that shape them. In this report, geomorphology relates to the form and structure of watercourses.
Groundwater	Subsurface water stored in pores of soil or rocks.
Hazard	The potential or capacity of a known or potential risk to cause adverse effects.
Headward erosion	The upstream lengthening and/or cutting of a valley or gully at its head, as the stream erodes away the rock and soil at its headwaters in the opposite direction that it flows.

Term	Definition
Hydraulic conductivity	The rate at which water at the prevailing kinematic viscosity will move under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow, usually expressed in metres per day (this assumes a medium in which the pores are completely filled with water).
Hydraulics	The physics of channel and floodplain flow relating to depth, velocity and turbulence.
Hydrograph	A graph which shows how a water level at any particular location changes with time.
Hydrology	The study of rainfall and surface water runoff processes.
Impervious	In the context of this report, impervious surfaces are surfaces non-permeable to water. These include hardstanding areas such as paved surfaces.
Infiltration	The downward movement of water into soil and rock, which is largely governed by the structural condition of the soil, the nature of the soil surface (including presence of vegetation) and the antecedent moisture content of the soil.
Landform	A specific feature of the landscape or the general shape of the land.
Light Detection and Ranging (LiDAR)	LiDAR is a remote sensing method used to examine the surface of the Earth. LiDAR has been used in this study to define the topography of the airport site and surroundings.
Longer term development	A future stage in the development of the proposed airport, where the airport is assumed to comprise parallel runways and handling approximately 82 million passengers annually. The EIS assumes this occurs in 2063 for assessment purposes.
LPI	NSW Land and Property Information
Meteorology	The science concerned with the processes and phenomena of the atmosphere, especially as a means of forecasting the weather.
MIKE21 modelling	MIKE21 is a two dimensional hydraulic modelling software program used to simulate surface flow and estimate flood levels and flow velocities.
Monitoring well/bore	A hole sunk into the ground and completed for the abstraction or injection of water or for water observation purposes. Generally synonymous with bore.
MUSIC modelling	MUSIC is a software program used to estimate the performance of stormwater quality management systems.
Newtons per square metre (N/m^2)	A measure of force per unit area, in this case, per square metre. In this report it is used to measure stream bed shear stress i.e. the force of water acting parallel to the stream bed. The level of shear stress is used as an parameter for prediction of the movement of stream bed sediments.
Overbank	The portion of the flow that extends over the top of watercourse banks.

Term	Definition
Overland flow path	The path that water can follow if it leaves the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Water travelling along overland flow paths, often referred to as 'overland flows', may either re-enter the main channel or may be diverted to another watercourse.
Permeability	The capacity of a porous medium to transmit water.
Pluviograph	A rain gauge with the capability to record data in real time to observe rainfall over a short period of time.
Probable maximum flood (PMF)	The probable maximum flood is the maximum flood which can theoretically occur based on the worst combination of the probable maximum precipitation and flood-producing catchment conditions that are reasonably possible at a given location.
Probable maximum precipitation (PMP)	The probable maximum precipitation is the greatest amount of rainfall which can theoretically occur over a given duration (period of time) for a particular geographical location.
RAFTS modelling	XP-RAFTS is a hydrology modelling software program used to simulate urban and rural runoff and routing through a watershed based on catchment characteristics and rainfall events.
Reach	Defined section of a stream with uniform character and behaviour.
Recharge	Addition of water to the zone of saturation; also the amount of water added. An area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.
Riparian	Pertaining to, or situated on, the bank of a river or other water body.
Risk	The chance of something happening that will have an impact measured in terms of likelihood and consequence.
Risk assessment	Systematic process of evaluating potential risks of harmful effects on the environment from exposure to hazards associated with a particular product or activity.
River Styles® framework	A geomorphic approach for examining river character, behaviour, condition and recovery potential which provides a template for river management.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Salinity	The total soluble mineral content of water or soil (dissolved solids); concentrations of total salts are expressed as milligrams per litre (equivalent to parts per million).
Sediment	Material of varying sizes that has been or is being moved from its site of origin by the action of wind, water or gravity.

Term	Definition
Sinuosity	Extent of curvature or meandering of a stream. Highly sinuous streams meander over a low gradient and short distance. Low sinuosity streams are straighter and have a steeper gradient.
Stream order	Stream classification system, where order 1 is for headwater (new) streams at the top of a catchment. Order number increases downstream using a defined methodology relating to the branching of streams.
Stage 1 (or initial) development	The initial stage in the development of the airport, including a single runway and handling approximately 10 million passengers annually. The EIS assumes 10 million passengers is reached in 2030 for assessment purposes.
Study area	The subject site and any additional areas which are likely to be affected by the proposal, either directly or indirectly. The study area extends as far as is necessary to take all potential impacts into account.
Surface water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Topography	Representation of the features and configuration of land surfaces.
Watercourse	Generic term used to refer to rivers, streams and creeks.
Water quality	Chemical, physical and biological characteristics of water. Also the degree (or lack) of contamination.
Water sharing plan	A legal document prepared under the *Water Management Act 2000* (NSW) that establishes rules for sharing water between the environmental needs of the river or aquifer and water users and also different types of water use.
Water table	The surface of saturation in an unconfined aquifer, or the level at which pressure of the water is equal to atmosphere pressure.
Western Sydney Airport	The airport proposed on the Commonwealth owned land at Badgerys Creek and assessed in accordance with the Western Sydney Airport environment impact statement.

Table of contents

1. Introduction 1
   - 1.1 Background 1
   - 1.2 Scope of the assessment 2
   - 1.3 Study area 2
   - 1.4 Structure of this report 2
2. Legislation and guidelines 5
   - 2.1 Environment Protection and Biodiversity Conservation Act 1999 5
   - 2.2 NSW Water Management Act 5
   - 2.3 Other policies and guidelines 6
3. Methodology 9
   - 3.1 Overview 9
   - 3.2 Data collection and review 9
   - 3.3 Existing environment modelling and analysis 12
   - 3.4 Stage 1 and longer term modelling and analysis 16
   - 3.5 Impact assessment 21
4. Existing environment 27
   - 4.1 Topography 27
   - 4.2 Land use 27
   - 4.3 Rainfall 27
   - 4.4 Surface water sources 28
   - 4.5 Hydrology and flooding 31
   - 4.6 Watercourse geomorphology 40
   - 4.7 Related features 44
5. Construction impacts 45
   - 5.1 Flooding and waterlogging 45
   - 5.2 Mobilisation of soils 45
   - 5.3 Watercourse geomorphology 45
   - 5.4 Groundwater seepage 46
   - 5.5 Construction water use 46
6. Operational impacts 49
   - 6.1 Stage 1 development 49
   - 6.2 Longer term development 63
7. Cumulative impacts 75
   - 7.1 Influence of climate change 75
   - 7.2 Influence of future urban development in the catchment 78
8. Mitigation and management measures 79
   - 8.1 Construction 79
   - 8.2 Operation 79

9. Summary and conclusion 83
10. References 85

Table index

Table 3-1 Key reference documents and data 9
Table 3-2 Landuse types and adopted impervious percentages 13
Table 3-3 Summary of existing catchment areas and impervious percentages 15
Table 3-4 Hydraulic model adopted roughness values 16
Table 3-5 Typical Annual Recurrence Intervals for Aerodromes 17
Table 3-6 CSIRO indicative change in rainfall one-day totals (CSIRO, 2007) 25
Table 4-1 Badgerys Creek AWS rainfall gauge data 27
Table 4-2 Critical storm durations modelled in RAFTS 31
Table 4-3 Peak flows at selected locations, existing conditions 32
Table 6-1 Catchment area comparison between existing and Stage 1 49
Table 6-2 Detention basin attenuation volume 50
Table 6-3 Catchment area comparison between the existing environment and the longer term development 63
Table 6-4 Longer term detention basin attenuation volume 64
Table 8-1 Impact and mitigation summary 81
Table A-1 Validation of model 98
Table A-1-2 Rainfall totals for 21 and 22 April 2015 99

Figure index

Figure 1-1 Airport site and surface water study area 3
Figure 3-1 Hydrology assessment existing subcatchment boundaries 14
Figure 3-2 Hydraulic model extent and key hydraulic structures 18
Figure 3-3 Key stormwater features – initial development 19
Figure 3-4 Key stormwater features – longer term development 20
Figure 3-5 Hydrology assessment Stage 1 subcatchment boundaries 22
Figure 3-6 Hydrology assessment longer term subcatchment boundaries 23
Figure 4-1 Monthly rainfall statistics at Badgerys Creek AWS 28
Figure 4-2 Local hydrological catchments 30
Figure 4-3 Locations of reported results for existing conditions 33

Figure 4-4 Badgerys Creek hydrograph at Elizabeth Drive, 100 year ARI event 6 hour storm duration 34
Figure 4-5 Cosgroves Creek hydrograph at confluence with Elizabeth Drive, 100 year ARI event 2 hour storm duration 34
Figure 4-6 Existing flood depths 1 year ARI event 36
Figure 4-7 Existing flood depths 5 year ARI event 37
Figure 4-8 Existing flood depths 100 year ARI event 38
Figure 4-9 Existing flood depths PMF 39
Figure 4-10 Watercourse stream order 41
Figure 4-11 Watercourse type 42
Figure 5-1 Stage 1 earthworks with watercourse stream order 48
Figure 6-1 Location A at Basin 1, comparison of existing and Stage 1 flows 51
Figure 6-2 Location B at Basin 2, comparison of existing and Stage 1 flows 51
Figure 6-3 Location C at Basin 3, comparison of existing and Stage 1 flows 52
Figure 6-4 Location D at Basin 4, comparison of existing and Stage 1 flows 52
Figure 6-5 Location E and F, comparison of existing and Stage 1 flows (no basin proposed) 53
Figure 6-6 Locations G and H, comparison of existing and Stage 1 flows 53
Figure 6-7 Locations I, comparison of existing and Stage 1 flows 54
Figure 6-8 Locations J, comparison of existing and Stage 1 flows 54
Figure 6-9 Location K, comparison of existing and Stage 1 flows 55
Figure 6-10 Location L, comparison of existing and Stage 1 flows 55
Figure 6-11 Flood depth impact, Existing and Stage 1, 1 year ARI event 58
Figure 6-12 Flood depth impact, Existing and Stage 1, 5 year ARI event 59
Figure 6-13 Flood depth impact, Existing and Stage 1, 100 year ARI event 60
Figure 6-14 Location A at Basin 1, comparison of existing and longer term flows 65
Figure 6-15 Location B at Basin 2, comparison of existing and longer term flows 65
Figure 6-16 Location C at Basin 3, comparison of existing and longer term flows 66
Figure 6-17 Location D at Basin 4, comparison of existing and longer term flows 66
Figure 6-18 Locations E and F, comparison of existing and longer term flows 67
Figure 6-19 Locations G and H, comparison of existing and longer term flows 67
Figure 6-20 Locations I, comparison of existing and longer term flows 68
Figure 6-21 Locations J, comparison of existing and longer term flows 68
Figure 6-22 Location K, comparison of existing and longer term flows 69
Figure 6-23 Location L, comparison of existing and longer term flows 69
Figure 6-24 Flood depth impact, Existing and longer term development, 1 year ARI event 71
Figure 6-25 Flood depth impact, Existing and longer term development, 5 year ARI event 72
Figure 6-26 Flood depth impact, Existing and longer term development, 100 year ARI event 73

Figure 7-1 Stage 1, Climate Change Flooding, 100 year ARI Event with 10% Increase in Rainfall Intensity....76

Figure 7-2 Longer Term, Climate Change Flooding, 100 year ARI Event with 30% Increase in Peak Rainfall Intensity....77

Appendices

Appendix A – Additional model development details

Appendix B – Hydrology results

Appendix C – Hydraulic model results

Appendix D – Hydrographs from hydraulic model

1. Introduction

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the Joint Study on Aviation Capacity in the Sydney Region (Department of Infrastructure and Transport, 2012) and A Study of Wilton and RAAF Base Richmond for civil aviation operations (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the Airports Act 1996 (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Scope of the assessment

The study assesses the impacts of the airport on:

- surface water hydrology and flooding; and
- geomorphology.

Groundwater impacts, impacts on aquatic ecology and impacts on surface water quality are discussed in separate reports. The key findings relevant to the scope of this report are included.

The key aspects of the study are to:

- describe the existing environment with respect to surface water hydrology, flooding and geomorphology;
- assess the likely impact of the airport on these features in the context of Commonwealth legislation, EIS guidelines and national, regional and local industry practice and guidelines; and
- identify measures to mitigate or manage the expected impacts.

1.3 Study area

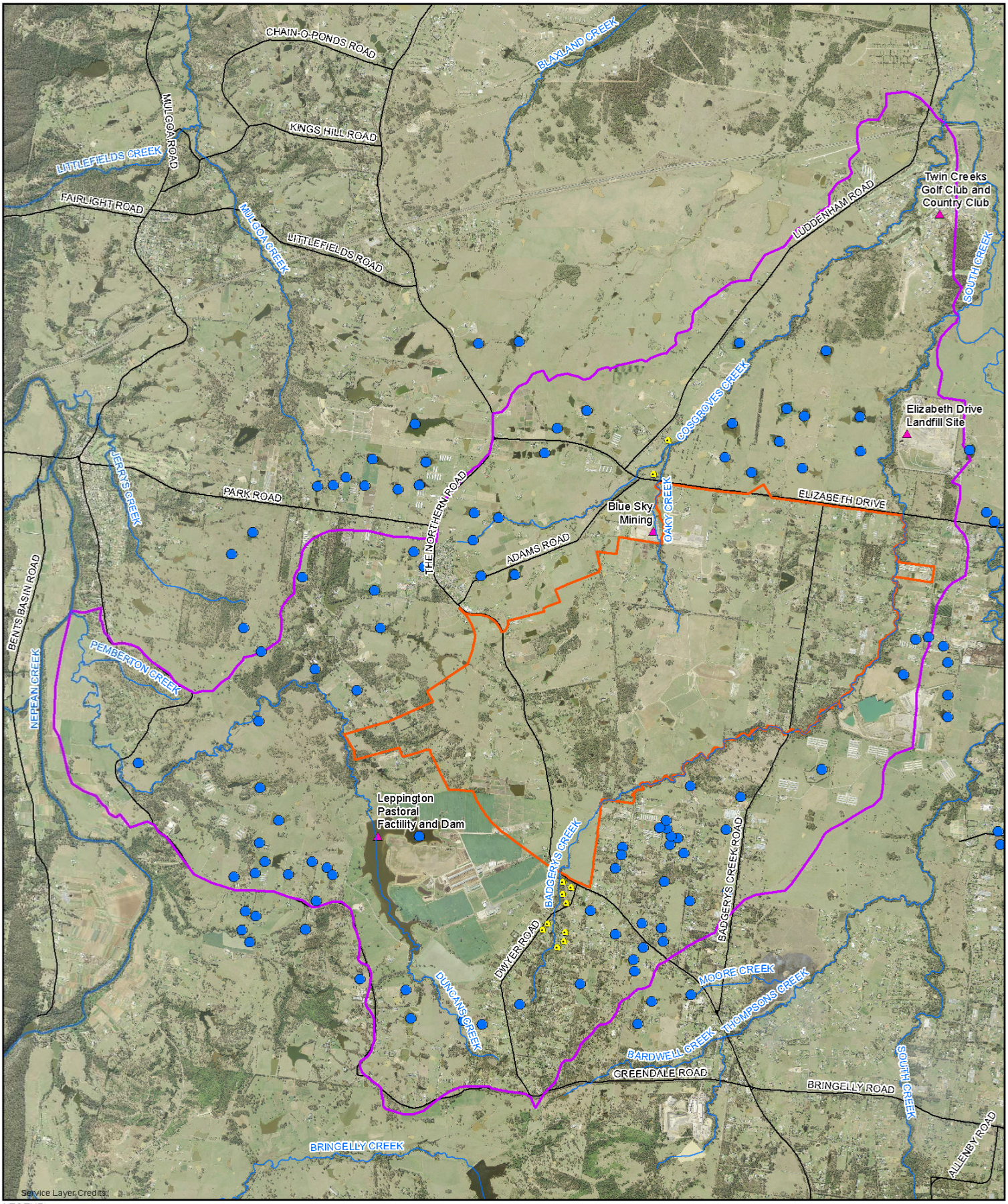
The study area for both the Stage 1 and longer term development consists of the airport site as well as the hydrological catchments of Duncans Creek to its confluence with the Nepean River, and Oaky, Cosgroves and Badgerys Creeks to their confluences with South Creek.

The airport site and the primary surface water study area are shown in Figure 1-1, together with a number of points of interest referred to in this report.

1.4 Structure of this report

The remainder of this report is structured as follows.

- **Section 2**: Provides the legislative context for the assessment including relevant policies and guidelines.
- **Section 3**: Describes in detail the methodology used in the surface water assessment, including details of the surface water modelling methodology.
- **Section 4**: Describes the existing environment, based on the findings of the desktop assessment, site visits and modelling analyses.
- **Section 5**: Describes the potential impact of the airport on surface water features during construction.
- **Section 6**: Describes the potential impact of the airport on surface water features during operation.
- **Section 7**: Assesses the likely cumulative impact of the airport together with other factors such as climate change and surrounding development.
- **Section 8**: Outlines management and mitigation measures to address the impacts.



LEGEND

- Airport site
- Watercourses
- Farm dam
- Surface water study area
- Surface water key features
- Dwellings located within or near to 1 in 100-year ARI flood extent, Badgerys/Cogroves

Paper Size A3

0 380 760 1,520

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Airport site and surface water study area

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 1-1

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2. Legislation and guidelines

The legislative requirements and guidelines relevant to this assessment are described in this section. The methodology outlined in the following sections has been developed to address the legislative and regulatory requirements

2.1 Environment Protection and Biodiversity Conservation Act 1999

The objects of the EPBC Act include to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance (MNES) and to promote the conservation of biodiversity.

MNES are relevant to surface water where either:

- surface water features form part of the natural environment associated with a MNES or
- a MNES is dependent on surface water features.

Surface water features are natural resources and are an integral part of the environment. They are relevant in the context of the EPBC Act wherever there is potential for impact upon them.

2.1.1 Environmental Impact Statement Guidelines

The Guidelines for the Content of a Draft Environmental Impact Statement, Western Sydney Airport (Australian Government, 2015), identify that impacts to the environment including hydrological changes must be assessed. Section 5 of the Guidelines (EPBC 2014/7391) require that:

(g) Impacts to the environment should include but not be limited to the following:

- *changes to siltation*
- *hydrological changes.*

This report has been prepared in accordance with the guidelines.

2.2 NSW Water Management Act

The *Water Management Act 2000* (NSW) *(WM Act)* is administered by the NSW Department of Primary Industries (DPI) Water (formerly NSW Office of Water) and is intended to ensure that water resources are conserved and properly managed for sustainable use benefitting both present and future generations. The WM Act is also intended to provide a formal means for the protection and enhancement of the environmental qualities of waterways and their in-stream uses as well as to provide for protection of catchment conditions. The intent and objectives of the WM Act have been considered as part of this assessment.

NSW Water Sharing Plans

Water sharing plans are implemented under the *Water Management Act 2000* (NSW) and specify the rules for the sharing of water between the environment and water users and between water users themselves. Water sharing plans also specify rules for the trade and management of water access licences.

The Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources (the water sharing plan), which commenced in 2011, covers 87 management zones that are grouped into six water sources. The airport is situated in the Hawkesbury and Lower Nepean Rivers catchment or source.

The Hawkesbury and Lower Nepean Rivers catchment is separated into management areas, which includes amongst others the Upper and Lower South Creek Management Zones and the Mid Nepean River Catchment Management Zone. Badgerys, Oaky and Cosgroves Creeks are interpreted to be within the Upper South Creek Management Zone, and Duncans Creek is interpreted to be within the Wallacia Weir Management Zone (one of the Mid Nepean River Catchment Management Zones).

Extraction from these zones currently occurs for irrigation and town and industrial water supply.

The water sharing rules listed in the water sharing plan for the Upper South Creek and Wallacia Weir Management Zones are summarised below.

Upper South Creek Management Zone

- Access rules stipulate at what flow rates users must cease to pump from the creek, based on A and B flow classes.
- Trading is permitted within the management zone (subject to assessment) but is not permitted into the management zone.

Wallacia Weir Management Zone

- Environmental flow protection rules apply when inflows to the dams are greater than the 80th percentile, depending on the ability of the weir to pass flows released upstream.
- Trading is permitted within the management zone and is permitted into the management zone from upstream management zones (but not from other management zones).
- Limited access to very low flows is allowed for during water shortages depending on conditions that trigger a water shortage.
- Lagoon rules prevent water trading onto a lagoon and application for new works on a lagoon.

Water Sharing Plans in relation to groundwater resources and groundwater recharge are discussed in the groundwater assessment report.

2.3 Other policies and guidelines

2.3.1 New South Wales Floodplain Development Manual

The New South Wales Floodplain Development Manual (former Department of Infrastructure, Planning and Natural Resources, 2005) concerns the management of flood-prone land within NSW. It provides guidelines in relation to the management of flood liable lands, including any development that has the potential to influence flooding, particularly in relation to increasing the flood risk to people and infrastructure.

2.3.2 Hawkesbury Nepean Catchment Action Plan

The Hawkesbury-Nepean and Sydney Metropolitan Catchment Management Authority (CMA) regions were amalgamated in late 2012. Following this, a Catchment Action Plan (CAP) for the Hawkesbury-Nepean catchment was developed and later superseded by a *Greater Sydney Local Land Service Transition Catchment Action Plan* (NSW Government, 2014).

Catchment Action Plans (CAPs) are ten year plans to guide the management of water, land and vegetation by state government and local communities.

The catchments of Badgerys Creek, Oaky Creek, Cosgroves Creek and Duncans Creek fall within the *Greater Sydney Local Land Service Transition Catchment Action Plan*. The action plan is relevant with respect to any influence the airport may have on the downstream catchments in relation to surface water and aquatic ecology.

Relevant strategies within the action plan include development of a more water sensitive catchment, promoting resilience through climate change adaptation and a number of strategies relating to protecting aquatic ecosystems.

2.3.3 Managing Urban Stormwater: Soils and Construction (Blue Book)

The NSW Government publishes the following documents about the management of erosion and sediment control during construction and other land disturbance activities.

Managing Urban Stormwater: Soils and Construction – Volume 1 (Blue Book)

The document provides guidance for local councils and practitioners on the design, construction and implementation of measures to improve stormwater management, primarily erosion and sediment control, during the construction phase of urban development.

Managing Urban Stormwater: Main road construction – Volume 2D

This document provides guidelines, principles and recommended minimum design standards for managing erosion and sediment control during the construction of main roads. The construction of main roads and highways commonly involves extensive earthworks, with significant potential for erosion and subsequent sedimentation of watercourses and the landscape, and the document therefore has been considered in the preparation of this report.

3. Methodology

3.1 Overview

The approach adopted to surface water assessment in this report includes the following steps:

- data collection and review;
- existing environment modelling and analysis;
- Stage 1 and longer term development modelling and analysis;
- impact assessment; and
- development of mitigation and management measures.

Each stage is explained in more detail below.

3.2 Data collection and review

3.2.1 Key project documents and data

Key data relevant to the project and surface water studies was collected and reviewed. Key reference documents and data are listed in Table 3-1.

Table 3-1 Key reference documents and data

Document / dataset	Data source	Description	Date
Aerial imagery	AusImage	Aerial imagery	2014
Airport Plan – Concept Plan – Longer Term Development	DIRD	Concept drawing of proposed longer term airport layout	May 2015
Airport Plan – Concept Plan – Stage 1 Development	DIRD	Concept drawing of proposed Stage 1 airport layout	May 2015
Airport Plan – Concept Plan – Stage 1 Land Use Zoning Plan	DIRD	Drawing of proposed land use zoning for Stage 1	May 2015
Airport Plan – Concept Plan – Longer Term Land Use Zoning Plan	DIRD	Drawing of proposed land use zoning for longer term development	May 2015
Stage 1 Surface Water Management Layout Plan	DIRD	Drawing of proposed surface water management strategy for Stage 1	2015
Ultimate Surface Water Management Layout Plan	DIRD	Drawing of proposed surface water management strategy for the longer term development	2015

Document / dataset	Data source	Description	Date
Draft Airport Plan – Western Sydney Airport	DIRD	Draft report as at the time of conducting the surface water assessment	May 2015
Environmental Field Survey of Commonwealth Land at Badgerys Creek	DIRD	Documentation of water quality sampling data collected by SMEC	2014
Hydrology models	DIRD	RAFTS model of the existing airport site and longer term development	2015
Hydraulic models	DIRD	MIKE 21 models of the existing airport site and longer term development	2015
LiDAR	NSW LPI	Topographical LiDAR outputs at 1 metre and 5 metre intervals	2014
Hydrolines layer	NSW LPI	Map layer defining watercourse centre lines	2012
Updated South Creek Flood Study	Worley Parsons	Flood study of South Creek and its contributing catchments	2015
Water quality models	DIRD	MIKE 21 models of the existing airport site and longer term development	2015
Western Sydney Airport – Feasibility Design Version 0.01	DIRD	Draft report as at time of conducting surface water assessment	March 2015
Western Sydney Airport Climatological Review v1	Bureau of Meteorology	Report containing analysis of climatic data from Badgerys Creek gauge	April 2015
Western Sydney Airport Usability Report v1	Bureau of Meteorology	Report documenting the meteorological parameters affecting the usability of the airport site	April 2015

A detailed list of references is provided in Section 10.

3.2.2 Review of related studies

A number of past studies investigated hydrology and flooding characteristics of the catchments of South Creek and the Nepean River. These are summarised below and relevant findings in relation to the existing environment are discussed in Section 4.

1997 – 1999 Environmental Impact Assessment

An Environmental Impact Statement for a second Sydney airport at Badgerys Creek was prepared in 1997 and updated following public consultation and review in 1999. The impacts for surface water hydrology and geomorphology documented in the *Draft Environmental Impact Statement – Second Sydney Airport Proposal* included removal of stream habitat and associated ecological impact. The focus of the water study was on surface water quality impacts.

An updated technical study associated with the 1999 EIS identified the following key impacts including associated ecological impacts:

- removal of wetland habitat;
- increases in downstream runoff; and
- changes in streamflow characteristics.

Updated South Creek Flood Study

This study was completed in January 2015 and is the most recent available flood study for the catchment of South Creek (Worley Parsons 2015). The study was prepared for Penrith Council, Liverpool City Council, Fairfield City Council and Blacktown City Council and will be used to inform floodplain management within the South Creek catchment. The study documents flooding under existing conditions and is relevant as a benchmark for definition of flood extents within the catchment.

A RAFTS hydrological model was developed for the study. The extent of the RAFTS model includes the airport site. The focus of the study was on South Creek and the available subcatchment mapping suggests that it is not of sufficient detail at the airport site for the purposes of this study.

Flood extents, levels and depths were generated using a hydraulic model. The model results cover a portion of Badgerys Creek at the airport site, but with regards to Cosgroves Creek the model does not extend as far upstream as the airport site.

Based on correspondence with the modellers who prepared the study, detailed information regarding hydraulic structures in the vicinity of the airport was not available during preparation of their study.

The study was validated against the findings of earlier studies of the South Creek catchment, including the *South Creek Flood Study* (NSW Department of Water Resources 1990) and the *South Creek Floodplain Risk Management Study and Plan* (Willing and Partners 1991).

The Updated South Creek Flood Study document was used in this assessment for the validation of findings where appropriate. The associated hydraulic models, hydrology models and input data used in the Updated South Creek Flood Study were not used in the current study. Consultation was undertaken with various parties to obtain the information but it could not be sourced in the available timeframes.

3.2.3 Field investigations

Field investigations at the airport site and surrounding areas were conducted on 6 May 2015 and 7 May 2015.

The field visits focused on the following:

- collection of details regarding key hydraulic structures (road bridge and culvert crossings);
- review of land use characteristics;
- visual inspection of watercourse condition at several locations; and
- inspection of debris marks from recent flooding, believed to be from the event which occurred between 21 April and 22 April 2015.

There were limitations on accessibility to private properties. This meant that conducting a walkover of the entire length of watercourses on the site and downstream was not possible. The available data was used in characterising existing watercourse types and condition as discussed in Section 4.

Geomorphological findings of the field investigations are described in Section 4. The field observations relating to hydrology were used mainly in the development and validation of the flood model.

Photographs of some of the key hydraulic structures used in the hydraulic modelling are provided in Appendix A.

The Twin Creeks Golf and Country Club Estate Manager provided rainfall record data from a daily rainfall gauge held on site which was used in the validation of the hydraulic model (refer Appendix A).

3.3 Existing environment modelling and analysis

Hydrologic and hydraulic modelling was undertaken to establish baseline conditions and assess the potential impact of the proposed airport. The methodology adopted for the modelling analysis is described in this section. Definition of the existing environment based on the results of the modelling is discussed in Section 4. Additional model development detail not contained in this Section is included in Appendix A.

3.3.1 Hydrology

Watercourse stream ordering

Stream ordering of watercourses was established using the Strahler stream classification system where watercourses are given an ‘order’ according to the number of additional tributaries associated with each watercourse (Strahler, 1952). This system provides a measure of system complexity and is used as an input into assessing hydrological significance and environmental attributes such as potential for fish habitat. Watercourse locations were determined from the NSW LPI hydrolines layer. The stream ordering was used as an input to various EIS studies.

Hydrological modelling

A RAFTS hydrology model prepared by the Department of Infrastructure and Regional Development's business advisor was available and was refined and updated for the purposes of the EIS.

Hydrological subcatchments and land use

Subcatchments were delineated using available elevation data and regional hydroline mapping. Aerial imagery was used to determine the existing landuse types within each catchment. Subcatchment boundaries are shown in Figure 3-1.

Impervious areas were calculated by adopting rates of imperviousness for typical landuse types within the modelled area. This is the approach adopted in Liverpool City Council's *Handbook for Drainage Design Criteria* (2003). Landuse types used in the hydrology modelling of the existing study area and the adopted percentage impervious for each are shown in Table 3-2. The dominant landuse in the study area is farmland (pasture), listed here as primary production.

The pervious and impervious areas for each catchment were input into the RAFTS model as subcatchments.

Table 3-2 Landuse types and adopted impervious percentages

Landuse type	% impervious
Low density residential	45%
Large lot residential	20%
Primary production	10%
Primary production (small lot)	15%
Dams	100%
Infrastructure	10%
Commonwealth land	10%



LEGEND

- Airport site
- Watercourses
- Existing subcatchment boundaries

Paper Size A3

0 380 760 1,520

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Hydrology assessment
existing subcatchment boundaries

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 3-1

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A summary of the Badgerys Creek, Cosgroves Creek and Duncans Creek catchments within the airport site and their percentage impervious is provided in Table 3-3.

Table 3-3 Summary of existing catchment areas and impervious percentages

Catchment	Catchment area (ha)	% of catchment within airport site	% impervious in existing catchment
Badgerys Creek to South Creek	2,799	38.2	12.1
Cosgroves Creek to South Creek	2,163	23.1	13.7
Duncans Creek to Nepean River	2,379	8.7	13.9

Design storms

Design storms were generated in RAFTS using design rainfall intensity-frequency-duration (IFD) data for the airport site from *Australian Rainfall and Runoff* (Institute of Engineers Australia 1987). Design storms of various durations (1 to 24 hours) and average recurrence intervals (100, 20, 5, 2 and 1 year) were simulated in the RAFTS model to assess the existing hydrology of the study area.

Probable maximum flood (PMF) simulations were conducted in RAFTS using probable maximum precipitation estimates calculated using the generalised short duration method as described by the Bureau of Meteorology (BOM 2003).

Further details of the model development and validation are provided in Appendix A.

3.3.2 Hydraulics and flooding

A flood model prepared using MIKE 21 software was developed for the Department of Infrastructure and Regional Development.

The model was refined and extended for the purposes of the EIS and used to define existing flooding downstream of the site and adjacent to it.

No hydraulic models were available for the tributaries of Duncans Creek on the site or for Duncans Creek itself. The land use downstream of the site was largely primary industry, with few dwellings identified close to the creek. Following the hydrology assessment, the benefit of developing a detailed hydraulic model of Duncans Creek to inform the impact assessment was considered limited. An impact assessment was carried out but was based on the findings of the hydrology model at the points of discharge from the site for Duncans Creek.

Model terrain

The hydraulic model terrain was developed from Light Detection and Ranging data (LiDAR). The LiDAR data from which the model terrain was sourced was provided on a one metre by one metre square grid. It was adjusted to a five metre by five metre square grid size for use in the model.

Hydraulic roughness

Hydraulic roughness parameters were selected based on aerial imagery and on-site observations. The values adopted are included in Table 3-4.

Table 3-4 Hydraulic model adopted roughness values

Land use	Hydraulic roughness
Water	0.02
Roads	0.02
Floodplain – grass with light vegetation	0.08
Channel – trees	0.12
Channel – grass	0.05

The downstream boundary of the model was chosen to ensure that flood behaviour at the study area boundary could be identified. A normal depth open channel flow was selected at the extreme downstream section of the model.

Representation of key hydraulic structures

Bridges and other flow controlling structures were represented in the model as a MIKE 21 feature. Dimensions were based on observations made during the site visit. Adjustments to the MIKE 21 grid were made to represent the road level across the structure.

The hydraulic model extents and key structures are shown in Figure 3-2.

3.3.3 Watercourse geomorphology

The assessment of the physical form and geomorphic condition of watercourses was broadly based on the methods and principles of the River Styles® framework (Brierley and Fryirs 2005). Determination of watercourse geomorphic types is largely based on the following parameters:

- degree of valley confinement and bedrock influences;
- presence and continuity of a channel;
- channel planform (number of channels, sinuosity);
- channel and floodplain geomorphic features; and
- nature of channel and floodplain sediments.

The assessment of the geomorphic type and condition of watercourses in the study area was primarily based on a desktop review of aerial imagery and topographic data. This was supported by visual inspections of watercourses at several locations undertaken over the period 6–7 May 2015.

3.4 Stage 1 and longer term modelling and analysis

3.4.1 Description of proposals for surface water

Development of the Stage 1 airport would involve significant earthworks to level the central northern portion of the site for the runway and related Stage 1 infrastructure to be built.

All existing surface water features within the Stage 1 construction zone would be removed to make way for the development.

The Stage 1 development area would be drained via a number of pipes and swales in order to maintain the serviceability of the site from a stormwater perspective and to the required design standards.

A number of stormwater detention and treatment basins are incorporated in the design of the airport for the management of the quantity and quality of stormwater runoff expected from the airport. Key stormwater features of the proposed Stage 1 development are shown in Figure 3-3.

In the longer term, development of the proposed airport could include construction of an additional runway in the south of the site, as well as development of ancillary facilities. All surface water features on the remainder of the airport site would be removed to make way for the longer term development.

Although the longer term plan would involve further development on the site, surface water management features would remain largely unchanged. Substantial changes to the catchments in the southern portion of the site however would result from associated earthworks in this area.

The detention basins constructed during the Stage 1 development would be maintained in the longer term, with a number being extended and enlarged to accommodate the runoff from the additional development areas. An additional basin would also be constructed in the south west of the site. Key stormwater features of the longer term development are shown on Figure 3-4.

The adopted design standards for the stormwater management infrastructure on the site are outlined in Table 3-5.

Table 3-5 Typical Annual Recurrence Intervals for Aerodromes

Aerodrome Area	Criterion	Storm Frequency (ARI, years)
Pavements		
Runways	No Ponding	50
Taxiways	No Ponding	50
Apron	No Ponding	10
Other paved areas	No Ponding within 30 m of buildings	50
Grassed Areas		
Runway Strip	Ponding within 75 m of runway centreline not to exceed 12 hours	5
Taxiway Strip and Apron Flanks	Ponding within 15 m of pavement edge not to exceed 12 hours	5

Capture and reuse of stormwater runoff from the proposed airport (for example roof water recycling) has not been incorporated into the design at this stage. Hence, the design and sizing of stormwater capture systems and detention basins does not include reuse of stormwater. Reuse of a portion of treated wastewater for typical recycled water applications is proposed.

Further results of the modelling analysis not included in the main body of the report are included in Appendix B.



LEGEND

- Airport site
- Watercourses
- Hydraulic model key structures
- Hydraulic model extent - Badgerys Creek
- Hydraulic model extent - Cosgoves Creek

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Hydraulic model extent and key structures

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 3-2

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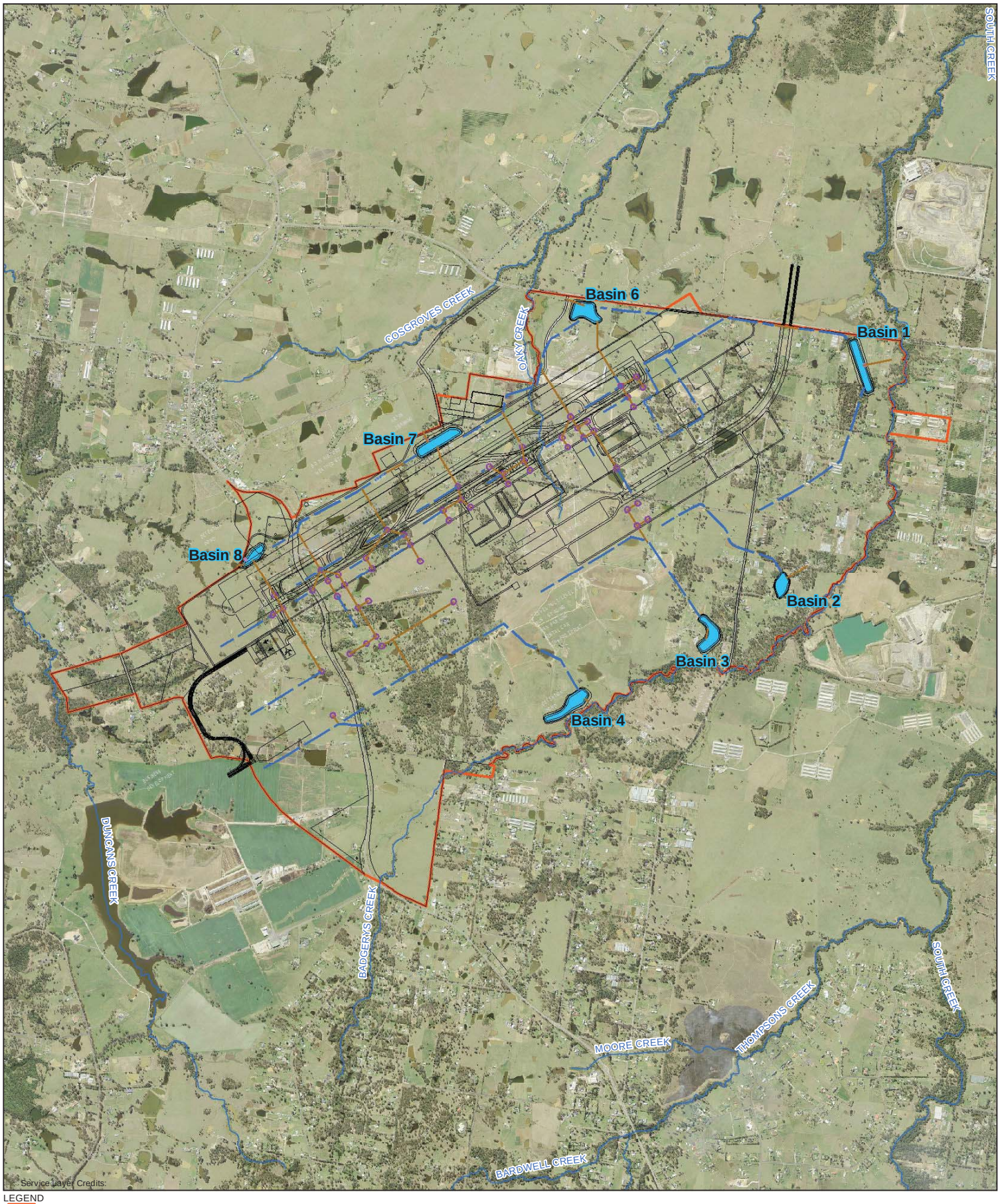

LEGEND

- Airport site
- Watercourses
- Stage one footprint
- Channel
- Culvert
- Pipe
- Pit
- Detention ponds

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Key development features, Stage 1

Job Number	21-24265
Revision	A
Date	06 Aug 2015

Figure 3-3

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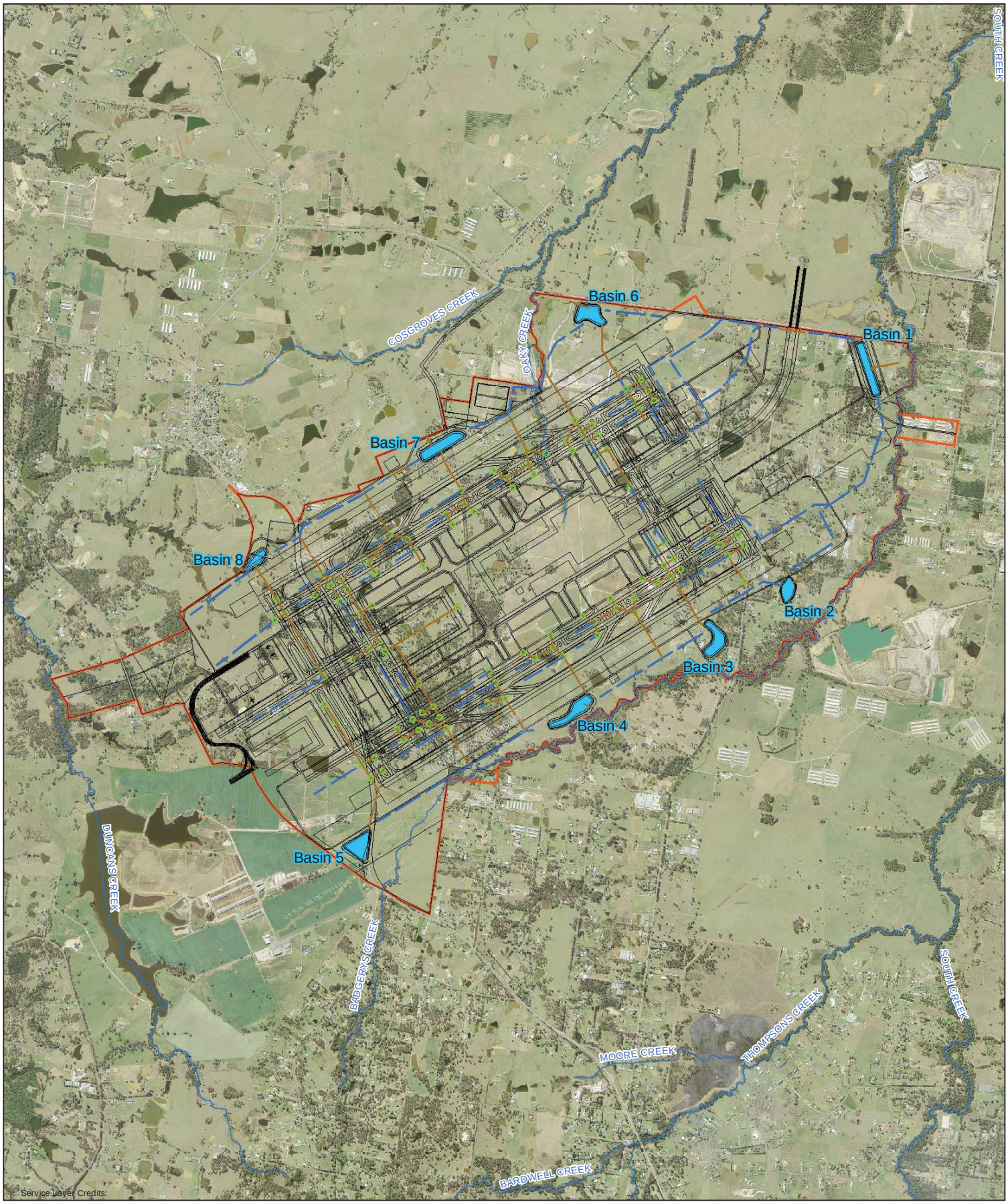

LEGEND

- Airport site
- Watercourses
- Longer term footprint
- Channel
- Culvert
- Pipe
- Pit
- Detention ponds

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
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Job Number	21-24265
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Key development features, Longer term

Figure 3-4

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3.4.2 Hydrology and hydraulics

An analysis of the Stage 1 surface water system was carried out to inform the impact assessment. The analysis was based on the land use plan, surface water management plan and design basis report provided.

The hydrology model provided by the business advisor was updated based on the following:

- surface water management plans; and
- land use plans.

There was no hydrology model available from the business advisor for Stage 1 and a RAFTS model was therefore developed for the purposes of this assessment. There was a longer term hydrology model available which was extended further downstream and updated in accordance with the latest available drainage layouts and with the latest land use plans for the proposed airport. Subcatchment boundaries were delineated based on the available information and are shown in Figure 3-5 for Stage 1 and in Figure 3-6 for the longer term development.

Proposed detention basin volumes were available for Stage 1 from the design information provided. Outlet configurations for the basins were assumed based on the proposed outlet configurations provided for the longer term development. Assumptions regarding proposed stage-storage information for the Stage 1 basin were made in the model based on the configuration of the longer term basins.

A Stage 1 hydraulic model was created by:

- incorporating the available design landform within the model topography; and
- incorporating the Stage 1 surface water runoff estimated by the hydrology assessment.

In order to refine hydraulic estimates, hydraulic structures were incorporated into both the Stage 1 and the longer term models, and their description was based on site observations.

3.5 Impact assessment

The assessment considered the impacts of the development on:

- surface flows, including the effectiveness of the proposed basins in mitigating changes to hydrology;
- watercourse geomorphology;
- flooding and flood risk to surrounding developments and people; and
- cumulative aspects.

3.5.1 Hydrology and hydraulics

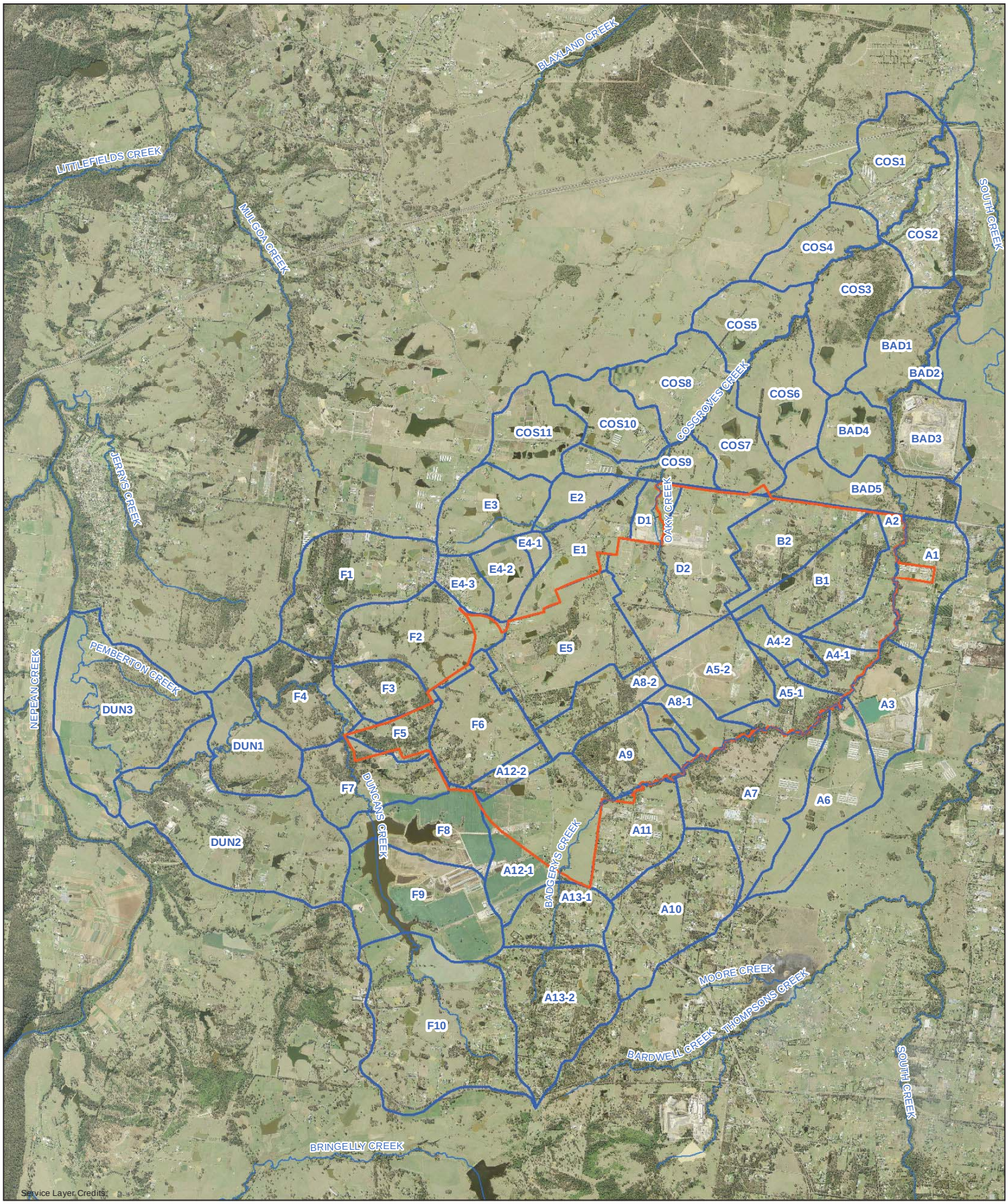
Findings are reported in section 6.1.1.

Outputs from the hydrology model were used:

- to inform the impact assessment of changes to flows as a result of the airport; and
- to confirm the effectiveness of the proposed basins in mitigating changes to hydrology.

The results of the hydraulic modelling were used to determine:

- the impact of the proposed airport on watercourse geomorphology; and
- the impact of the proposed airport on flooding and the flood risk to surrounding developments and people.



LEGEND

- Airport site
- Watercourses
- Stage 1 subcatchment boundaries

Paper Size A3

0 380 760 1,520

Metres

Map Projection: Transverse Mercator
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Hydrology assessment
Stage 1 subcatchment boundaries

Figure 3-5

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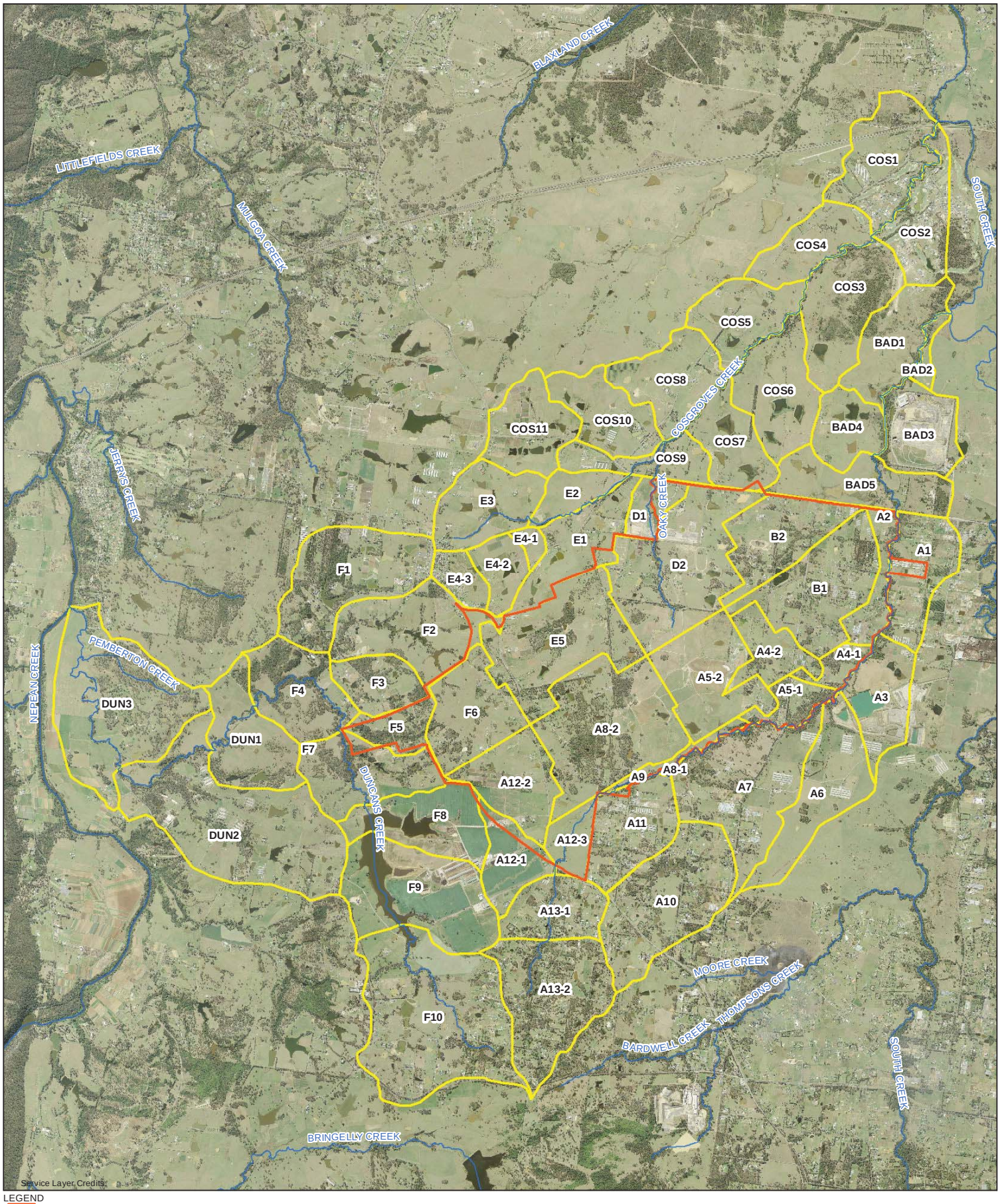

LEGEND

- Airport site
- Watercourses
- Ultimate subcatchment boundaries

Paper Size A3

0 380 760 1,520

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Hydrology assessment

Longer Term subcatchment boundaries

Figure 3-6

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Changes in catchment area and land use were identified for their potential to change the flows discharging from the site during both Stage 1 and the longer term development.

The significance of the magnitude of change between the existing and the Stage 1 or longer term scenarios depends on factors such as watercourse stability (see below), the sensitivity of biodiversity to changes in surface water parameters and the sensitivity of surrounding infrastructure such as residences to flooding. These factors were considered when assessing changes to surface water between the existing condition and the Stage 1 and longer term airport.

As part of the flood analysis, differences in predicted flood depth of greater than or less than 100 mm were reviewed for the potential to influence flooding of surrounding residences and other infrastructure

3.5.2 Geomorphology

The footprints of the Stage 1 and longer term developments were reviewed to assess the length and stream order of mapped watercourses directly subsumed by the development footprints. Changes in baseline hydraulics at discharge points from the site were considered together with watercourse type to determine the likelihood of such changes affecting watercourse stability.

Changes in shear stress from the existing case of less than 5 N/m^2 were considered to be minor in influencing watercourse stability, provided that actual shear stress levels were expected to be low (less than 100 N/m^2).

3.5.3 Cumulative impacts

Cumulative impacts of the Stage 1 and longer term development were considered including the future effects of climate change, as well as surrounding development within the catchment.

Accounting for the future effects of climate change

Background to adopted climate change methodology

The NSW Office of Environment and Heritage (OEH) publishes information regarding the expected effects of future climate change on rainfall and sea levels. The document *Metropolitan Sydney Climate Change Snapshot* (OEH November 2014), which incorporates the airport site, is the most recent relevant New South Wales publication. It identifies predicted changes to rainfall seasonality and average rainfall in the near future (from 2020 – 2039) and in the far future (from 2060 – 2079).

In the Sydney region, the majority of the climate change models show that autumn rainfall will increase in the near future and in the far future. The majority of models show that spring rainfall will decrease in the near future, though far future predictions are less clear. It is important to note that there is a significant degree of uncertainty in the findings of the climate change modelling, and that the NSW Government is conducting ongoing research into climate change.

The publication does not provide details regarding changes to flood-producing rainfall events other than to confirm that changes to rainfall intensity are expected.

The *Practical Consideration of Climate Change* (NSW Department of Environment and Climate Change 2007) publication references climate change modelling carried out by the CSIRO in 2007 for the NSW Government to assess the impacts of climate change on rainfall intensities. The results showed a trend of increased rainfall intensities for the 40 year ARI one-day rainfall event across New South Wales. The projected increase in rainfall totals in the Sydney Metropolitan Area are indicated in Table 3-6.

Table 3-6 CSIRO indicative change in rainfall one-day totals (CSIRO, 2007)

Location	40 Year 1 day rainfall total projected change by 2030	40 Year 1 day rainfall total projected change by 2070
Sydney Metropolitan Area	-3% to +12%	-7% to +10%
New South Wales average	-2% to +15%	-1% to +15%

The values in the table are considered indicative. OEH is currently working with the University of New South Wales to analyse the effects of climate change on flooding and it is expected that new information will become available.

For catchments in NSW, the *Practical Consideration of Climate Change* publication suggests considering a 10 per cent, 20 per cent and 30 per cent increase in peak rainfall and volume to account for the future effects of climate change when considering flood events.

Adopted climate change methodology

Climate change predictions are not incorporated into the main impact assessment but are considered as a future cumulative impact. Consideration was given to the potential for both increases and decreases in rainfall as outlined in the *Metropolitan Sydney Climate Change Snapshot*.

For the flood assessment, the cumulative impact of the Stage 1 and longer term development together with the predicted impacts of climate change were assessed for the following modelling scenarios based on the upper and lower range recommendations of the *Practical Consideration of Climate Change* publication:

- Stage 1 Development and 100 year ARI flood event with 10 per cent increase in rainfall intensity; and
- longer term development and 100 year flood ARI event with 30 per cent increase in rainfall intensity.

Accounting for the effects of future development

The analysis also considered the cumulative impacts of future development surrounding the airport site. This is discussed further in Section 7.

4. Existing environment

4.1 Topography

The proposed airport site is located in the south-west portion of the Cumberland Plain (PPK, 1997) and includes rolling hills dissected by a number of drainage lines. The ridge system trends northwest to southeast in the vicinity of The Northern Road and reaches elevations of just over 120m AHD. There are some other isolated ridge lines in and around the Luddenham Dyke and The Northern Road with approximate elevations of slightly more than 100m AHD. The topography generally slopes away from these ridgelines to the south and east into Oaky, Cosgrove and Badgerys Creeks as part of the South Creek catchment and to the northwest into Duncans Creek as part of the Nepean River Catchment. The lowest points of the site are where Badgerys Creek exits the north eastern extent of the site (approximately 44m AHD).

4.2 Land use

The airport site is rural, with a mixture of vacant lots, large agricultural lots and smaller scale residential and rural use. A large number of small farm dams are present across the airport site.

Paved areas on the site are associated mainly with buildings and the arterial and local roads located on the site or passing through it.

4.3 Rainfall

An Automatic Weather Station (AWS) operated by the Bureau of Meteorology is located on the site.

This data from the station has been analysed by the Bureau of Meteorology in the *Western Sydney Airport Climatological Review* (Bureau of Meteorology 2015).

Results from the analysis of the gauge are summarised in Table 4-1.

Table 4-1 Badgerys Creek AWS rainfall gauge data

Gauge name	Badgerys Creek AWS
Gauge Number	067108
Location	33.90 S, 150.73 E
Period of data	Dec 1998 – Present
Data Set Completeness	93.9%
Data resolution	1 minute
Mean Annual Rainfall (mm)	676.4

Monthly statistics, taken from Table 4-1 of the *Western Sydney Airport Usability Report, Meteorological Impacts* (Bureau of Meteorology 2015) are provided in Figure 4-1.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Rainfall (mm)	77.4	108.0	77.3	43.2	40.1	52.1	23.0	35.9	33.9	52.7	74.5	63.6
Highest Monthly Rainfall (mm)	192.2	342.4	198.0	129.4	155.6	220.0	71.6	231.0	82.2	182.2	173.2	131.2
Lowest Monthly Rainfall (mm)	13.6	13.4	21.4	1.8	1.8	2.0	2.8	1.0	6.4	0.4	8.4	14.2
Highest Daily Rainfall (mm)	138.0	106.8	67.8	82.4	54.0	63.8	28.4	70.0	50.8	63.0	63.0	65.0

Figure 4-1 Monthly rainfall statistics at Badgerys Creek AWS

The findings of the Bureau of Meteorology studies also indicate that heavy rainfall events of probability 1 Exceedance Year (EY) and rarer are more likely to occur between November and March, based on the available record. The likely timing of heavy rainfall events would be relevant for consideration during the scheduling of the airport construction (refer also to Section 5).

4.4 Surface water sources

4.4.1 Regional

The airport site is situated in the Hawkesbury-Nepean basin. The Hawkesbury-Nepean catchment is one of the largest coastal basins in NSW with an area of 21,400 square kilometres (NSW Office of Water). The airport site is located downstream of Warragamba Dam in a part of the catchment termed the lower Hawkesbury-Nepean.

The airport site drains partially to the Nepean River upstream of Warragamba Dam and partially to South Creek and then the Hawkesbury River downstream of Warragamba Dam via a system of tributaries.

South Creek drains a catchment of approximately 414 square kilometres and flows generally from south to north along its length (Worley Parsons 2015). It has its headwaters near Narellan and flows for a length of around 70 kilometres to its discharge point into the Hawkesbury River near Windsor. South Creek could be sensitive to impacts from the airport if they propagate downstream via the tributaries.

The catchment is shale-based and is characterised by meandering streams. The catchment is highly disturbed due to increasing urbanisation and associated land clearing.

Based on available flood maps for the Hawkesbury-Nepean River, as well as Penrith and Liverpool Council Local Environmental Plan Flood Maps, the airport site is not affected by flooding from the Hawkesbury-Nepean system. In particular, it is not within the available modelled flood extents of the PMF resulting from the overtopping of Warragamba Dam.

4.4.2 Local

The airport site is located in the upper reaches of the catchments of Badgerys Creek, Cosgroves Creek, Oaky Creek (a tributary of Cosgroves Creek) and Duncans Creek. Badgerys Creek and Cosgroves Creek are tributaries of South Creek which is itself a tributary of the Hawkesbury River.

Duncans Creek is a tributary of the Nepean River.

The catchments of Cosgroves and Oaky Creeks, Badgerys Creek and Duncans Creek are shown in Figure 4-2. The creeks and their associated ecosystems are environmental receptors for potential impacts from the airport development.

Further details of the hydrological and geomorphological features of key catchments are described in greater detail in later sections of this section.

Badgerys Creek

Badgerys Creek has its headwaters in the vicinity of Findley Road, Bringelly, approximately two kilometres upstream of the airport site. It flows generally in a north to north-east direction. It passes through the airport site starting at the site's southern extent and continues for a distance of approximately 1.2 kilometres before its course returns to the airport site boundary. The creek then forms the south-eastern boundary of the airport site as far as Elizabeth Drive. Downstream of the airport site, Badgerys Creek continues for a further four kilometres until its confluence with South Creek.

Between the airport site and the confluence, the creek passes the Elizabeth Drive landfill site operated by SUEZ Environnement (previously operating as SITA).

Badgerys Creek has a catchment area of approximately 2,800 hectares (28.0 square kilometres) in total and an area of 2,360 hectares (23.6 square kilometres) at Elizabeth Drive, the downstream extent of the airport site.

In addition to being used for agricultural and landfill purposes, the catchment of Badgerys Creek contains a number of residential properties downstream of the site and adjacent to the site which would be sensitive to changes in flood behaviour.

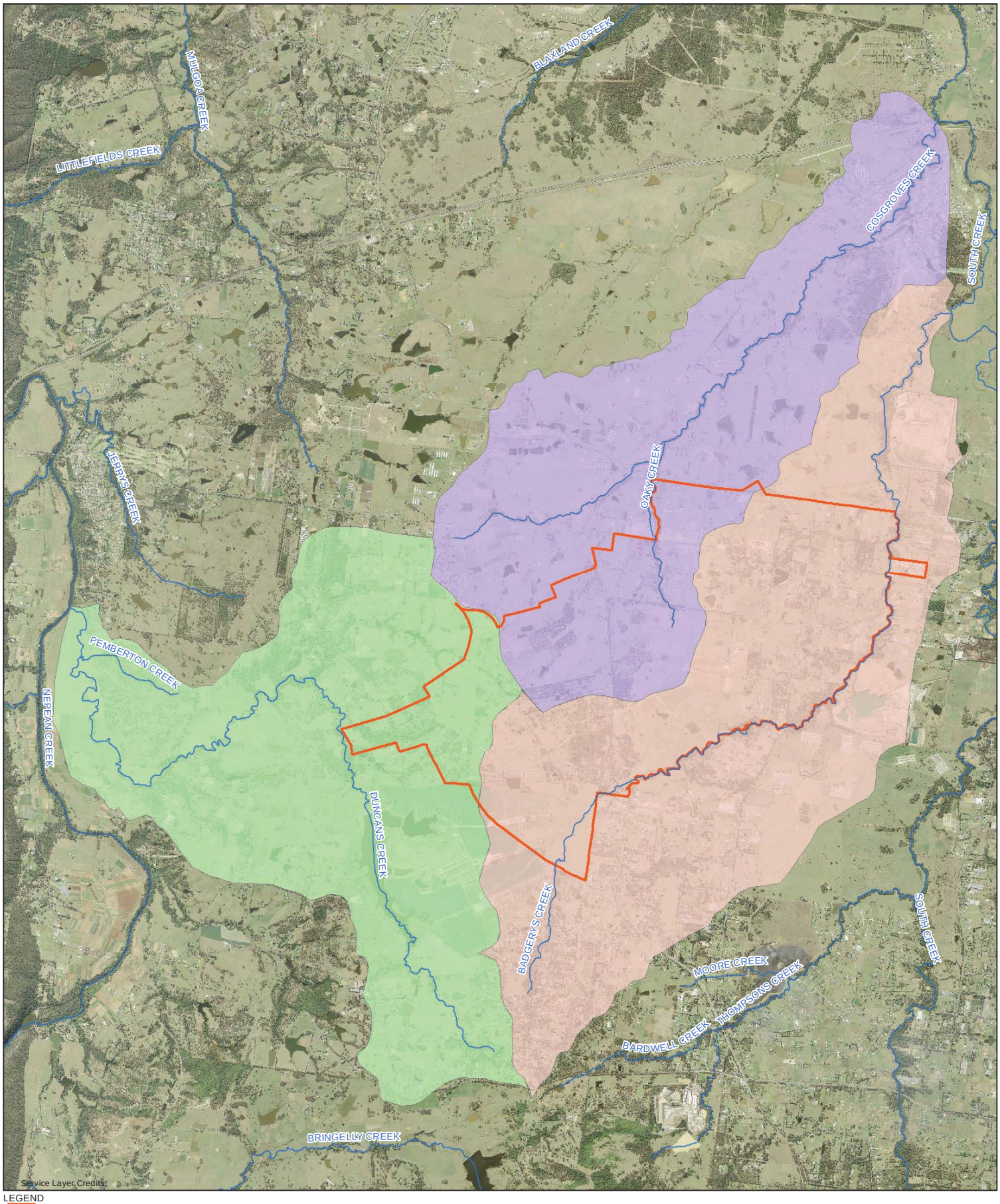
Oaky and Cosgroves Creeks

The headwaters of Oaky Creek are located on the airport site. The watercourse flows in a north-westerly direction for around two kilometres before it reaches the western boundary of the airport site. From this point, it meanders away from the airport site boundary, through the Blue Sky Mining site for several hundred metres, before rejoining the airport site boundary and continuing along it for 400 metres as far as the north-west corner of the site. Downstream of the airport site, the watercourse continues for a further half a kilometre before its confluence with Cosgroves Creek. Downstream of the confluence, the watercourse continues as Cosgroves Creek.

Downstream of the confluence with Oaky Creek, Cosgroves Creek continues for approximately seven kilometres before joining with South Creek. In the reach between Oaky Creek and South Creek, Cosgroves Creek passes through rural lots, the Twin Creeks Golf and Country Club and beneath an above-ground Sydney Water Corporation water pipeline.

Oaky Creek has a catchment area of 382 hectares (3.82 square kilometres) in total, and 361 hectares (3.61 square kilometres) at the downstream extent of the airport site. The total catchment area of Cosgroves Creek at the confluence with South Creek is approximately 2163 hectares (21.63 square kilometres).

The catchments are largely rural and without residential development downstream of the site, with the exception of the Twin Creeks Golf and Country Club residential estate downstream of the site towards Cosgroves Creek's confluence with South Creek.



LEGEND

- Airport site
- Watercourses

Catchment

- Badgerys creek
- Duncans creek
- Oaky and Cosgroves creeks

Paper Size A3

0 380 760 1,520

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Local hydrological catchments

Figure 4-2

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Duncans Creek

Duncans Creek has its headwaters in Bringelly and flows initially in a north-westerly direction. A number of unnamed tributaries of Duncans Creek are located on the airport site. A large water storage dam is located on the creek at the Leppington Pastoral Company site. Information regarding the dam was requested from the owners but available data was limited to the total dam size of 5,000 ML. Downstream of the dam the creek continues, passing close to the southern tip of the airport site before turning sharply towards the south west and later meandering north again before discharging into the Nepean River around nine kilometres downstream of the southern site extent. The Duncans Creek catchment downstream of the site is rural and zoned for primary production (plant or animal cultivation) according to the Liverpool City Council Local Environmental Plan.

A small portion of the site north west of The Northern Road drains to Duncans Creek via several tributaries.

4.5 Hydrology and flooding

4.5.1 Hydrological modelling findings

The RAFTS hydrology model was used to understand characteristics of flood flows on, and downstream of, the site.

The critical storm for each catchment is the storm producing the highest flood peak at a given location for a given ARI. The critical duration is influenced by factors such as overall catchment size as well as the properties of contributing sub-catchments.

Table 4-2 indicates the critical duration storm events which range from two hours to nine hours depending on design storm average recurrence interval and location.

Table 4-2 Critical storm durations modelled in RAFTS

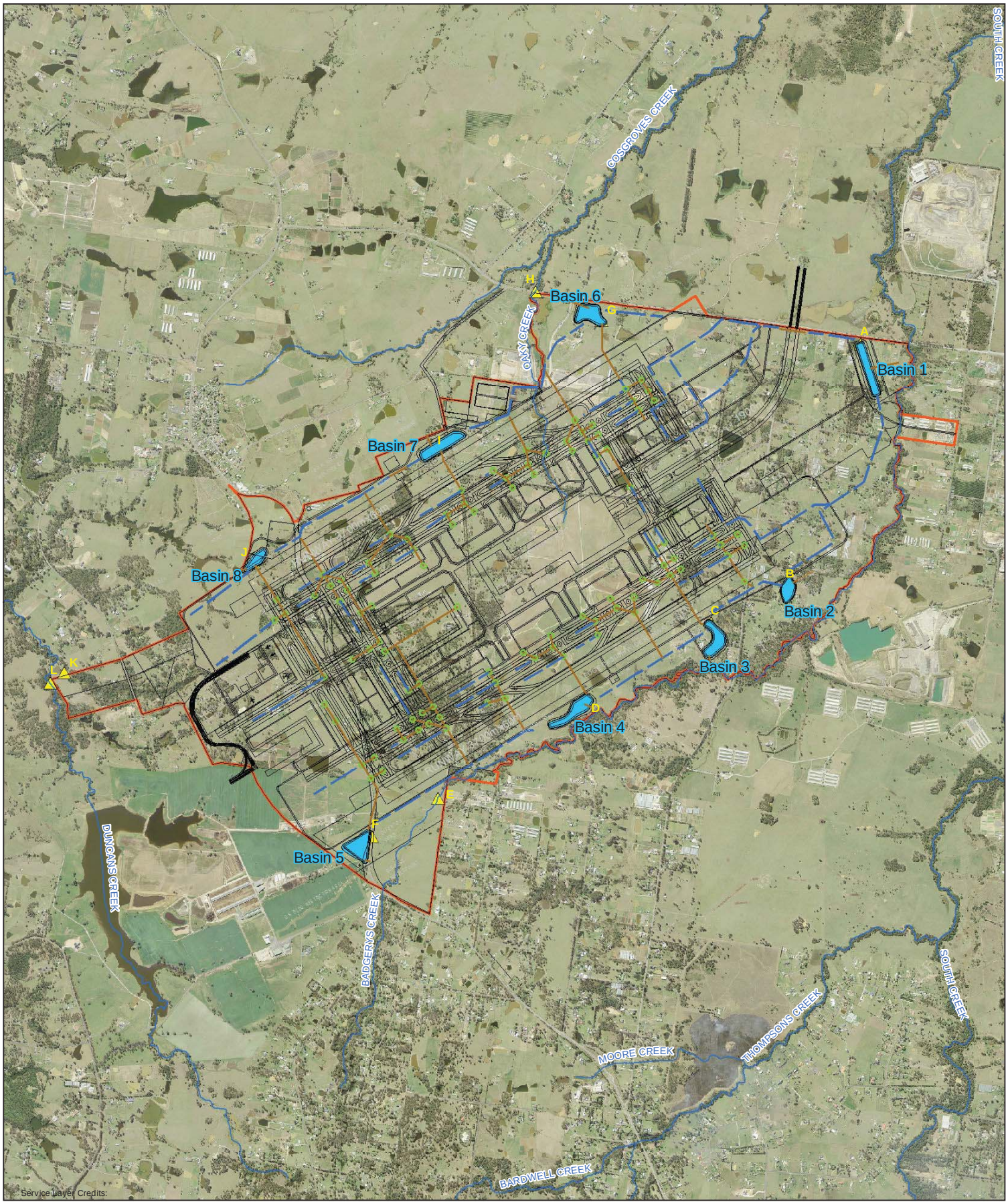
Location	100 year ARI	20 year ARI	5 year ARI	2 year ARI	1 year ARI
Badgerys Creek at Elizabeth Drive	6 hr	6 hr	9 hr	9 hr	9 hr
Oaky Creek at Elizabeth Drive	2 hr	2 hr	9 hr	9 hr	9 hr
Cosgroves Creek at Elizabeth Drive	2 hr	2 hr	2 hr	9 hr	9 hr
Badgerys Creek at South Creek	6 hr	6 hr	9 hr	9 hr	9 hr
Cosgroves Creek at South Creek	6 hr	6 hr	6 hr	9 hr	9 hr
Duncans Creek at Nepean River	6 hr	6 hr	6 hr	9 hr	9 hr

The results indicate that peak flows are typically generated by longer duration storms for smaller ARI events which are reflective of the greater influence of initial storm losses on peak flows for the smaller shorter duration events.

Peak flows at selected locations are shown in Table 4-3 below. Locations correspond to the hydrology assessment reporting locations depicted on Figure 4-3.

Table 4-3 Peak flows at selected locations, existing conditions

Location	Peak flow (m^3/s), 100 year ARI event	Peak flow (m^3/s), 1 year ARI event
A	33.5	8.4
B	8.2	1.9
C	12.9	3.2
D	9.1	2.3
E	26.3	6.5
H	37.6	8.9
I	16.5	4.1
J	10.9	3.3
K	9.6	2.1
L	19.8	4.6



LEGEND

- Airport site
- Hydrology assessment reporting locations
- Watercourses
- Longer term footprint
- Channel
- Culvert
- Pipe
- Pit
- Detention ponds

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
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Hydrology assessment reporting locations

Figure 4-3

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4.5.2 Hydraulic modelling

Peak flood flows extracted from the flood model for the 100 year ARI event for Badgerys and Oaky Creeks at Elizabeth Drive are included as Figure 4-4 and Figure 4-5 for the critical storm durations for each catchment (refer to section 4.5.1.

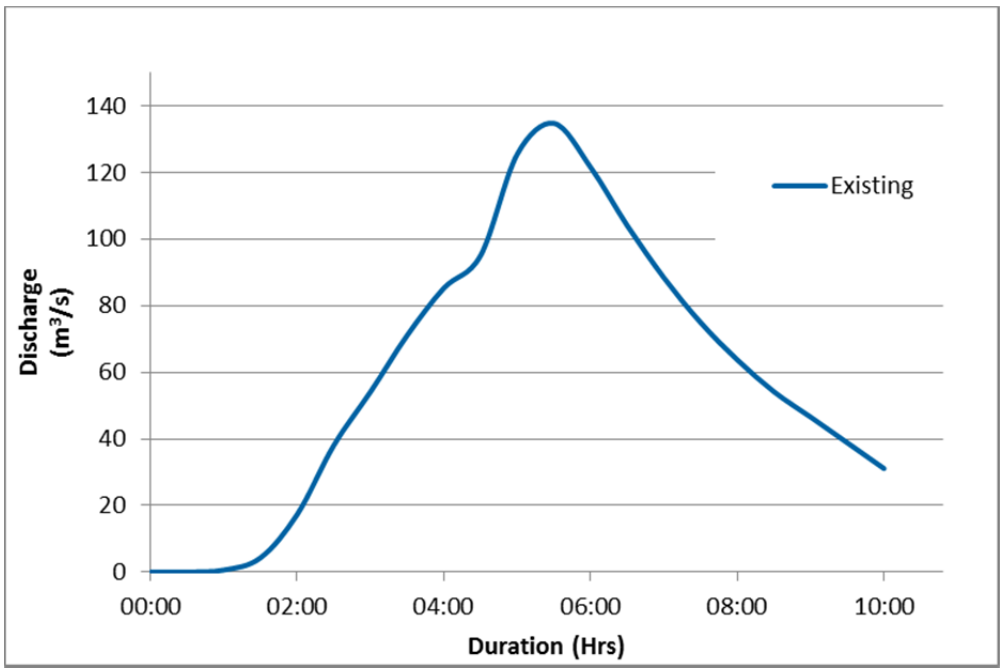

Figure 4-4 Badgerys Creek hydrograph at Elizabeth Drive, 100 year ARI event 6 hour storm duration

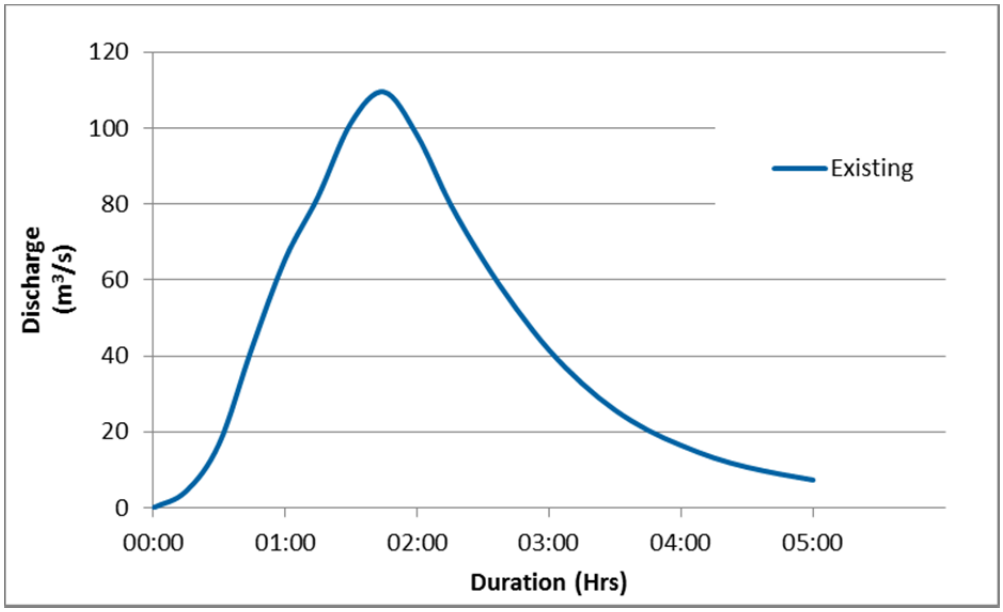

Figure 4-5 Cosgroves Creek hydrograph at confluence with Elizabeth Drive, 100 year ARI event 2 hour storm duration

- The extent of flooding under existing conditions and predicted flood depths are shown in Figure 4-6 to Figure 4-9 for Badgerys Creek and Cosgroves and Oaky Creeks.
- In the 1 year ARI event, flooding is mostly confined to main watercourse channels and dams.
- In the 5 year ARI event, much more out of bank flooding is expected of depths up to around 0.6 metres on Oaky and Cosgroves Creek and deeper flood depths on Badgerys Creek, particularly upstream of Elizabeth Drive.
- In a 100 year ARI event, significant out of bank flooding is also expected. On Badgerys Creek near the downstream area, the floodplain is more extensive on the airport side (western bank) than on the eastern bank due to the wider and flatter floodplain in this location.

A number of the flood-affected rural residential lots outside the airport site are located in Bringelly in the area bounded by the airport site, The Northern Road and Badgerys Creek Road. Based on the available imagery, though a number of lots would experience some inundation in a 100 year ARI event, most existing dwellings in this area remain outside the flood extent. There are a number of existing dwellings located within the flood extent or in close proximity to the flood extent clustered on Badgerys Creek upstream of the site (Figure 1-1). Two dwellings in close proximity to the flood extent were also identified downstream of the airport site on Cosgroves Creek. On the eastern bank of Badgerys Creek are a number of flood affected lots, though the existing dwellings are located beyond the 100 year flood extent. This includes dwellings on the parcel of land located on the eastern side of Badgerys Creek that may in future become part of the airport site which are not within the 100 year flood extent and are therefore not marked on the map.



LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

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Existing flood depths
1-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 4-6

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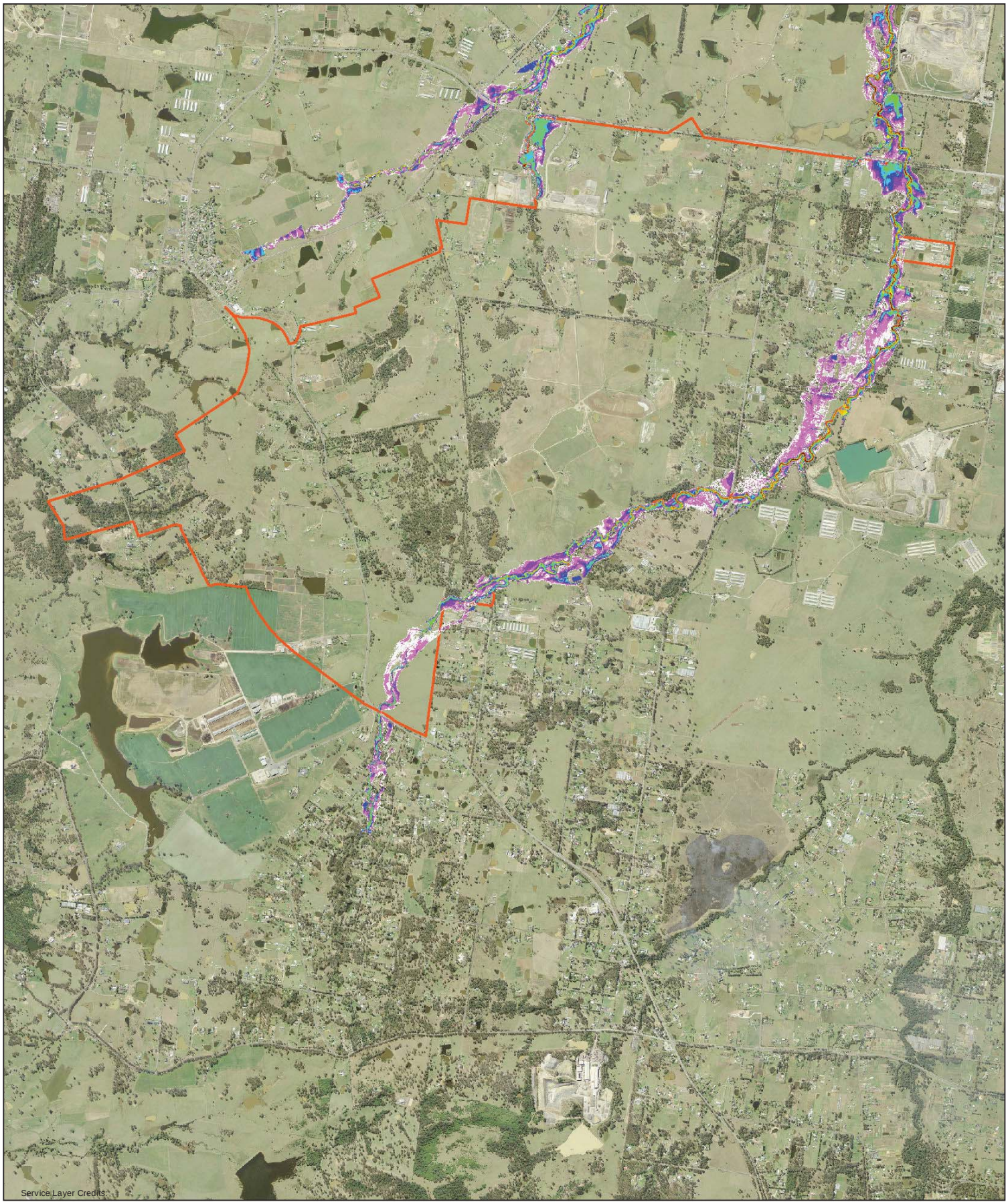

LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Existing flood depths
5-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 4-7

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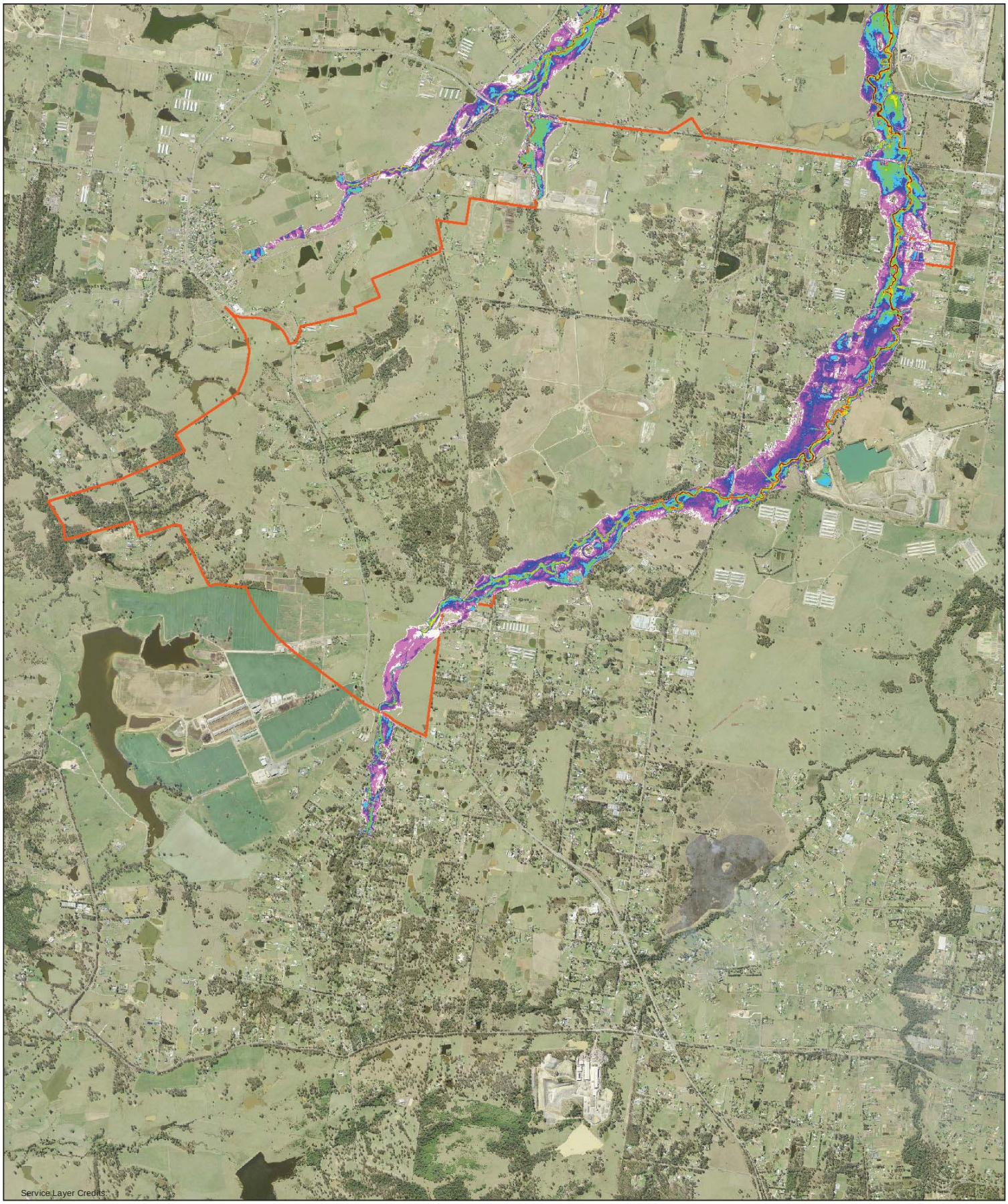

LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Existing flood depths
100-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 4-8

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 53]

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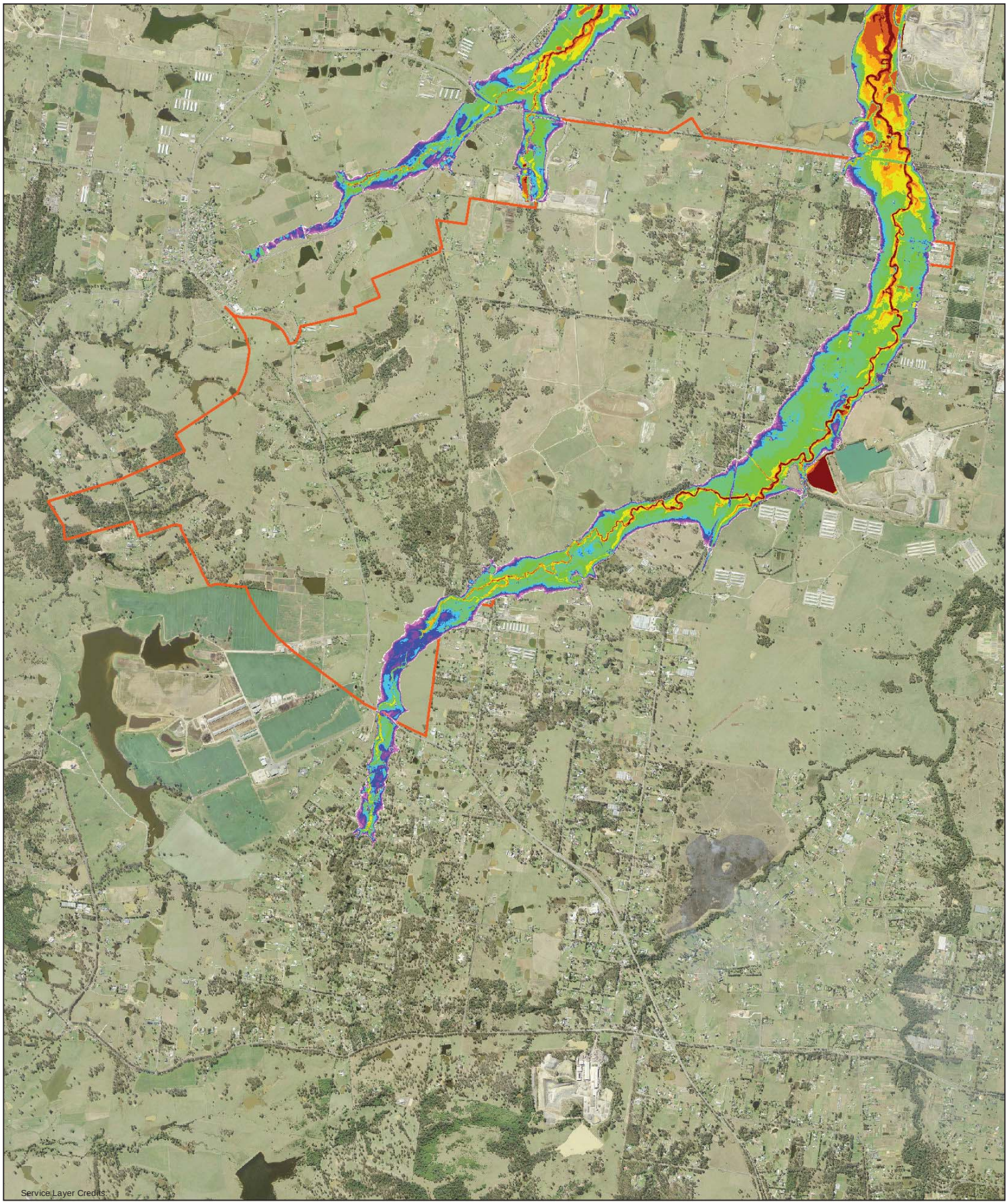

LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Existing flood depths
PMF

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 4-9

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 54]

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4.6 Watercourse geomorphology

The general topography of the airport site is undulating, with rolling, broad crested hills developed on the geology of the Wianamatta Group shales. These shales are generally composed of claystones, siltstones and carbonaceous shales with sparse sandstone lenses. As a result, the primary weathering products derived from the airport site will consist of fine grained sediments (clay and silt). Existing drainage from the airport site predominantly flows either easterly to the northerly flowing Badgerys Creek or northerly to Cosgroves Creek. Watercourses in the south–western section of the site drain to the westerly flowing Duncans Creek.

4.6.1 Stream orders

The Strahler stream order of mapped watercourses on the airport site is displayed in Figure 4-10. The majority of watercourses are first and second order, accounting for approximately 70% of the total length of the mapped watercourses on the airport site. Badgerys Creek attains the highest stream order on the site, being fourth order for most of its length along the eastern boundary of the airport site.

4.6.2 Watercourse types

A total of five watercourse geomorphic types were identified during the desktop and field assessment of the watercourses across the airport site. These are as follows:

- poorly defined drainage lines;
- steep confined watercourses;
- valley fill systems;
- channelised fill systems; and
- partly confined to unconfined, fine grained watercourses.

There are also numerous farm dams constructed along watercourses, accounting for 16 per cent of the mapped watercourse length on the airport site.

The mapped distribution of watercourse types and farm dams located on defined watercourses is shown in Figure 4-11 and their characteristics are described below.

Poorly defined drainage lines

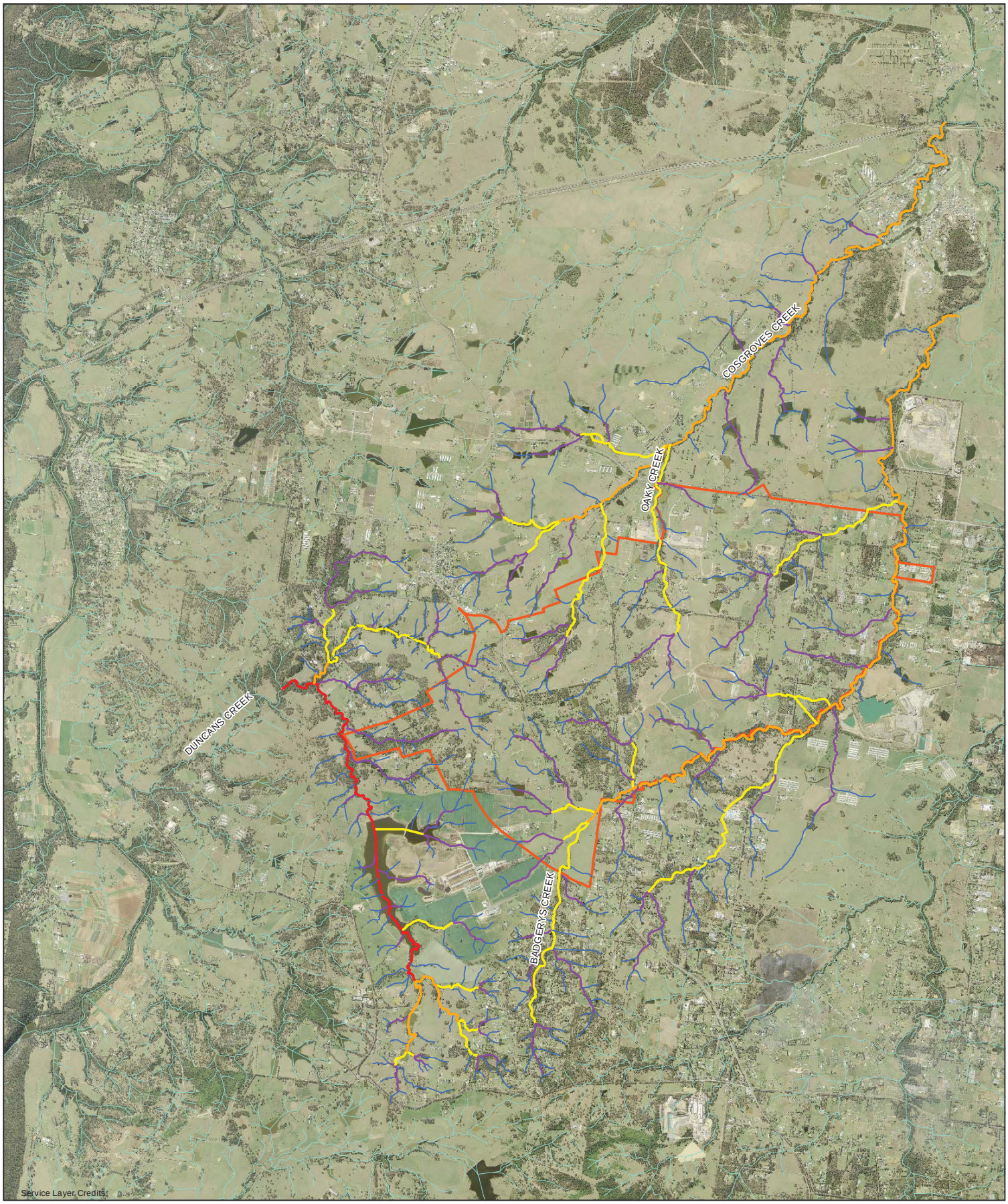
Poorly defined drainage lines are primarily located along first order watercourses within the airport site. These systems consist of a narrow depression set within a gently concave valley. There are no defined channels and as a result flow occurs via sheet flow during rainfall events. Typically, these watercourses are geomorphologically stable with no visible signs of erosion or instability.

Poorly defined drainage lines are predominantly first order watercourses and account for 31 per cent of the mapped watercourse length on the airport site.

Steep confined watercourses

This watercourse type is characterised by a steep gradient channel occupying a narrow v-shaped valley. The channel is laterally and vertically stable, although the channel may slowly erode the valley wall if it consists of weathered bedrock or colluvium. Floodplains are absent such that sediment storage is limited to small bars and benches.

This watercourse type is only located in the south-western section of the airport site and accounts for 3 per cent of the mapped watercourse length on the airport site.



LEGEND

Airport site

Strahler Stream Order

- Not classified
- 1
- 2
- 3
- 4
- 5

Paper Size A3

0 380 760 1,520

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Strahler stream order

Figure 4-10

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LEGEND

Airport site

Watercourses

Type

- Not assessed
- Poorly defined drainage line
- Steep confined channel
- Valley fill
- Channelised fill
- Low to moderate sinuosity fine grained
- Dam

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Watercourse type

Figure 4-11

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 37]

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Valley fill systems

Valley fill systems consist of flat valley floors with no defined channel such that the whole valley floor acts as a channel with valley margins as the banks. During high intensity rain events, water flows across the surface as sheet flow. As such, the flow energy is dissipated across the valley floor, resulting in the deposition of fine-grained suspended sediments. Low energies associated with flow dissipation lead to long term accumulation of sediments derived from upstream. If the valley floor is disturbed, a headcut may be initiated (refer also to *Channelised fill,* below*)*. This will form a continuous channel that will incise, enlarge and progress up stream with each subsequent flow event.

Valley fill systems are located throughout the study area along first to third order streamlines and account for 32 per cent of the mapped watercourse length on the airport site.

Channelised fill systems

Channelised fill systems exhibit a continuous channel that has incised, probably since European settlement, into valley fill through headcut retreat and channel expansion. The floodplains represent former valley fill surfaces and are generally flat and featureless. Channelised fill systems generally have an intermittent flow regime and do not usually retain surface water between flow events. Moderate stream energies generated during higher flow events can re-activate erosional processes. Headcuts will progress upstream and unprotected banks will erode. Most channels have incised to a point where all flows are contained within the channel such that the former fill surfaces are rarely inundated. Consequently, flow energy concentrates within the channel resulting in increased rates and occurrences of channel erosion.

Channelised fill systems have a scattered distribution along first to fourth order streamlines and account for 3 per cent of the mapped watercourse length on the airport site.

Partly confined to unconfined, fine grained systems

This waterway type exhibits a single channel set within floodplain deposits of alluvial silt and sand. For the most part, floodplains flank either side of the channel, however, in some locations the channel abuts the bedrock valley margin.

The channel generally holds water in isolated pools between flows. The channel itself is of low gradient and low energy such that sediment transported is predominantly limited to fine grained silts and clays in suspension. The low capacity channel allows overbank flows to be readily dissipated across the floodplain surfaces, activating flood channels and depositing fine grained sediments on the floodplain

Partly confined to unconfined, fine grained systems are located along third and fourth order watercourses and account for 15 per cent of the mapped watercourse length on the airport site.

4.6.3 Watercourse geomorphic condition

Both through and downstream of the airport site, Badgerys and Cosgroves Creeks display evidence of past and ongoing bed degradation. This is evidenced through the presence of active headcuts and over-steepened eroding banks. As a result, despite having a generally well-vegetated riparian zone, these watercourses are considered to be in moderate geomorphic condition.

As a result of past clearing, the construction of online dams and ongoing agricultural activities, tributaries of Badgerys and Cosgroves Creeks across the airport site are also considered to be in largely moderate geomorphic condition.

4.7 Related features

4.7.1 Ecology and groundwater

Based on available mapping discussed in the biodiversity assessment conducted for this EIS (GHD 2015), none of the watercourses on the site or immediately downstream is considered to be a groundwater dependent ecosystems (GDEs) that is reliant on the surface expression of groundwater (groundwater seepage). South Creek to the east and the Nepean River to the west are both mapped as this type of GDE.

Many farm dams and ponds on the airport site are considered to be artificial freshwater wetlands, some of which are in good condition and feature predominantly native plant species. They are associated with artificial dams and flooded depressions that have been formed by the construction of barriers across small drainage lines. Because they are not natural geomorphic features, they do not comprise a local occurrence of the Threatened Ecological Community (TEC) 'Freshwater wetlands on coastal floodplains'. Nonetheless, they are considered to have ecological value.

The biodiversity assessment found that the Australian Painted Snipe (*Rostratula australis*) bird may occur at wetlands and nearby flooded grassland within the airport site. Even though there are no local records of this birdspecies, and none were recorded during surveys, the species is cryptic. Wetlands at the airport site provide potential foraging and breeding habitat for this species.

Other receptors in the catchment include ecologically sensitive riparian vegetation which is reliant on occasional flooding.

An aquatic ecology assessment found the macroinvertebrate communities downstream of the site to be in generally poor health, though the sampling undertaken occurred in a limited season. Fish communities identified were found to be "indicative of a disturbed habitat". Fish habitat downstream of the site was found to be mostly minimal, with some reaches of some moderate habitat present.

5. Construction impacts

5.1 Flooding and waterlogging

Stage 1 of the airport would be constructed over a period of approximately ten years. During this timeframe, the likelihood of a large rainfall event occurring is high. The historical record indicates that the likelihood for large rainfall events is skewed towards summer occurrence (refer also to Section 4.3). It is possible that impacts could occur both on the site, with general disruption to construction activities, and off the site, with impacts to surrounding properties and watercourses.

As the site is constructed and impervious area is added, the volume of runoff from the site would increase due to a reduction in ground surface infiltration. Without mitigation, this would result in increased peak flows from the site and the potential for associated flooding and geomorphological impacts downstream. However, detention basins have been incorporated into the site design to mitigate the increase in runoff, reducing offsite impacts of potentially increased peak flows. The detention basins would be utilised during the construction phase and subsequently, following construction, they would be used to manage operational stormwater.

The airport site will include substantial and large-scale earthworks which will modify drainage direction and overland flow paths, changing the nature of flooding on site. Without progressive introduction of formal drainage designed to cater to the new site conditions, there is potential for disruption to construction activities due to flooding and waterlogged soils, as well as the potential for downstream flooding.

5.2 Mobilisation of soils

Impacts of increased sedimentation are discussed in detail in the surface water quality assessment report prepared for this EIS (GHD, 2015) but are mentioned here for their potential to change surface water flows.

There is potential for large quantities of sediment to be directed into the network of temporary drainage as it is progressively constructed. If not appropriately managed, this would cause blockage of the on-site stormwater management network, reducing its effectiveness and increasing the likelihood of flow breakouts and overland flow paths with the effect of causing on-site flooding or flooding downstream.

5.3 Watercourse geomorphology

The primary impact on watercourse geomorphology during the Stage 1 construction will be the loss of natural drainage lines and watercourses within the construction footprint (Figure 5-1). The total length of mapped watercourses within the Stage 1 construction footprint is approximately 36.5 km, predominantly consisting of first and second order watercourses (Table 5-1). In addition, approximately 4.4 km of third order watercourses lie within the Stage 1 construction footprint.

Table 5-1 Length of watercourses by stream order within the Stage 1 construction footprint

Stream Order	Length (km)
1	22.2
2	9.9
3	4.4

The construction footprint for the longer term development is not yet well defined. However, further expansion of the airport facilities is expected to occur between the Stage 1 construction area and Badgerys Creek. This expansion will subsume additional watercourses, primarily first and second order tributaries of Badgerys Creek.

Without appropriate erosion and sediment controls, the disturbance as a result of construction may also result in higher rates of offsite sediment generation, leading to sedimentation within pools along watercourses adjoining and downstream of the airport site. However, it is expected that construction practices would be in accordance with current erosion and sediment control standards and the offsite movement of sediment would be minimal. Hence, the risk of significant pool sedimentation is considered low.

5.4 Groundwater seepage

Groundwater seepage is expected during construction and will be required to be collected and managed, either by discharge back to the environment and/or removal offsite and disposal at an appropriately licensed treatment facility. Further details of the activities expected to generate seepage are provided in the groundwater assessment prepared for this EIS (GHD, 2015).

If treated water is discharged to the environment, there are a range of potential water quality impacts that could occur which are discussed separately in the surface water quality assessment. Whether treated or undertreated, there is also potential for impact on downstream flows and associated ecology if the volume of discharge disrupts the natural flow regime downstream of the point of discharge. The groundwater seepage disposal strategy is still to be determined, however the groundwater assessment determined that seepage volumes are expected to be low.

5.5 Construction water use

It has been estimated (refer to the project description) that construction would require, on average, 1.3ML of water per day during bulk earthworks.

Additional high water demand activities would be associated with the asphalt and concrete batching plants.

It is envisaged that within the earthworks footprint, temporary basins would be constructed to catch any runoff for reuse in the earthworks. This would be insufficient to meet the estimated 1.3 ML/day requirement for the bulk earthworks. At other times, potable would be used to supplement construction water requirements. To avoid constraints in potable water supply capacity, potable water would be extracted from the network in off peak times and used to fill the temporary basins for later use.

There are two existing potable water supply pipes located adjacent to the site. The first is located along Elizabeth Drive, the second on The Northern Road. Connection points would be determined in consultation with Sydney Water Corporation. The Contractor may also investigate alternative water sources, and seek appropriate approvals for their use.



LEGEND

- Airport site
- Earthworks area
- 1
- 2
- 3

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Stage 1 earthworks

Figure 5-1

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6. Operational impacts

6.1 Stage 1 development

6.1.1 Impacts on hydrology and flooding

Identified changes and potential implications

The establishment of the Stage 1 Development would result in major modification to existing flow paths and catchment boundaries with resultant potential impacts on surface water flows and the receiving watercourses.

In general, as part of the Stage 1 works, a portion of the airport site draining towards the Oaky and Cosgroves Creeks' catchments to the north would be diverted south towards Badgerys Creek whilst a portion of the airport site draining to Badgerys Creek would be diverted to Duncans and Oaky Creeks.

Under the existing case, a tributary of Badgerys Creek crosses Elizabeth Drive around 350 metres west of the main crossing and joins with Badgerys Creek downstream of Elizabeth Drive. Under Stage 1, the crossing would be removed and the tributary catchment at Elizabeth Drive diverted into Basin 1 and then to Badgerys Creek. A summary of changes to catchment areas is provided in Table 6-1 based on Geographical Information System (GIS) area calculations.

Table 6-1 Catchment area comparison between existing and Stage 1

Location	Catchment area (existing) (ha)	Catchment area (Stage 1) (ha)	% impervious (existing)	% impervious (Stage 1)
Badgerys Creek at Elizabeth Drive	2,052	2,362 ↑	12%	14%
Oaky Creek at Elizabeth Drive	361	292 ↓	10%	49%
Cosgroves Creek at Elizabeth Drive	536	603 ↑	14%	20%
Badgerys Creek at South Creek	2,799	2,800	12%	14%
Cosgroves Creek at South Creek	2,163	2,148 ↓	14%	21%
Duncans Creek at Nepean River	2,379	2,385 ↑	14%	15%

The table shows that there would be, as a result of the Stage 1 development:

- a net increase in catchment area draining to Badgerys Creek at Elizabeth Drive and a minor net increase in percentage imperviousness of the resulting catchment area;
- a net decrease in catchment area draining to Oaky Creek due to diversions to Badgerys Creek and a substantial net increase in catchment percentage imperviousness;
- a net increase in catchment area draining to Cosgroves Creek at Elizabeth Drive and a moderate net increase in catchment imperviousness;
- a negligible change in catchment for Badgerys Creek at South Creek;
- a net decrease in catchment area draining to Cosgroves Creek at South Creek and a moderate net increase in catchment imperviousness; and
- a negligible net increase in catchment area draining to Duncans Creek and negligible increase in catchment percentage imperviousness.

Under Stage 1, bulk earthworks including extensive cutting and filling across the site to level it would result in changes to storage characteristics, as would the removal of the farm dams. The model results account for these changes with respect to the representation of changes to catchment slope, boundary and rainfall losses.

The airport would change surface run-off conditions in the catchments it intersects, which may also create minor incidental losses associated with evaporative changes.

A decrease in catchment area, dependent on impervious fraction, would tend to decrease flows downstream and conversely, in the case of an increase in catchment area, would tend to increase flows downstream.

The increase in catchment imperviousness would, without intervention, tend to increase the peak flows and the potential to influence timing of flows by causing flows to peak earlier.

The effect of the change in catchment area, whether major or minor, is dependent on the changes in flows and hydraulics that result from the changes. The changes in flow are discussed later in this report.

Design control measures

Detention basins are proposed at most site discharge points for the dual purpose of treating water quality and mitigating potential increases in peak flows (refer to Figure 3-3). Where no basin is proposed, this is because it was not deemed necessary during design development. In general, detention basins used for construction would be reused in the longer term, though only a portion of the eventual longer term water capacity would be provided in the initial development stage.

The proposed storage basin volumes are presented in Table 6-2, together with the percentage size of the basin in Stage 1 compared to that proposed in the longer term.

Table 6-2 Detention basin attenuation volume

Basin Number	Initial basin volume (m^3) compared to longer term volume (%)
1	64,000 (80%)
2	8,100 (30%)
3	15,900 (30%)
4	10,400 (20%)
5	*Not included in Stage 1 and 65,000 in longer term*
6	75,000 (100%)
7	82,000(100%)
8	41,000 (100%)

Predicted impacts

Comparison of flows under existing and Stage 1 conditions for a 1 year ARI and 100 year ARI events are provided in Figure 6-1 to Figure 6-10. The figures show, at the various locations indicated in Figure 4-3:

- the existing flows;
- the flows entering the detention basins (where there is a detention basin proposed); and
- the flows leaving the detention basin or point of discharge.

The plots show flows for the critical duration at each location. Plots for a short and a long duration storm are included in Appendix B.

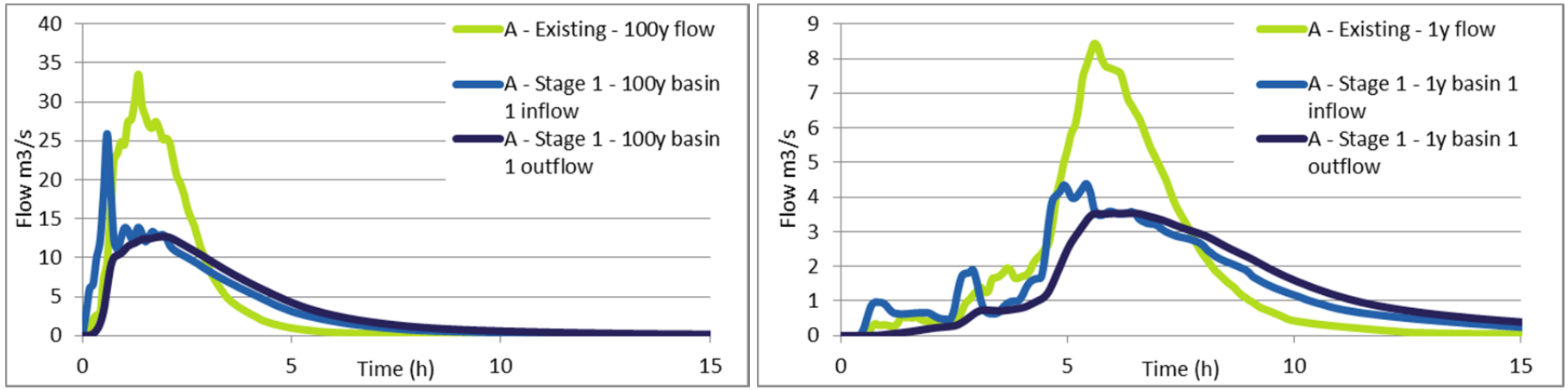


Figure 6-1 Location A at Basin 1, comparison of existing and Stage 1 flows

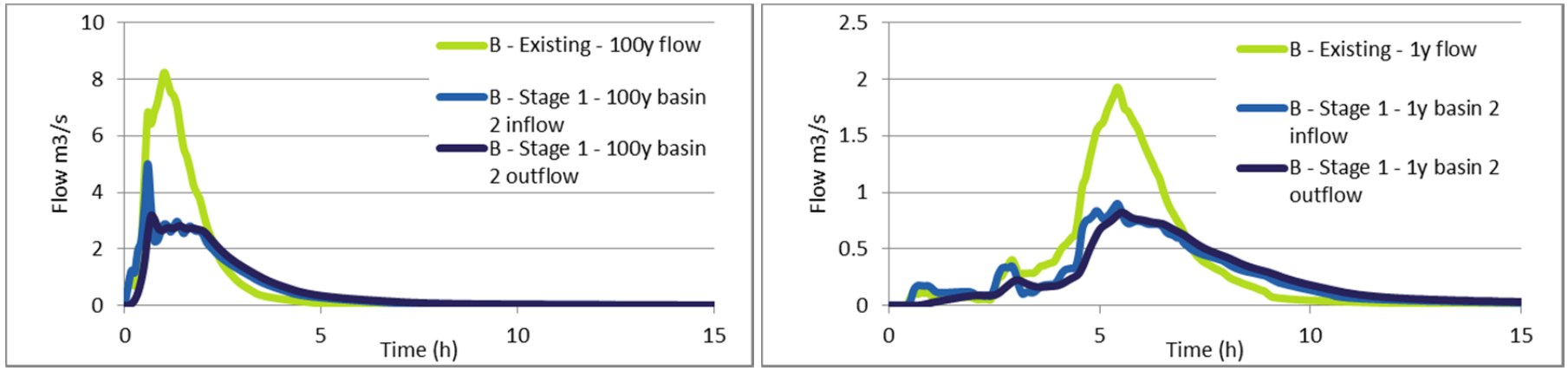
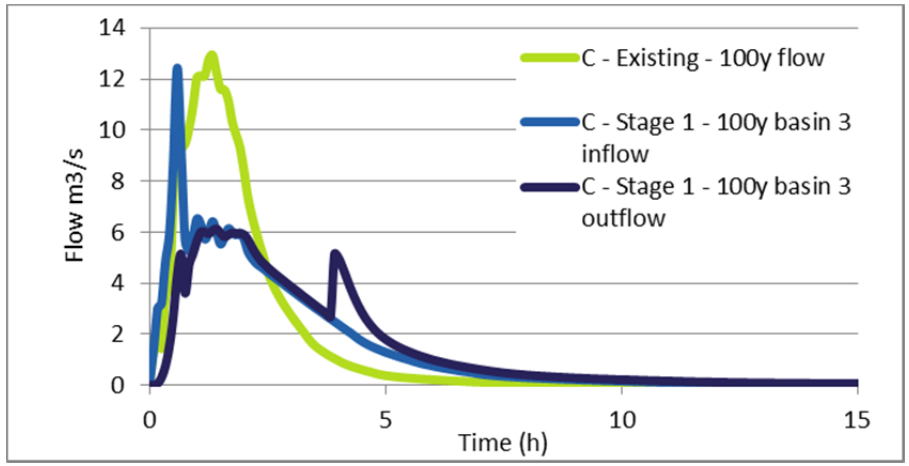


Figure 6-2 Location B at Basin 2, comparison of existing and Stage 1 flows



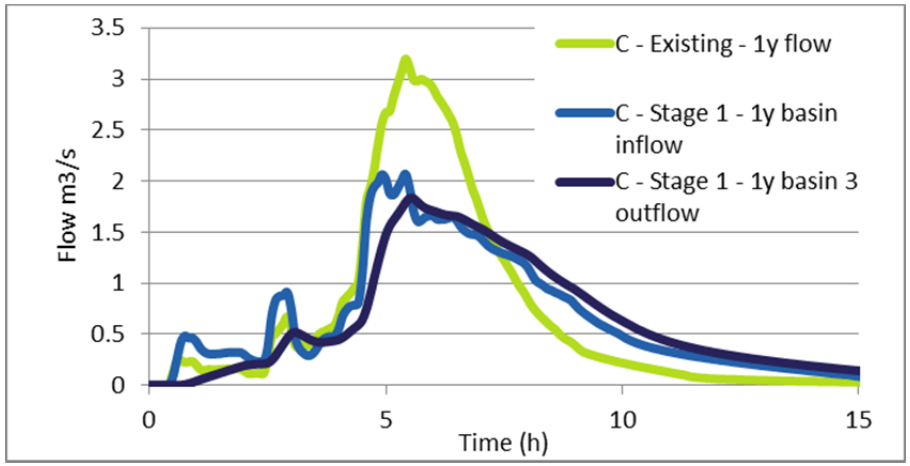
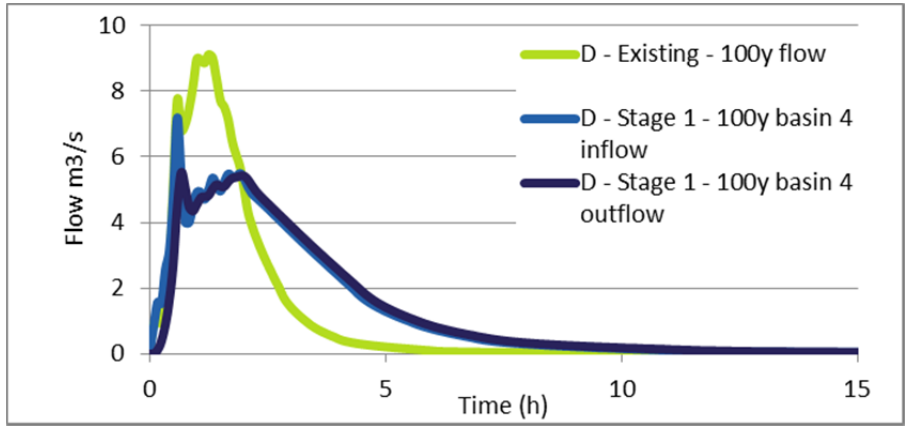


Figure 6-3 Location C at Basin 3, comparison of existing and Stage 1 flows



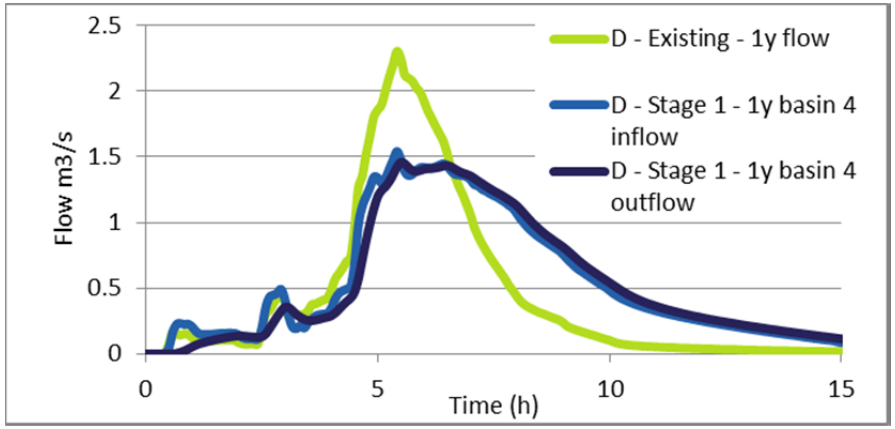
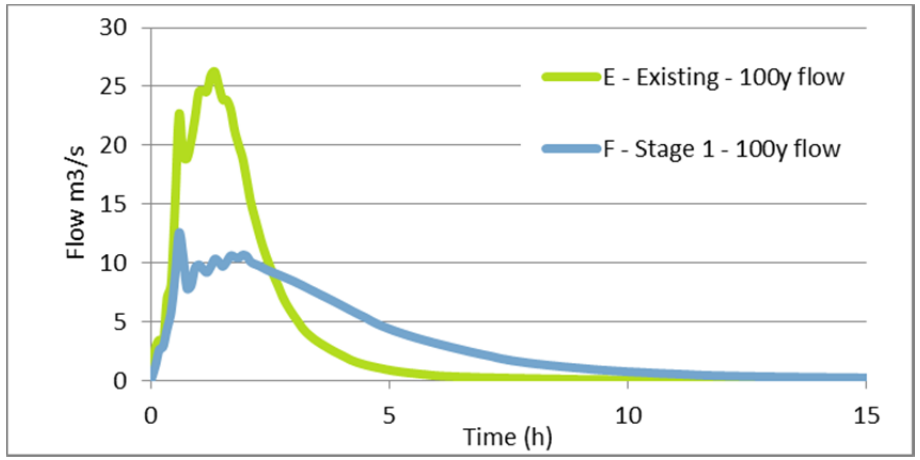


Figure 6-4 Location D at Basin 4, comparison of existing and Stage 1 flows



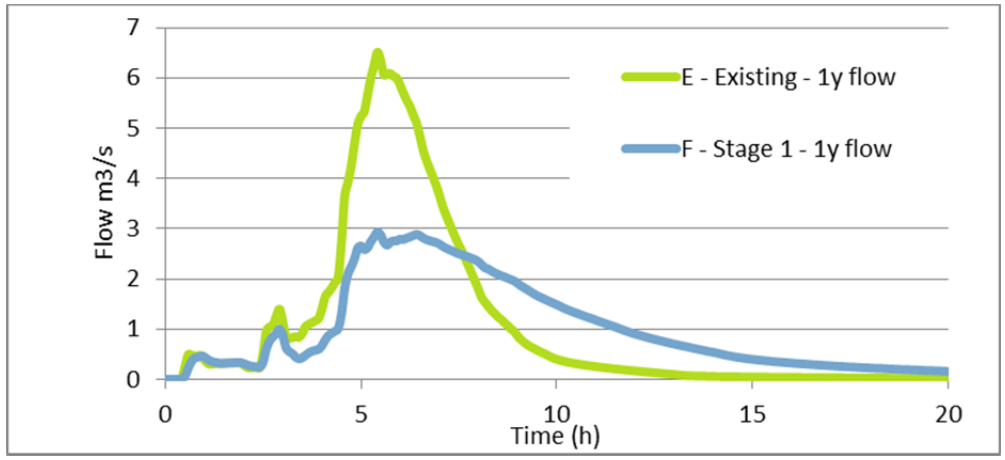
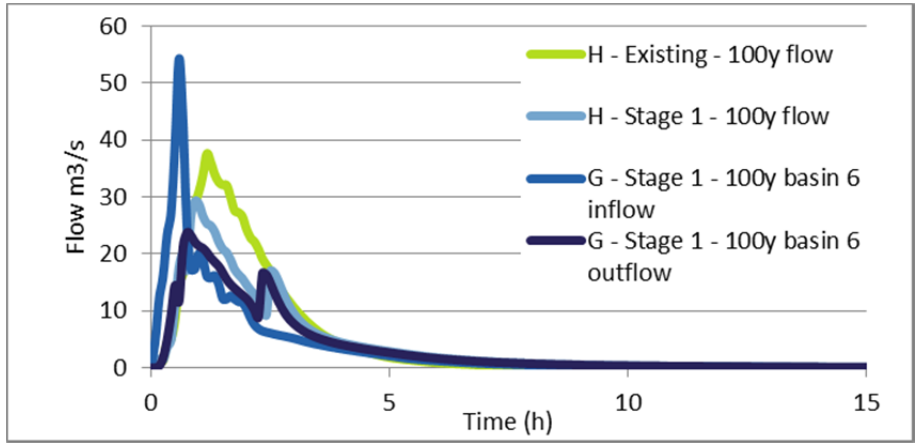


Figure 6-5 Location E and F, comparison of existing and Stage 1 flows (no basin proposed)



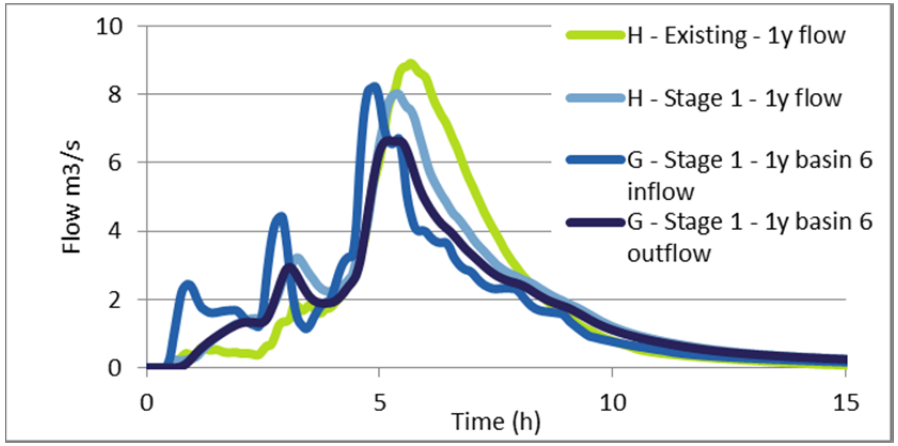
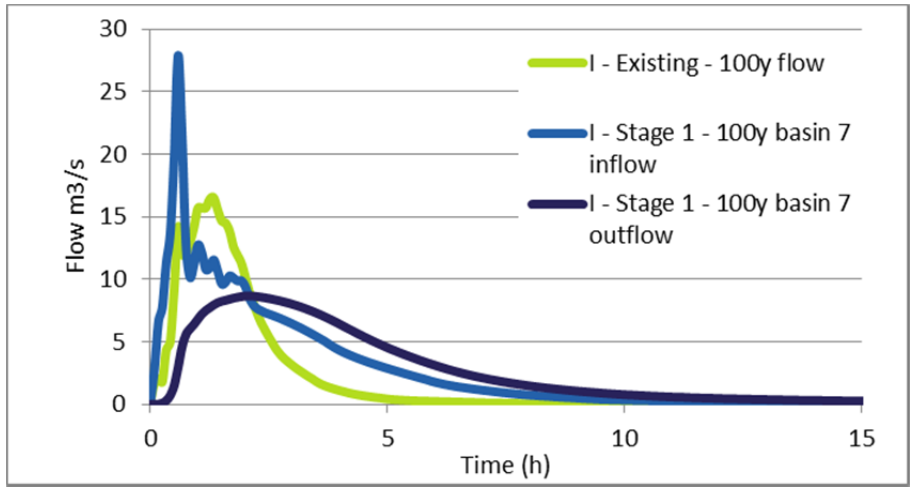


Figure 6-6 Locations G and H, comparison of existing and Stage 1 flows



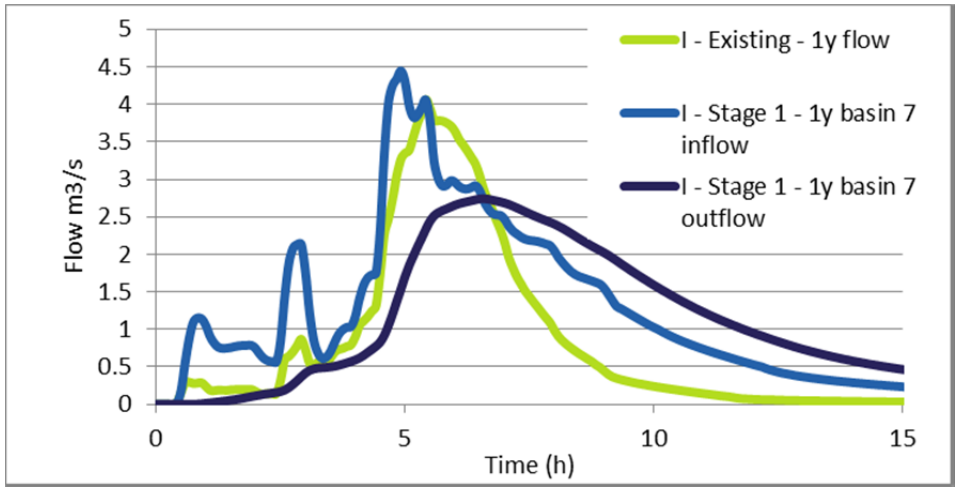
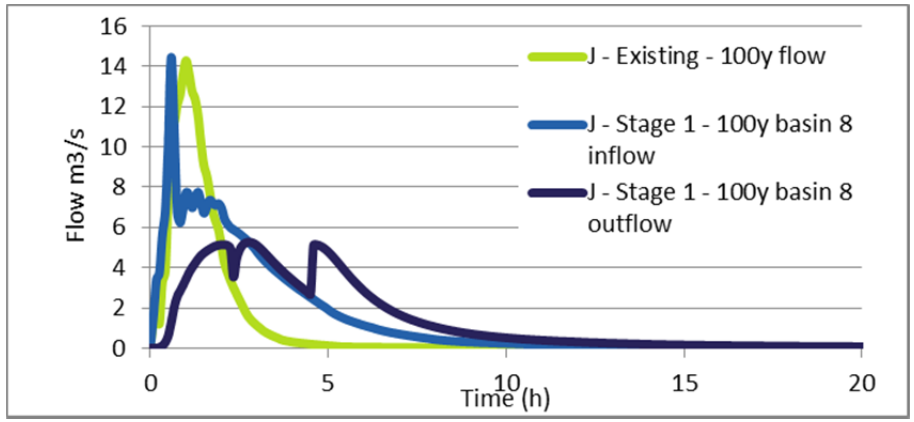


Figure 6-7 Locations I, comparison of existing and Stage 1 flows



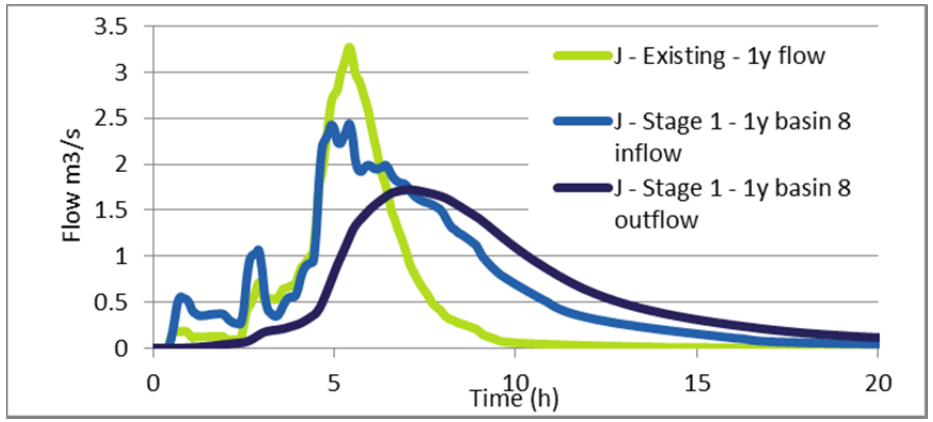
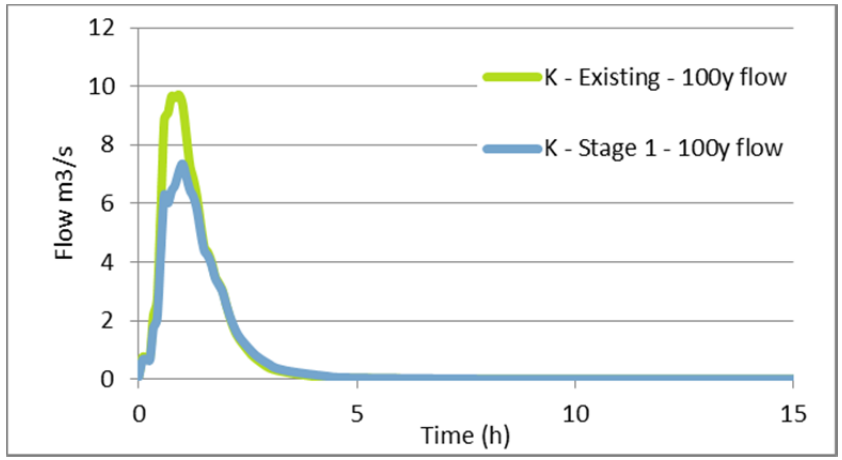


Figure 6-8 Locations J, comparison of existing and Stage 1 flows



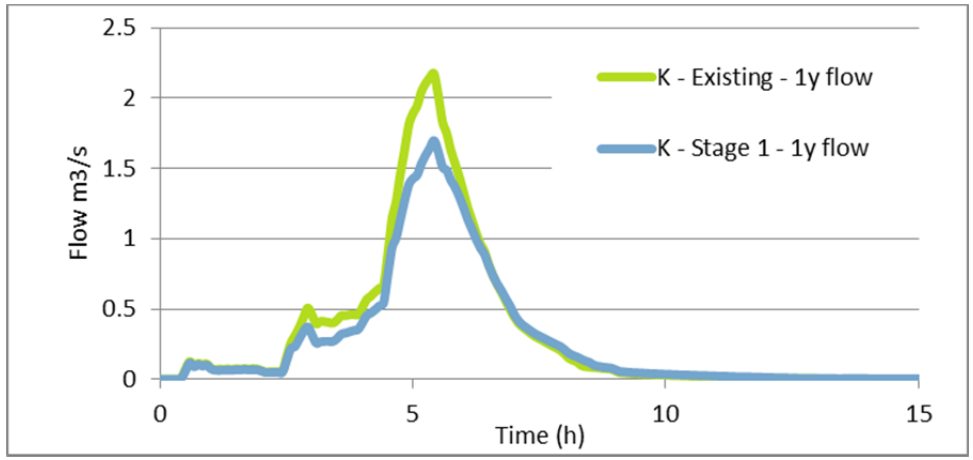
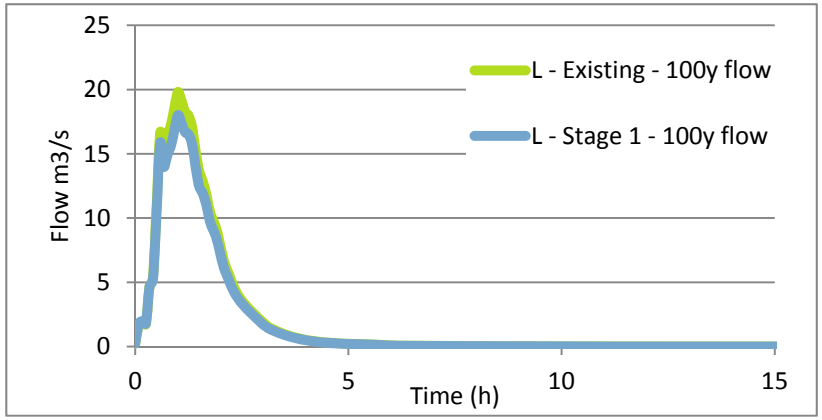


Figure 6-9 Location K, comparison of existing and Stage 1 flows



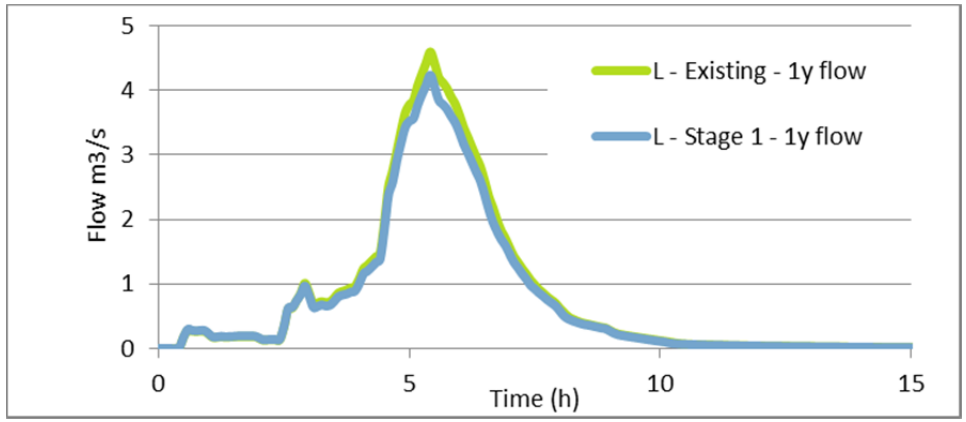


Figure 6-10 Location L, comparison of existing and Stage 1 flows

It is noted that, due to changes in catchment configuration between the existing case and Stage 1, some of the reported locations vary slightly between the two scenarios.

Where the existing flows are indicated to be greater than the flows entering the basins under Stage 1 (basins 1 to 4), this is generally because a portion of the total catchment flow would bypass the basin in Stage 1. The basins attenuate the flows substantially, to compensate for the volume of un-attenuated flows bypassing the basins. This effect would be particularly notable in Stage 1 for the flows discharging to the southern portion of the site. The management of surface water would need to be developed further during the Stage 1 detailed design process to refine the sizing of the basins.

In the south-east portion of the site, a moderately sized area of the catchment draining under existing conditions to Badgerys Creek would be modified to drain north, resulting in less flow to Location F under Stage 1.

For the basins 6 to 8, there is some variation in discharge between existing and Stage 1 conditions. The basins are generally effective at mitigating peak flow increases from the site in the 100 year event and 1 year event.

The plots for location J and K show the predicted flows into tributaries of Duncans Creek. Marginal decreases are expected for the critical duration storm events. However, a small potential increase in flow is predicted at location K for a 100 year ARI short duration event. Propagation of increased flooding or change in watercourse stability is expected to be limited to localised areas around the point of discharge. However, as there are dwellings in the upper reaches of this tributary, mitigation measures need to be considered.

A review of the plots in Appendix B, indicates that for small (1 year ARI) short duration events, the increase in impervious area in Stage 1 influences the peak more than for longer duration events, with some evidence of a potential increase in flows at the point of discharge (for example, at location 6).

It is possible that localised scour and erosion at the points of discharge may occur and mitigation measures to address this are discussed in Section 8 of this report.

The influence of the current Stage 1 design on downstream hydraulics is assessed below and in Section 6.1.2.

Impacts on low flows and watercourse flooding

The impacts of the proposed Stage 1 airport on flood depths are shown in Figure 6-11 to Figure 6-13. In the figures, a positive value indicates an increase in flooding in Stage 1 over the existing case, and a negative value indicates a decrease. Extents of flooding in Stage 1 are included in Appendix C.

Oaky and Cosgroves Creeks

In a 1 year ARI event, flood impacts downstream of Elizabeth Drive include decreases in flow depth of up to around 50 mm in overbank areas. Within the channels, increases in level are within 100 mm of existing flow depth, except for a 200 m reach of Oaky Creek immediately downstream of Elizabeth Drive and upstream of its confluence with Cosgroves Creek where increases in flow depth of up to 250 mm are predicted.

Increases in depth on Cosgroves Creek upstream of the site are less than 10 mm and are considered relatively minor.

For a 5 year flood event, a decrease in flood level (though within 100 mm of existing) is predicted downstream of the airport, except in the case of the 200 m reach of Oaky Creek noted above. For the 100 year flood event, a decrease in flood level is predicted. The variations in

results for different ARI events reflect the influence of the basins which varies depending on the magnitude and timing of flows.

The dwellings identified as being located in, or within close proximity of, the 100 year ARI flood event would not experience an increase in flood levels based on the findings of this assessment.

Badgerys Creek

In a 1 year ARI event, flow depths downstream of Elizabeth Drive are predicted to decrease, but generally by less than 120 mm.

The exception is for the tributary of Badgerys Creek that joins Badgerys Creek approximately 300 metres downstream of Elizabeth Drive under existing conditions. Because that creek is proposed to be diverted to Basin 1 upstream of Elizabeth Drive and the stream extent within the site would be removed, there would be little to no flow in the reach of creek downstream of Elizabeth Drive. Measures to address the changed flow condition are discussed in Section 9.

Decreases in water levels along Badgerys Creek of up to around 150 mm would be expected in the critical duration event, generally due to the influence of the basins.

In a 100 year ARI event, the modelling shows some increases in flood level in Badgerys Creek between Basin 2 and Basin 3. This is due to the 3D design model incorporating infrastructure at this location from an earlier version of the concept design. That design version was subsequently superseded and therefore no significant impact on flooding at this location is predicted, other than localised changes at the point of discharge.

No worsening of flooding would therefore be expected to occur in surrounding dwellings and infrastructure during Stage 1 based on the proposed design.

Effectiveness of the basins

The current basin designs result in either a reduction in flows to the downstream creeks, with associated potential impacts on stream stability and ecology, or an increase in peak flows and change in timing at the point of discharge and on a limited reach of Oaky Creek, with associated potential flood and watercourse stability impacts.

There is some vegetation in the riparian corridors outside the site that is considered reliant on occasional flooding based on the biodiversity assessment. Discussion with the ecology team indicated that small changes in flows would be unlikely to influence the vegetation, provided that the vegetation still experienced occasional flooding. This is expected to be the case and the impact on this vegetation would be low as a result of the proposed changes. The exception to this finding is the tributary of Badgerys Creek discussed in the preceding section. Threatened ecological communities have not been mapped outside the site as part of the biodiversity assessment, but there is evidence of some remnant native vegetation along this reach of creek which would be reliant on occasional flooding and would be impacted under the current proposals.

The macroinvertebrate surveys found that the numbers of macroinvertebrates sensitive to changes in flow downstream of the site would generally be low and the influence of minor fluctuations in flow on macroinvertebrates is expected to be limited.

Where increases in flow discharging from the basins are predicted, no major impacts to flood prone residences are predicted, though some increases in flow depths are indicated.

No major impacts to creek stability are predicted, with the exception of a reach of Oaky Creek. Mitigation measures are discussed in Section 8.



LEGEND

Airport site

Flood depth difference (m)

<-2
-2 - -1
-1 - -0.5
-0.5 - -0.3
-0.3 - -0.1
-0.1 - 0
0 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
>2

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Flood depth impact - Existing and Stage 1
1-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 6-11

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Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site

Flood depth difference (m)

<-2
-2 - -1
-1 - -0.5
-0.5 - -0.3
-0.3 - -0.1
-0.1 - 0
0 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
>2

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Flood depth impact - Existing and Stage 1
5-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 6-12

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LEGEND

Airport site

Flood depth difference (m)

<-2
-2 - -1
-1 - -0.5
-0.5 - -0.3
-0.3 - -0.1
-0.1 - 0
0 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
>2

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Flood depth impact - Existing and Stage 1
100-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 6-13

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In summary, there is a degree of variation in how the basins respond to different storm durations and magnitudes which results in a range of potential flow outcomes. The attenuation of the incoming flows by the basins indicates that a basin strategy can be used to manage the increase in flow peaks and impacts to flood peak timing. Hence, it is expected that the basin strategy would mitigate the major impacts of changes to surface water from the development, though refinement of the strategy during design development would be required to reduce impacts to negligible levels and address specific more substantial impacts on Oaky Creek and the identified tributary of Badgerys Creek.

Surplus recycled water

It is proposed that airport wastewater be treated on-site. Sludge would be transported off-site, and the treated water re-used for restrooms, washing of vehicles and aircrafts, cooling towers and landscaping. It is possible that availability of recycled water would exceed demand, in which case an alternative use for the surplus recycled water would need to be sought. A strategy would be developed that may include consideration of options such as on-site subsurface irrigation. Any irrigation scheme would need to be developed to ensure no significant downstream flow impacts, particularly where runoff of additional irrigation water could alter the natural stream flow patterns.

Groundwater discharge

Groundwater seepage into cuts and subsurface basement areas would be required to be kept separate from surface water, treated and discharged back to the environment and/or removed offsite to an appropriately licensed treatment facility. This would present a long term (operational) water quality management and disposal issue. If not managed appropriately, it is possible that groundwater could interact with surface water and pose a risk to downstream water quality (discussed in a separate report) or interrupt the flow regime. However, groundwater seepage is not considered to be likely in significant volumes and discharge of high volumes into the surface water system would not be required.

6.1.2 Impacts on watercourse geomorphology

Changes to catchments and impervious areas have the potential to impact indirectly on the channel morphology of watercourses downstream of the airport site. In particular, catchment changes that result in increasing downstream flow durations and/or increased hydraulic shear stress can exacerbate erosion of the bed and banks of watercourse channels downstream of the airport site.

Figures D-1 to D-6 (Appendix D) display discharge hydrographs derived from the hydraulic model for the reporting location downstream of Elizabeth Drive along both Cosgroves and Badgerys Creeks. The hydrographs are for the modelled 1, 5 and 100 year ARI events for existing, Stage 1 and longer term conditions. These indicate that the modelled flow event durations for the Stage 1 conditions are similar to those of existing conditions along both watercourses downstream of the airport site.

Additionally, with the exception of the 1 year ARI event along Cosgroves Creek, modelled peak discharges reduce in response to the Stage 1 Development. The hydrograph for the 1 year ARI event along Cosgroves Creek indicates a slight increase in peak discharge from approximately 16 m^3/s to 18 m^3/s. This is considered to be a minor increase and is unlikely to lead to any measurable morphological impact along Cosgroves Creek downstream of the airport site. Hence, as flow durations for the modelled events under Stage 1 conditions remain similar to the existing conditions and peak discharges typically reduce, the potential for significant impacts to the morphology of watercourses downstream is considered low.

To further explore the spatial distribution of potential morphological impacts to watercourses adjoining and downstream of the airport site, the modelled shear stress distributions for the Stage 1 and existing conditions were compared. Figures C-8 to C-10 (Appendix C) display maximum modelled shear stress differentials between the Stage 1 Development and the existing conditions for the 1, 5 and 100 Year ARI events. These indicate that changes in shear stress values as a result of the Stage 1 Development largely remain within – 5 to +5 N/m^2 of those in the modelled existing results along Cosgroves Creek and typically reduce compared to the existing levels along Badgerys Creek.

To provide context, Figures C-1 to C-3 (Appendix C) also display the modelled maximum shear stress distributions for existing conditions. These indicate that maximum shear stress values under existing conditions along Cosgroves and Badgerys Creek are typically less than 100 N/m^2, with very localised higher values in the range of 100 to 200 N/m^2 during the 100 Year ARI event.

Based on a synthesis from various studies by Blackham (2006), shear stress thresholds for the disturbance of vegetation and surface erosion lie in the range of 100 to 200 N/m^2, varying largely by vegetation type. Given the modelled shear stress changes under the Stage 1 Development are typically at least less than 5% of this threshold range, the Stage 1 Development is unlikely to result in widespread and significant further exceedances of thresholds for the disturbance of vegetation and surface erosion along watercourses adjoining and downstream of the airport site. This further supports the conclusion that the Stage 1 Development will have a low impact on the morphology of watercourses adjoining and downstream of the airport site.

However, the results indicate higher increases in modelled Stage 1 shear stress values along a reach of Oaky Creek extending approximately 100 to 200 metres downstream from Elizabeth Drive depending on the flow event modelled. Typically, these increases are in the range of 10 to 20 N/m^2 for all events modelled. Existing modelled 100 year ARI event shear stress values lie between 20 to 60 N/m^2 (Figures C-1 to C-3 Appendix C) and with the increases, the thresholds for the disturbance of vegetation and surface erosion are approached. It is therefore considered that there is a potential for the current form of the proposed Stage 1 Development to result in an increase in scour and erosion along this reach of Oaky Creek immediately downstream of Elizabeth Drive.

The results show elevated increases in modelled shear stress values along sections of Badgerys Creek between Basin 2 and Basin 3. However, as a result of changes to the land use plan (refer to the discussion in section 6.1.1), there is no significant impact on flood flow hydraulics predicted at this location.

6.1.3 Impacts on water quantity from wastewater

An estimated 2.5 ML of wastewater per day would be generated during operation of the Stage 1 Development. Wastewater would be reticulated to a treatment facility before being recycled or irrigated at the airport site. Recycled water could be utilised for a range of potential uses.These include the use of reclaimed water in maintenance of plant and infrastructure, industrial cooling processes or landscaping and also in irrigation. Irrigation water has the potential to affect the quantity of flow into receiving waterways depending on the means of application and irrigation technology.

Any irrigation of reclaimed water would likely occur on land previously disturbed by the construction of the Stage 1 Development (the construction impact zone).

The irrigation area would be designed and operated in accordance with the risk framework and management principles contained in the National Guidelines on Water Recycling (Environment Protection and Heritage Council 2006) and the Environmental guidelines: Use of effluent by

irrigation (NSW DEC 2004). The following would apply with respect to water quantity (effects on soils are discussed in other chapters of this EIS).

- The irrigation area would be delineated based on the expected rate of irrigation and the drainage characteristics of the receiving soil.
- The irrigation area would be designed to include capacity to store treated water for the duration of typical wet weather events.
- The rate of irrigation would be optimised to avoid the ponding of reclaimed water or creation of excess surface water runoff.
- Soil and groundwater conditions would be monitored to identify and correct trends in soil salinity, sodicity or other potential effects of irrigation.

It is considered that this approach would avoid impacts to the patterns of flow in the downstream environment.

6.2 Longer term development

6.2.1 Impacts on hydrology and flooding

Identified changes and potential implications

As with Stage 1, there would be a change in the on-site catchment area in the longer term as a result of the proposed development. A summary of changes to catchment areas between the existing and longer term developments is provided in Table 6-3. The longer term catchment areas and changes in impervious areas are based on comparison against the existing case absent of any airport development. They incorporate changes which would occur in Stage 1 as well as the subsequent longer term effects.

Table 6-3 Catchment area comparison between the existing environment and the longer term development

Location	Catchment area (existing) (ha)	Catchment area (longer term) (ha)	% impervious (existing)	% impervious (longer term)
Badgerys Creek at Elizabeth Drive	2052	2394 ↑	12%	30%
Oaky Creek at Elizabeth Drive	361	289 ↓	10%	53%
Cosgroves Creek at Elizabeth Drive	536	600 ↑	14%	29%
Badgerys Creek at South Creek	2799	2831 ↑	12%	27%
Cosgroves Creek at South Creek	2163	2142 ↓	14%	24%
Duncans Creek at Nepean River	2379	2360 ↓	14%	17%

The table shows that there would be substantial increases in impervious areas for all catchments. Changes in catchment area are relatively small, though the overall impact of these in terms of the flow patterns that result is examined further in this Section.

The increase in catchment area (where applicable) and in catchment imperviousness would, without intervention, tend to increase the peak flows and have the potential to influence timing of peak flows. Flows may peak earlier, though later peaks could also occur.

A decrease in catchment area, dependent on impervious fraction, would tend to decrease flows downstream. In the longer term, the effects could also create a transfer of water from the Water Sharing Plan's Wallacia Weir Management Zone (in which Duncans Creek is located) to the Upper South Creek Management Zone (in which Badgerys, Oaky and Cosgroves Creeks are located). These zones are discussed further in section 2.2

The increase in imperviousness for the longer term development is, in some catchments, a further increase from that proposed in Stage 1.

Design control measures

An extension of the Stage 1 detention basins is proposed together with provision of an additional detention basin in the longer term.

The proposed storage basin volumes in the longer term are presented in Table 6-4.

Table 6-4 Longer term detention basin attenuation volume

Basin Number	Basin volume (m^3)
1	80,000
2	27,000
3	53,000
4	82,000
5	65,000
6	75,000
7	82,000
8	41,000

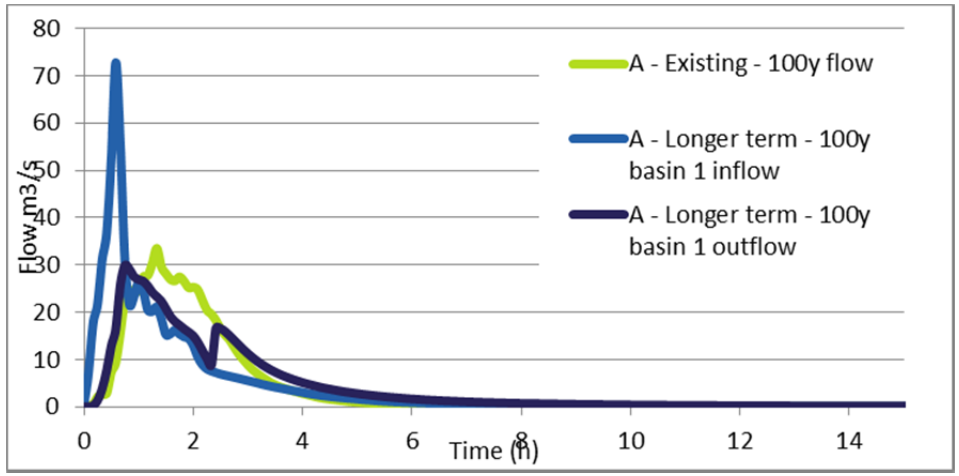
Predicted impacts with design control measures in place

Comparisons of flows under existing and longer term conditions for a 1 year ARI and 100 year ARI events are provided in Figure 6-14 to Figure 6-23. The figures show, at the various site discharge points indicated in Figure 4-3:

- the existing flows;
- the flows entering the detention basins (where there is a detention basin proposed); and
- the flows leaving the site (via the detention basins, where there is a detention basin proposed).

The plots show flows for the critical duration at each location. Plots for a short and a long duration storm are included in Appendix B.

On Duncans Creek, there is a predicted increase in flow in a 100 year ARI event at Location K, though this impact is predicted to dissipate once the tributary passing through Location K joins Duncans Creek shortly downstream of the site. Nonetheless, there is potential for localised increase in flooding and scour at this location under large flood events. No basin is currently proposed at this location.



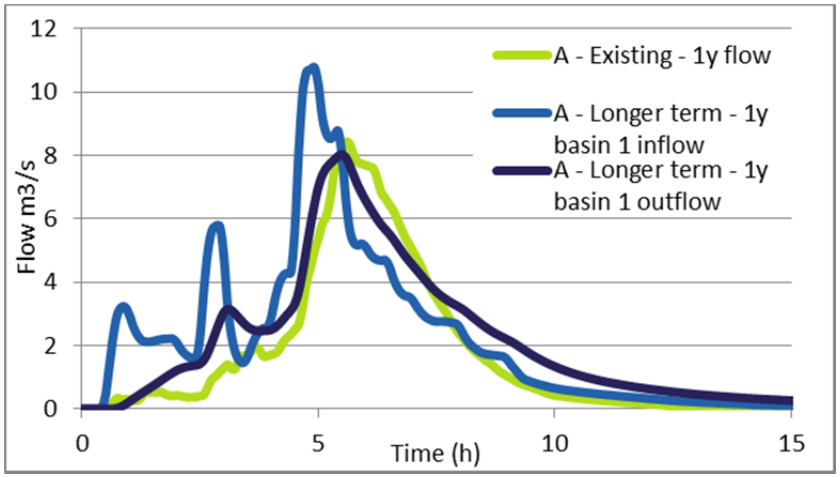
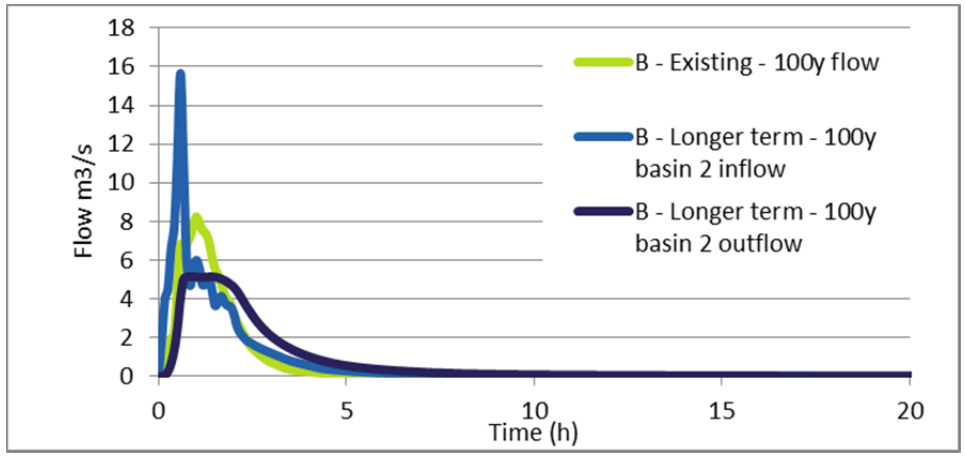


Figure 6-14 Location A at Basin 1, comparison of existing and longer term flows



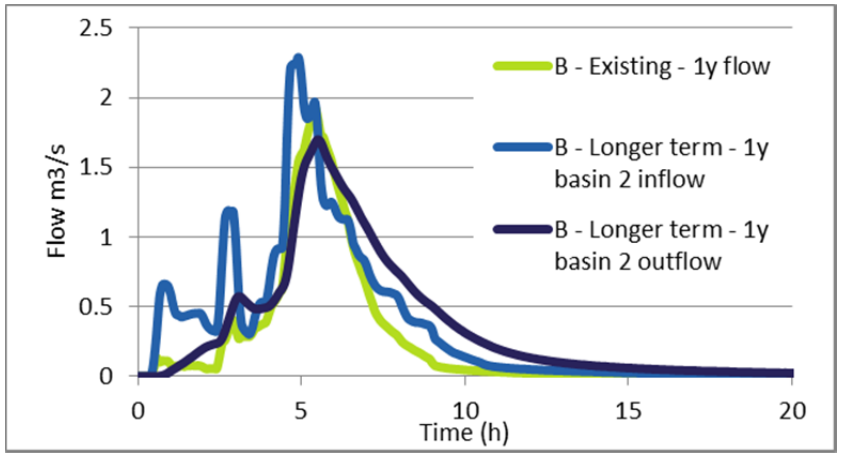
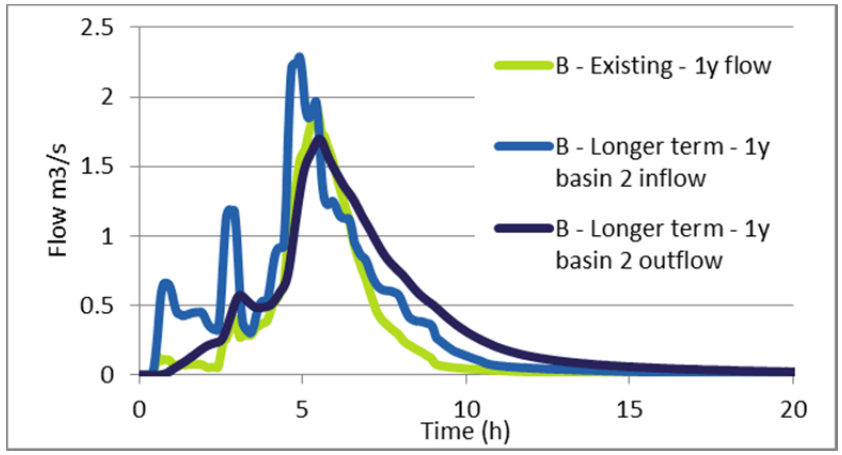


Figure 6-15 Location B at Basin 2, comparison of existing and longer term flows



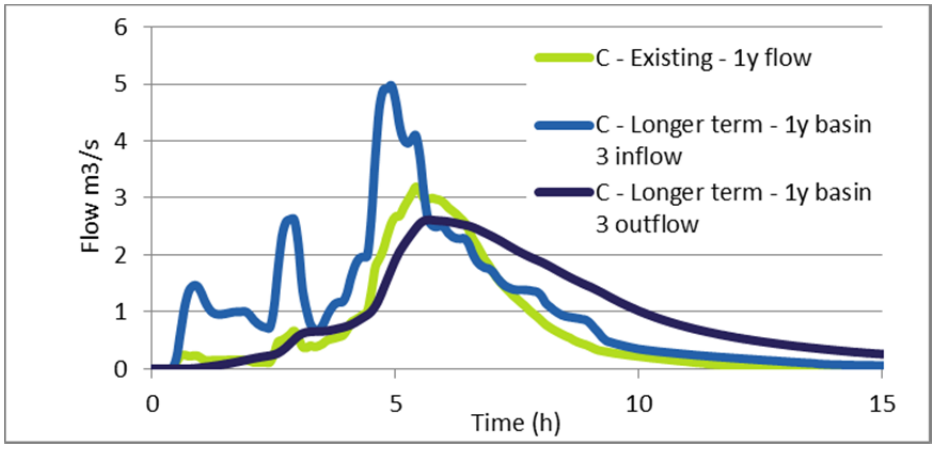
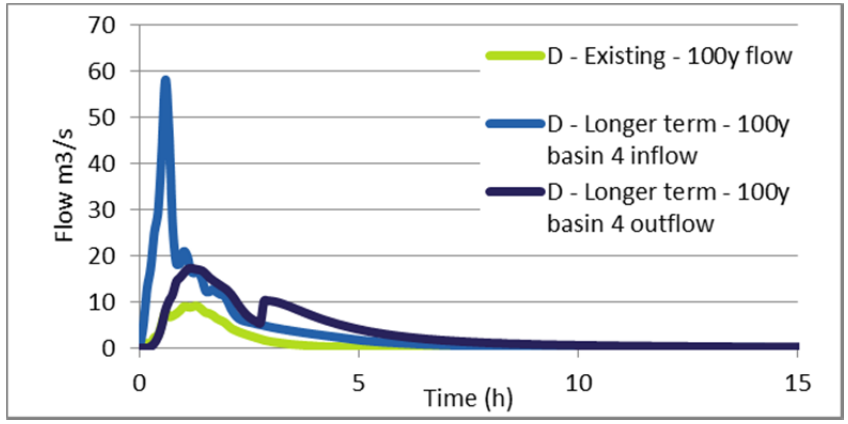


Figure 6-16 Location C at Basin 3, comparison of existing and longer term flows



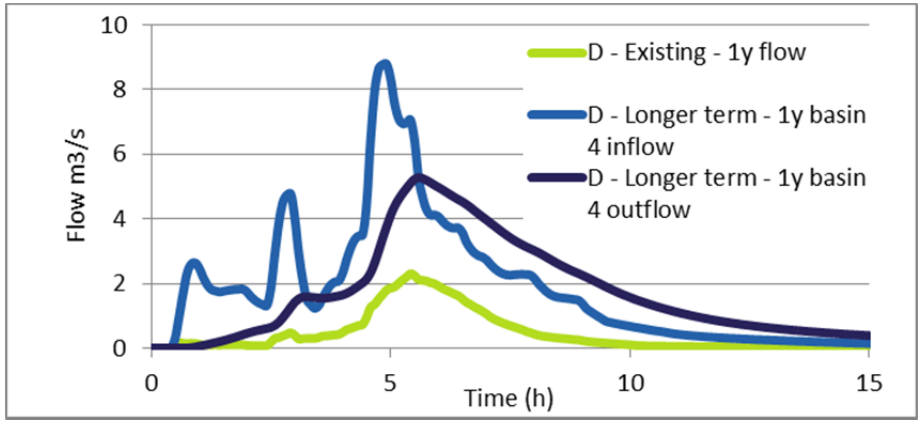
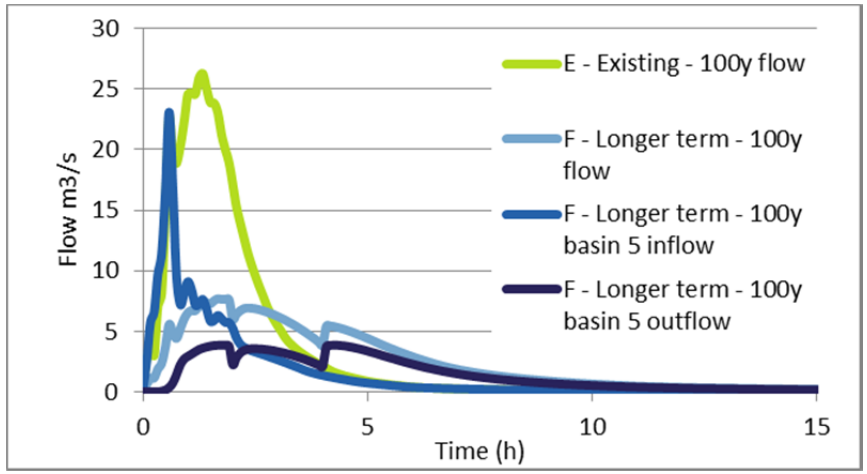


Figure 6-17 Location D at Basin 4, comparison of existing and longer term flows



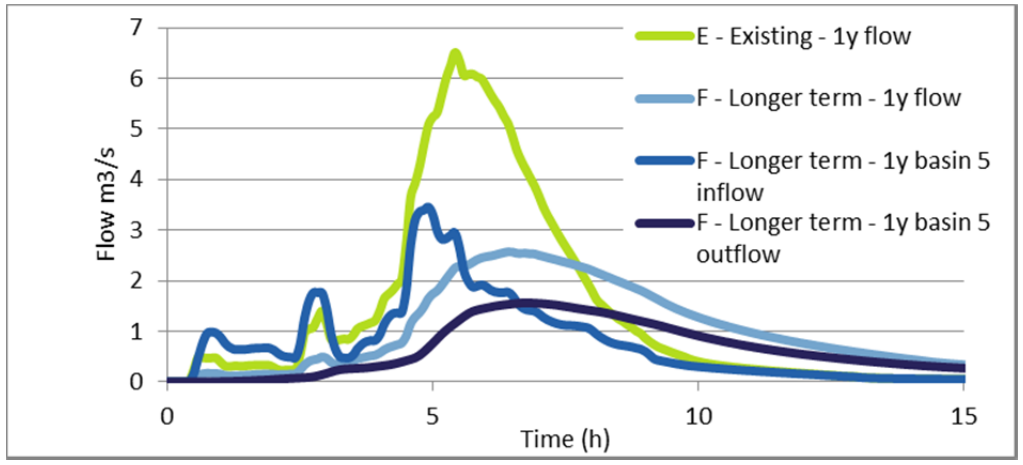
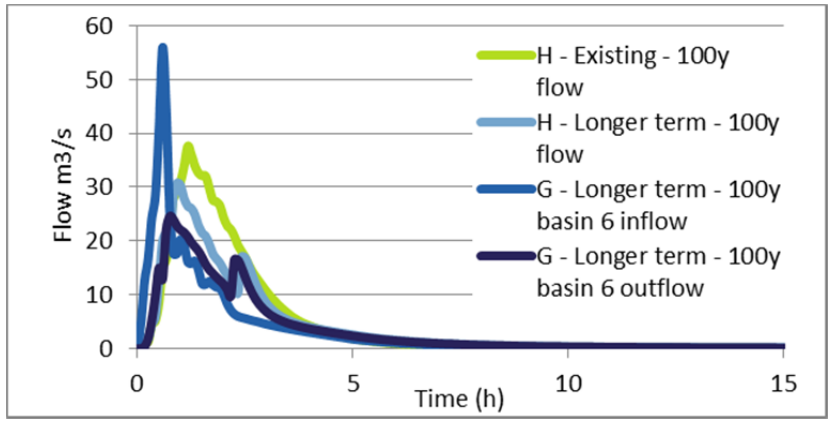


Figure 6-18 Locations E and F, comparison of existing and longer term flows



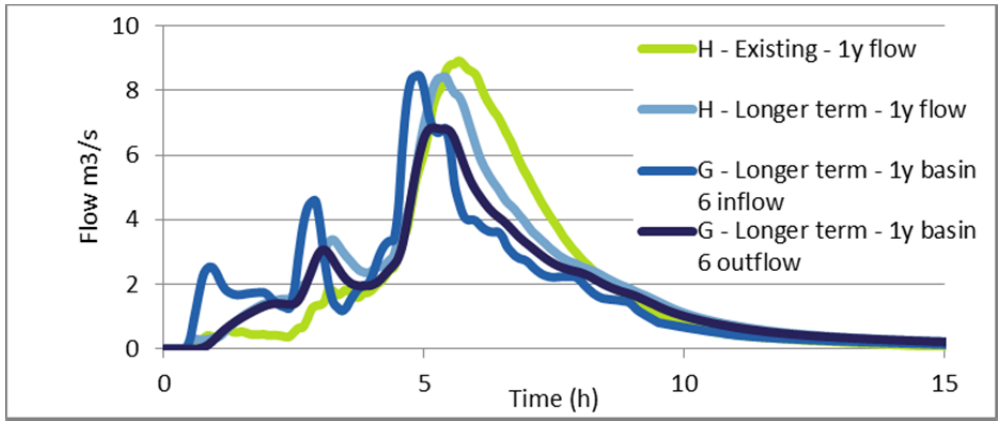
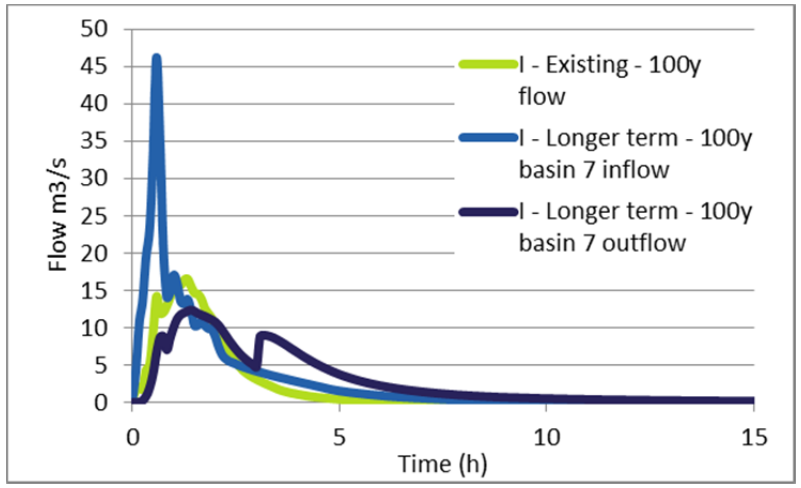


Figure 6-19 Locations G and H, comparison of existing and longer term flows



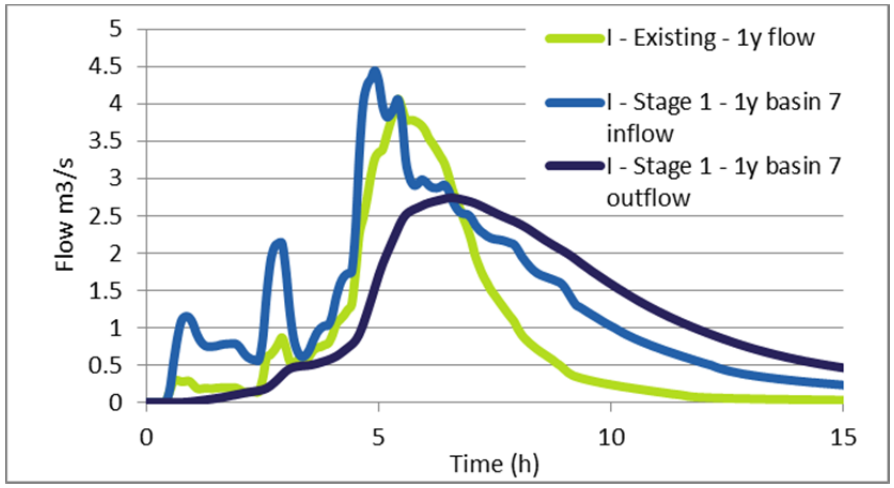
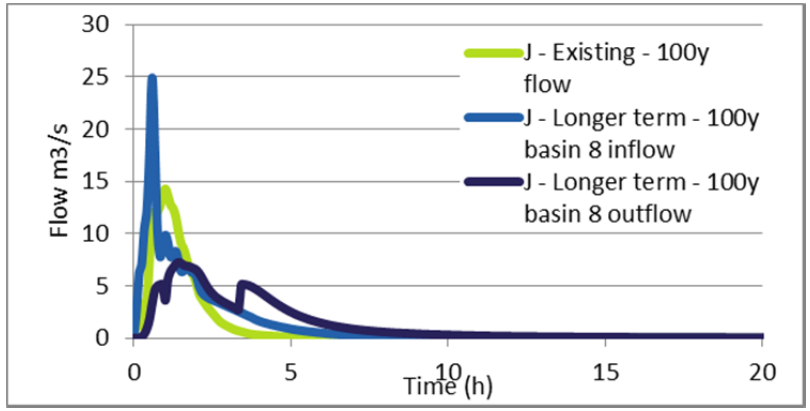


Figure 6-20 Locations I, comparison of existing and longer term flows



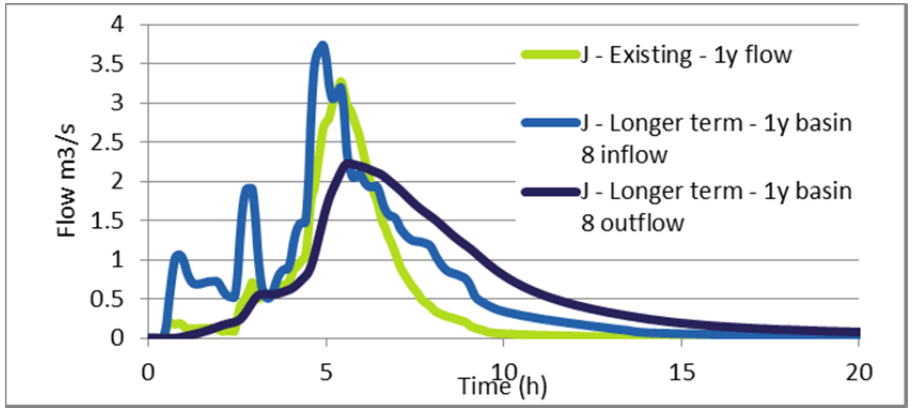
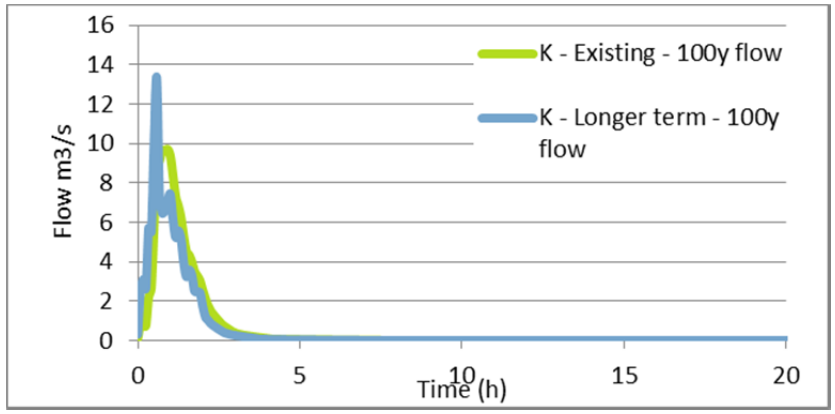


Figure 6-21 Locations J, comparison of existing and longer term flows



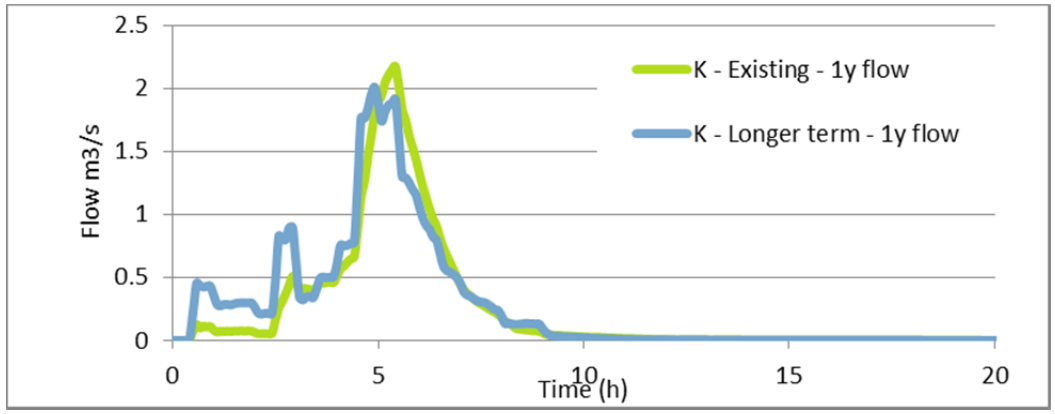
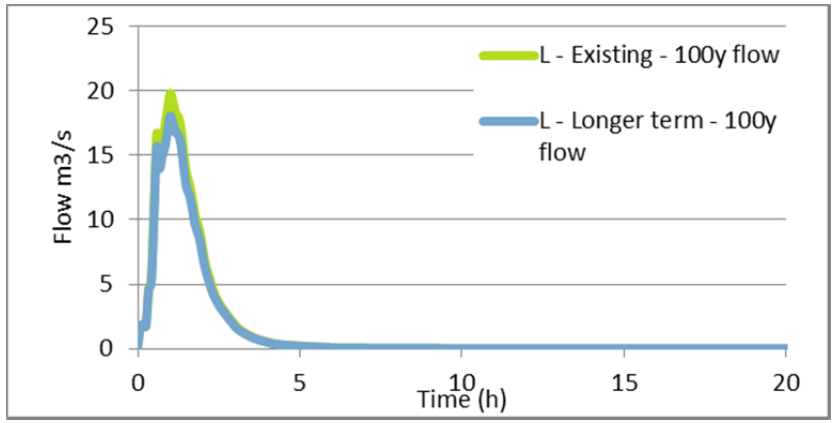


Figure 6-22 Location K, comparison of existing and longer term flows



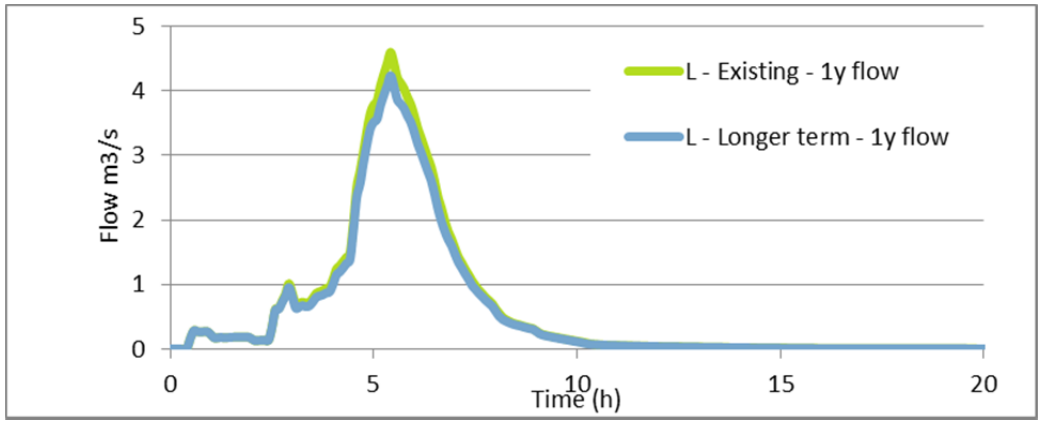


Figure 6-23 Location L, comparison of existing and longer term flows

Impacts on low flows and watercourse flooding

Figure 6-24, Figure 6-25 and Figure 6-26 show the predicted impacts of the longer term development on flood depths for the 1 year ARI, 5 year ARI and 100 year ARI events.

Oaky and Cosgroves Creeks

In a 1 year ARI event, flow depths downstream of Elizabeth Drive are predicted to increase by up to 120 mm generally and up to 250 mm on Oaky Creek upstream of its confluence with Cosgroves Creek.

Increases in depth on Cosgroves Creek upstream of the site are less than 10 mm different to the existing level and are considered relatively minor.

For the 5 year ARI and 100 year ARI, depths are within 25 mm of the existing level and no worsening of flooding to surrounding dwellings and infrastructure is expected.

Badgerys Creek

In a 1 year ARI event, flow depths downstream of Elizabeth Drive are predicted to decrease, but generally by less than 120 mm. The exception is the tributary of Badgerys Creek (discussed under Stage 1).

In other events, decreases in water levels along Badgerys Creek of up to around 150 mm would be expected in the critical duration event, generally due to the influence of the basins.

As with the Stage 1 Development, increases in flood level shown in the vicinity of Basin 2 and 3 is an anomaly which occured as a result of updated design drawings and the previous location of infrastructure which has since been removed.

No worsening of flooding would therefore be expected to surrounding dwellings and infrastructure based on the proposed design.

A portion of Badgerys Creek passes through the proposed longer term development area, in the south of the airport site. This area is proposed for business use in the longer term. There is potential for a range of impacts to Badgerys Creek if the surrounding development is not appropriately managed. Impacts could include increased flooding, and influences on creek geomorphology. Proposals for treatment of the creek where it passes through the site would be developed in subsequent design stages.

6.2.2 Impacts on watercourse geomorphology

Further changes to catchment areas and impervious areas as a result of the longer term development may also indirectly impact the channel morphology of watercourses downstream of the airport site. In particular, further catchment changes that result in increasing downstream flow durations and/or increased hydraulic shear stress can result in exacerbated erosion of the bed and banks of watercourse channels downstream of the airport site.

6.2.3 Impacts on water quantity from wastewater

The principles applying in Stage 1 to the use of recycled water for water quality would also be expected to apply in the longer term. As a result, impacts to surface water would be minimal.



LEGEND

Airport site

Flood depth difference (m)

<-2
-2 - -1
-1 - -0.5
-0.5 - -0.3
-0.3 - -0.1
-0.1 - 0
0 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
>2

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Flood depth impact - Existing and Longer Term
1-year ARI event

Figure 6-24

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LEGEND

Airport site

Flood depth difference (m)

<-2
-2 - -1
-1 - -0.5
-0.5 - -0.3
-0.3 - -0.1
-0.1 - 0
0 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
>2

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Flood depth impact - Existing and Longer Term
5-year ARI event

Figure 6-25

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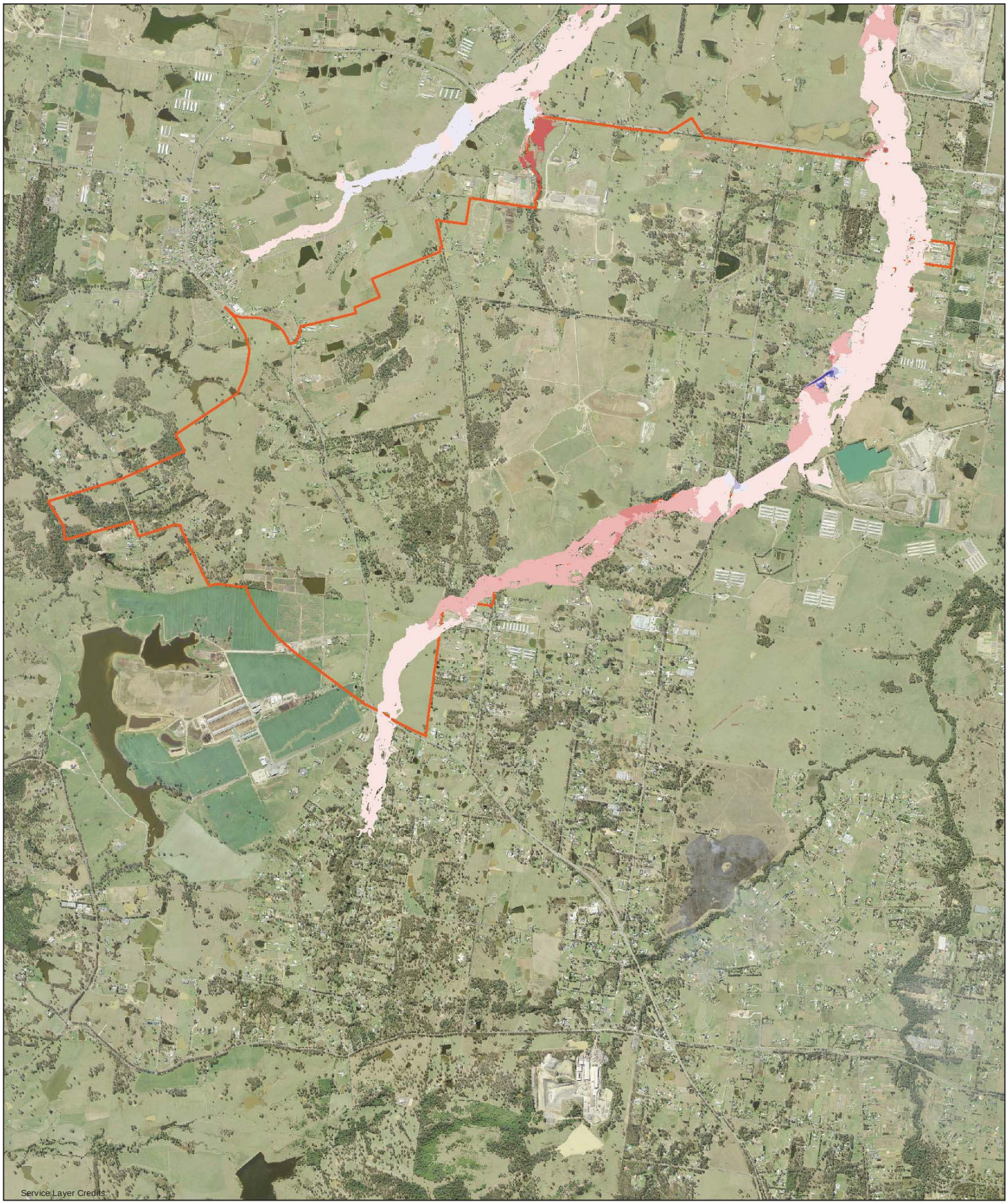
Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site

Flood depth difference (m)

<-2
-2 - -1
-1 - -0.5
-0.5 - -0.3
-0.3 - -0.1
-0.1 - 0
0 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
>2

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Flood depth impact - Existing and Longer Term
100-year ARI

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 6-26

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Figures D1 to D6 (Appendix D) display discharge hydrographs derived from the hydraulic model for the reporting location downstream of Elizabeth Drive along both Cosgroves and Badgerys Creek. The hydrographs are for the modelled 1, 5 and 100 year ARI events for existing, Stage 1 and longer term conditions. These indicate that the modelled flow event durations for the longer term conditions are similar to that of existing conditions along both watercourses downstream of the airport site.

Additionally, with the exception of the 1 year ARI event along Cosgroves Creek, modelled peak discharges reduce in response to the longer term development. The hydrograph for the 1 year ARI event along Cosgroves Creek indicates a slight increase in peak discharge from approximately 16 m^3/s to 19 m^3/s. This is considered to be a minor increase and is unlikely to lead to any measurable morphological impact along Cosgroves Creek downstream of the airport site. Hence, as flow durations for the modelled events under the longer term development conditions remain similar to existing conditions, and peak discharges typically reduce, the potential for significant impacts to the morphology of watercourses downstream is considered low.

To further explore the spatial distribution of potential morphological impacts to watercourses adjoining and downstream of the airport site, the modelled shear stress distributions for the longer term and existing conditions were also compared. Figures C15 to C17 (Appendix C) display maximum modelled shear stress differentials between the longer term development and the existing conditions for the 1, 5 and 100 year ARI events. These differences are similar to the differences between the existing conditions and the conditions during the Stage 1 Development, with shear stress changes largely remaining within – 5 to +5 N/m^2 to those of the modelled existing results along Cosgroves Creek and typically reducing along Badgerys Creek. This therefore indicates that the longer term development will also have a low impact on the morphology of watercourses adjoining and downstream of the airport site.

However, as per the Stage 1 Development, the longer term results indicate higher increases in modelled shear stress values along the reach of Oaky Creek extending approximately 100 to 200 metres downstream from Elizabeth Drive depending on the flow event modelled. Again, it is considered that there is a potential for the current form of the longer term development to result in an increase in scour and erosion along this reach of Oaky Creek immediately downstream of Elizabeth Drive.

Similarly, the longer term results show increases in modelled shear stress values along sections of Badgerys Creek between Basin 2 and Basin 3. As discussed in 6.1.2, the design layout used in the hydraulic model has been subsequently superseded. Therefore no impact on flood flow hydraulics is predicted at this location.

7. Cumulative impacts

7.1 Influence of climate change

It is possible that impacts of the development on hydrology and geomorphology could be exacerbated through future climatic changes, in particular changes to rainfall seasonality and intensity.

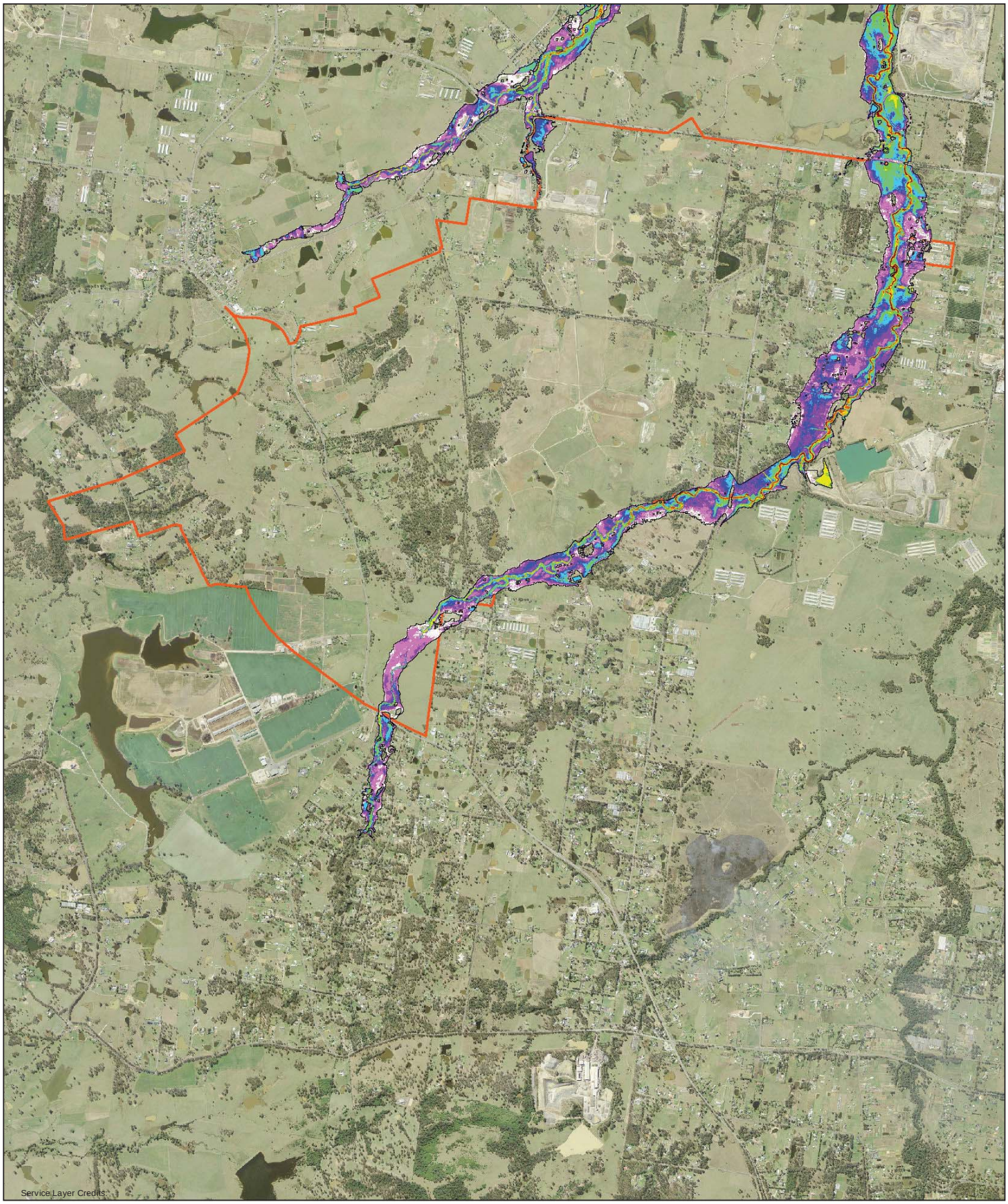
Under current available climate change predictions, decrease in rainfall is predicted during spring, at least in the near future (refer to Section 3.5.3). A decrease in rainfall has the potential for a range of impacts on the surface water environment, including drying of creeks and associated impacts on stream health and ecology. The basins have been designed for existing climatic conditions and have the effect of creating a minor decrease in flows to the downstream creeks (refer to Section 6.1.1 and 6.2.1). If rainfall, and hence runoff, to the basins decreases in the future, together with a general decrease in rainfall in the wider catchment, the airport site impacts on surface water runoff could be exacerbated and could also compound the impacts of climate change locally.

It is predicted that summer rainfall will increase in the future and it is possible that the intensity of flood-producing rainfall events will likewise increase in the future. At present, the design of the airport basins results in no increase in flooding downstream (though localised increases in flow are possible at discharge locations). Because of the proposed basins on the airport site, the future impact of climate change in the area is not predicted to be any worse as a result of the airport than it would be if the airport were not built. The exception is the reach on Oaky Creek downstream of the site where the airport tends to increase flood levels (refer also to Section 6). However, Figure 7-1 and Figure 7-2 indicate that the effects on flood extent would be minimal.

The potential increased localised flows at discharge points do have the potential to cause erosion and scour at basin outlets which can be managed with mitigation measures.

On the airport site, the flood immunity of any runways and associated infrastructure could be reduced in the future as a result of increases in the magnitude of flood events.

The extent of increase in flooding due to climate change is shown on Figure 7-1 and Figure 7-2.



LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Flood extent for Stage 1 without climate change

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

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Stage 1 - Climate Change Flooding 100-year ARI Event, 10% Increase in Rainfall Intensity

Job Number	21-24265
Revision	A
Date	06 Aug 2015

Figure 7-1

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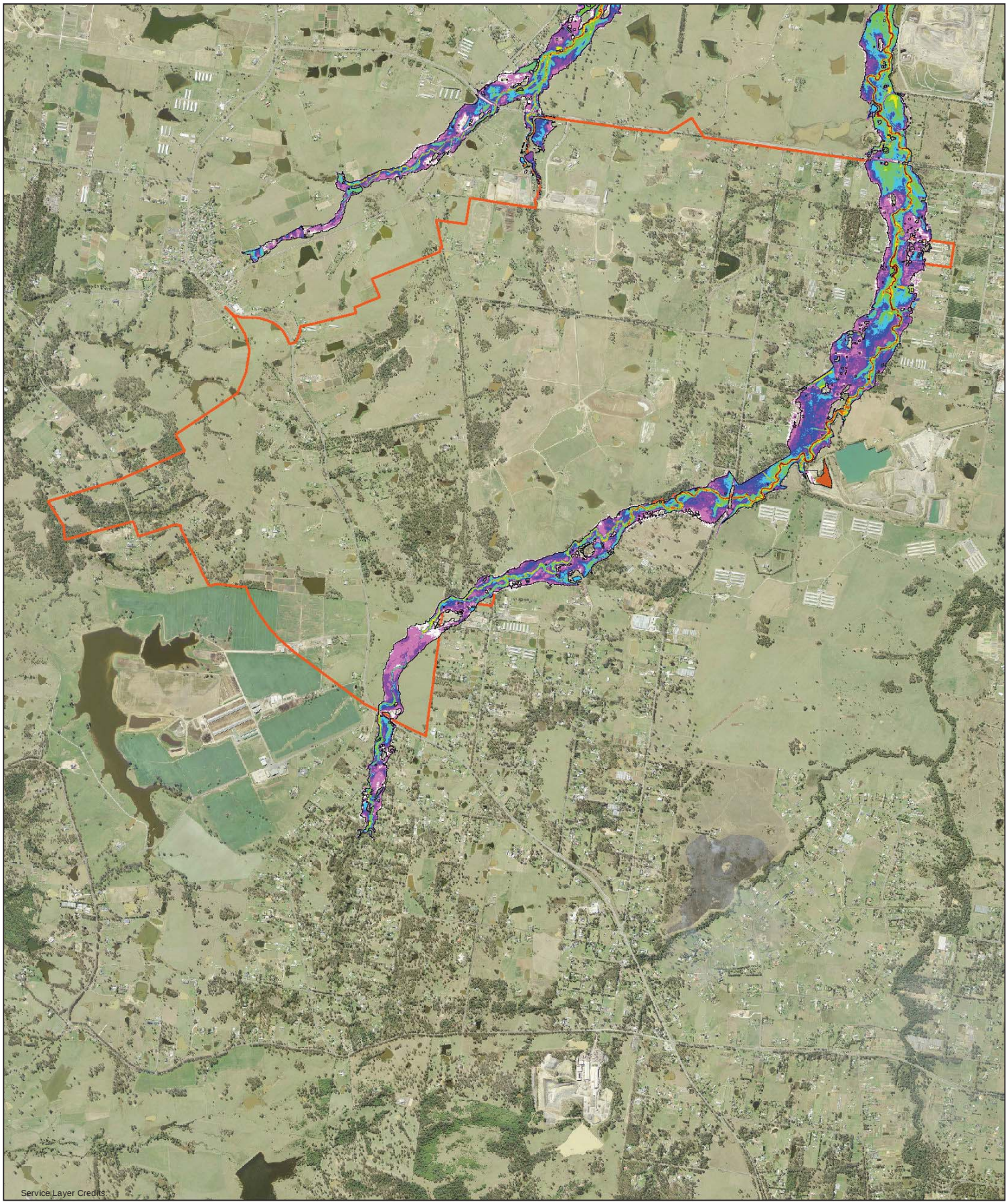

LEGEND

Airport site

Flood depth (m)

0.1 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 3
3 - 4
>4

Flood extent for Longer term without climate change

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Longer Term - Climate Change Flooding 100-year ARI Event, 30% Increase in Peak Rainfall Intensity

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure 7-2

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7.2 Influence of future urban development in the catchment

Though currently largely zoned for agricultural and primary industry uses, the areas downstream of the site to the north include part of the broader Western Sydney Employment Area (WSEA). It is likely that further urban development will take place in the future in these areas. Many of the impacts identified in this report are similar in nature to the range of impacts that could result from surrounding urban development. The cumulative effect of future development may exacerbate changes to the natural flow regime with resultant impacts on creek stability and flooding.

The South West Growth Priority Area incorporates portions of the area upstream of Badgerys Creek and also on to its eastern bank adjacent to the airport site. Should redevelopment occur in the catchment upstream of the site, there would be the potential to influence flooding of the proposed airport. Upstream development could also have the effect of exacerbating impacts from the proposed airport. Any new development would be subject to requirements to review and mitigate impacts downstream through measures such as on-site detention. The implications of potential future development in relation to mitigation measures are considered in Section 8 of this report.

8. Mitigation and management measures

8.1 Construction

The range of potential impacts identified during construction, and potential mitigation and management measures to address those impacts, are summarised in Table 8-1.

The increased impervious surface area associated with the proposed works would have the potential for adverse impacts on the hydrological regime in terms of increased runoff volumes and peak flows as the site is progressively constructed. The Construction Management Report identified that stormwater management features including drains, swales and basins would be constructed progressively to manage potential flow increases.

Where necessary, temporary stormwater drainage would need to be installed to manage on-site surface water, including consideration of potential flooding given the extended timeframe over which the airport will be developed.

There is potential for large quantities of sediments to be directed into the stormwater management network resulting in blockage. This impact is discussed in detail in the water quality report.Mitigation measures would include the development of appropriate erosion and sediment control measures for the construction stage.

Infrastructure to manage surface water on site would also incorporate allowance for the separation of “clean” and “dirty” water. A detailed construction surface water management strategy would be incorporated into a Soil and Water Management Plan (SWMP), which should also consider seasonal variability of rainfall when planning construction stage activities.

Water use during construction is expected to be high and a construction water supply strategy needs to be developed to cater to the needs of the proposed airport development. Consultation with Sydney Water Corporation is required to investigate the capacity of existing potable sources to provide the likely demand for the proposed airport. The possibility of alternative water sources would also be considered during detailed design development.

8.2 Operation

The range of potential impacts identified during operation, and potential mitigation and management measures to address those impacts, are summarised in Table 8-1. The impacts stem from the following key factors discussed in Section 6:

- changes to the catchments in terms of catchment area, configuration and degree of imperviousness;
- resulting changes in the peaks, volumes and timing of flows discharging from the site leading to influence on downstream flow depths and velocities; and
- removal or diversion of watercourses on the site.

The biodiversity assessment concluded that the surface water management systems at the airport site should be designed to avoid substantial alteration to surface water drainage patterns and the volume of downstream flow to minimise the potential for adverse impacts to the downstream environment.

The primary design control measure already proposed to minimise these impacts is the use of detention basins to mitigate increases in peak flow and changes to timing of flows and manage discharge velocities. The assessment undertaken indicates that the current basin strategy does influence flow peaks, though it does not entirely mitigate impacts across all magnitudes and durations of storm events.

There is also potential for some of the impacts to be exacerbated due to the cumulative impact of upstream or downstream development and the possible future effects of climate change.

To mitigate against downstream impacts, the basin configuration, including high and low flow outlet structures and volume characteristics, would need to be further assessed as part of the detailed design of the proposed airport with the aim of mimicking natural flows as closely as reasonably practical.

This would need to consider a range of eventualities, such as low flows, flood flows and storm durations and also management of localised scour and erosion at basin outlets, as well as the cumulative impacts of climate change and surrounding development.

The design of the airport drainage would need to consider the possible future effects of climate change and its impact on flooding of the airport site from the surface water ponding or inundation of the drainage system. Consideration should be given based on emerging climate research on the extent to which allowance for climate change should be incorporated into the design standards.

At Basin 1, consideration should be given to preserving the third order tributary of Badgerys Creek downstream of the site by maintaining a second crossing of Elizabeth Drive.

Where Badgerys Creek passes through the site, any long term development in this area would need to take appropriate consideration of the creek, which is a third to fourth order stream at this location. Management measures would include preserving the riparian corridor and mitigating changes to the flow regime such that there would be no increase in flooding or geomorphological impacts downstream.

Mitigation of groundwater seepage is discussed in detail in the groundwater assessment for the EIS. A monitoring program is proposed that would monitor both groundwater and surface water quality. This would provide warning of excessive groundwater seepage that may have downstream hydrological impacts and would allow remedial action to be taken.

During operation, options for the expansion of potable water supply lines would be investigated in consultation with Sydney Water and in consideration of their existing plans for expansion of the network to supply additional homes associated with the South West Growth Centre.

Table 8-1 Impact and mitigation summary

Section reference	Activity	Description of consequences	Control measures incorporated in design / management plans	Project phases	Mitigation / management measures
5.1	Volume of runoff expected from the site will increase due to reduction in infiltration into the ground as site is constructed	Downstream flooding	Detention basins	Construction	Limited based on current design. Basin design to be refined during airport design development to address flooding across the full range of flood events and appropriate construction phasing
5.1	Flooding and waterlogged soils on site	Disruption to construction activities, damage to equipment	-	Construction	Develop construction surface water management strategy as part of Soil and Water Management Plan
5.1	Water use during construction and operation	Impact on regional and/or local water resources	Use of farm dams on site where practical during construction, use of recycled water during operation to supplement potable water supply	Construction and operation	Strategy for water supply to be developed during ongoing design development and in consultation with Sydney Water Corporation
5.2	Site construction	Permanent removal of watercourses and artificial wetland area including associated habitat destruction	-	Operation (Stage 1 and longer term)	The significance of the habitat removal is assessed in the biodiversity report together with the need for offset measures
6.1.1 and 6.2.1	Diversion of tributary into Badgerys Creek upstream of Elizabeth Drive	Increased likelihood of flooding to Elizabeth Drive	Detention basins to manage peak flows	Operation (Stage 1 and longer term)	Detailed design of detention basins

Section reference	Activity	Description of consequences	Control measures incorporated in design / management plans	Project phases	Mitigation / management measures
6.1.1 and 6.2.1	Diversion of tributary into Badgerys Creek upstream of Elizabeth Drive	Drying of 200 m of third order tributary downstream of Elizabeth Drive	-	Operation (Stage 1 and longer term)	Design for additional crossing of Badgerys Creek to facilitate creek flows and retain existing confluence downstream of Elizabeth Drive
6.1.1 and 6.2.1	Decrease in catchment area draining to Oaky and Cosgroves Creeks	Removal of flow from creek resulting in potential downstream habitat and creek degradation, noting that change in flows is minor	-	Operation (Stage 1 and longer term)	Review design of detention basins during detailed design to achieve appropriate flow at the outlet
6.1.1 and 6.2.1	Increase in site discharge due to increase in site impervious area	Flood impact to residents downstream	Detention basins	Operation (Stage 1 and longer term)	Limited based on current design. Basin design to be refined during airport design development to address flooding across the full range of flood events
6.2.1	Development in south of site where Badgerys Creek passes through	Range of potential impacts to creek on the site and downstream	-	Operation (longer term)	Plans for business area to incorporate strategy appropriate to a third order stream at this location
6.1.2 and 6.2.2	Increases in shear stress due to change in downstream flows	Increase in scour and erosion along this reach of Oaky Creek immediately downstream of Elizabeth Drive.	Detention basins	Operation (Stage 1 and longer term)	Review design of detention basins during detailed design to achieve appropriate flow at the outlet
6.1.1 and 6.2.1	Increase in flows at point of discharge on tributary of Duncans Creek	Localised erosion, scour and flooding, increased flood risk to properties in the immediate vicinity	-	Operation (Stage 1 and longer term)	Review need for basin at this location during design development and incorporate findings if required.

9. Summary and conclusion

A surface water hydrology and geomorphology assessment was carried out to determine the impact of the proposed staged development of the airport on flooding and watercourse geomorphology during both construction and operation. It also explored mitigation and management measures for acceptable design.

The study considered key indicators of changes including:

- changes in discharge from the site;
- changes in watercourse bed shear stress; and
- changes in downstream water level.

The study finds that construction of the airport would result in a major modification of the site in terms of land use characteristics and surface water runoff generated. It would also result in removal of a large number of watercourses and farm dams. The ecology aspects of removal of surface water habitat and associated flora and fauna species is assessed separately in the biodiversity report.

During construction, a detailed surface water management plan would be developed and would need to consider impacts of flooding on-site over the course of the construction period.

Downstream of the site, the assessment finds that the detention basin strategy would be effective at limiting the downstream impacts such that:

- any increases in flood level would not worsen flooding to surrounding roads and dwellings; and
- the risk to changes in creek geomorphology would be low, other than for a short reach of Oaky Creek.

Some localised increases and decreases in water level were predicted downstream of the site. These were generally found to be minor, with the exception of changes to water level at Oaky Creek and on a tributary of Badgerys Creek. These impacts need to be managed through subsequent design development.

The assessment finds that there would be a need to further develop the basin strategy during design development such that the basins would be effective at mimicking natural flows as closely as possible across a range of storm durations and magnitudes including low and high flows. Consideration should be given to the need to introduce a basin or alternative water quantity management measure at one of the site discharge points into a tributary of Duncans Creek.

Another mitigation requirement would be to ensure that any future development in the vicinity of Badgerys Creek where it passes through the site would be appropriate for a third order creek, including protecting and preserving habitat along the riparian corridor and ensuring no worsening of flooding downstream.

During construction of the airport, demands on potable water would be high and there is a need to develop a strategy for water supply to the airport site to meet the construction requirements and also the ongoing operational requirements. During operation of the airport, use of potable water on site would be supplemented with recycled water to reduce demand on potable water.

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Appendices

Appendix A – Additional model development details

Hydrology model

Parameters

Links

Links are used in RAFTS to connect catchments and route runoff downstream. Lagging links were used in the RAFTS models developed for this study. Lagging links are used to delay, or translate, the flow (hydrograph) from an upstream location to a downstream location, to account for the travel time between two points.

Lag times were estimated by calculating travel distances along major flowpaths in mapping software, and converting distance to time by assuming an average flow velocity of 1 m/s. Review of hydraulic model results supported the use of this velocity, and this assumption was tested in the sensitivity analysis of the RAFTS model.

Catchment slope

Catchment slopes were estimated along the major flowpath for each catchment from the catchment boundary to the outlet. The equal area slope method was used. Catchment slopes ranged from 0.5 % – 7.3% and the average slope was 2.0 %.

Losses

An initial/continuing loss model was adopted in RAFTS to estimate runoff from design rainfall. Losses were adopted for pervious and impervious catchments and applied across the model. Pervious catchment losses were selected based on Australian Rainfall and Runoff (1987) recommendations for design loss rates for New South Wales.

Surface roughness (n)

Surface roughness coefficient values were adopted for pervious and impervious catchments and were applied across the model based on industry standard values.

Storage coefficient multiplication factor (BX)

The current study adopted the RAFTS default value for BX of 1 for consistency with the modelling and design work carried out by the business advisor. Previous studies have used BX to calibrate model results to historical flood data.

Table A-1 Comparison of RAFTS parameters for flood studies

Parameter	Current study	1990 South Creek flood study	SMEC study 1991 report for second Sydney airport	Updated South Creek flood study (Worley Parsons 2015)
BX	1.0	1.3	1.3	1.3
Surface roughness	Pervious catchments 0.025 Impervious catchments 0.015	No information available	No information available	0.025
Losses Initial loss/continuing loss (IL/CL)	Pervious catchments IL 10 mm CL 2.5 mm/hr Impervious catchments (100% impervious) IL 1 mm CL 0 mm/hr	IL 35 mm (40 hour storms), or IL 10 mm (9 hour storms), based on critical durations of 9 and 40 hours for most of the catchment CL 1 mm/hr	IL 5 mm CL 0.5 mm/hr	Pervious catchments IL varies 5-37.1 mm CL 0.94 mm/hr Impervious catchments (75-100% impervious) IL 1 mm CL 0 mm/hr

Probable maximum flood derivation

Results of probable maximum flood simulations in RAFTS are provided in Table A-2, with the peak flow and critical duration storm event shown for a range of key locations. Critical durations ranged from two to four hours depending on location.

Hydrographs from the simulation of the two hour probable maximum flood event are shown in Figure A-1 together with the rainfall hyetograph for the event. The hydrographs shown are at the Elizabeth Drive crossing of Badgerys, Oaky and Cosgroves Creek.

Table A-2 Probable maximum flood peak flows

Location	Design PMP event peak flow (m^3/s) (critical duration)
Badgerys Creek at Elizabeth Drive	883 (2.5 hr)
Oaky Creek at Elizabeth Drive	205 (2 hr)
Cosgroves Creek at Elizabeth Drive	371 (2 hr)
Badgerys Creek at South Creek	1055 (4 hr)
Cosgroves Creek at South Creek	967 (2.5 hr)
Duncans Creek at Nepean River	957 (4 hr)

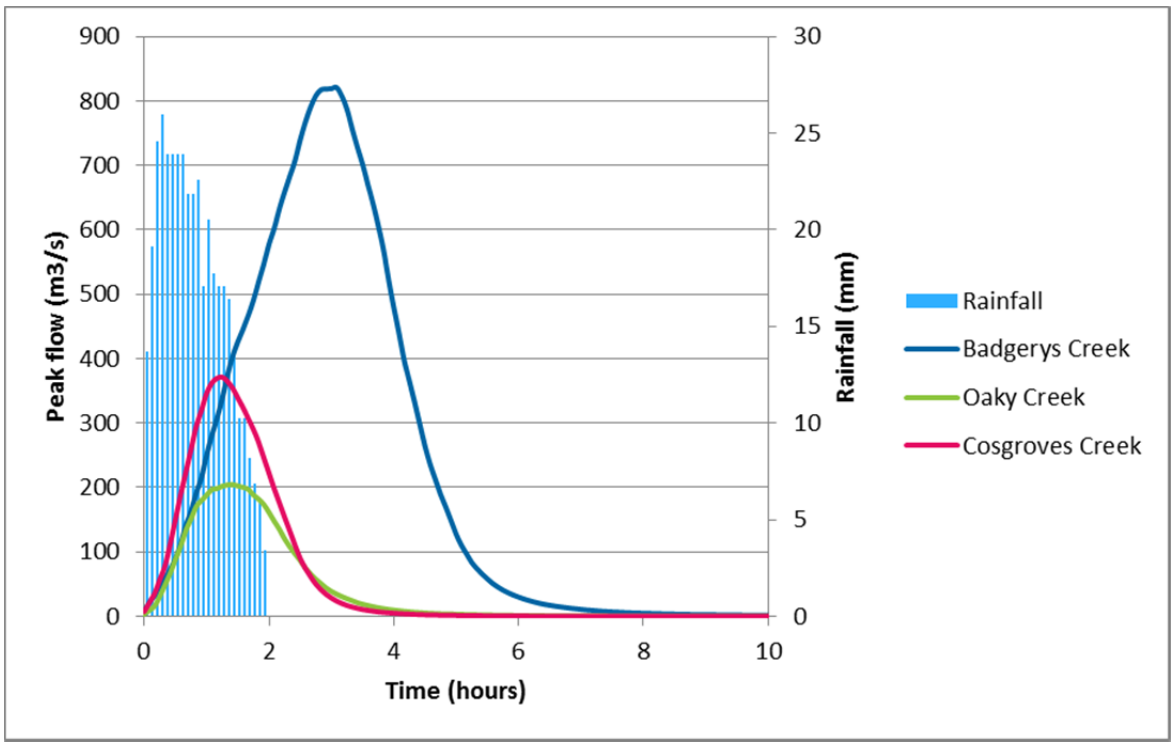


Figure A-1 Probable maximum flood (2 hr event) simulation results at Elizabeth Drive

Comparisons against previous studies

Results of the RAFTS model were compared to design storm flow estimates from other sources, including previous flood studies and the probabilistic Rational Method for eastern New South Wales as described in *Australian Rainfall and Runoff* (Institute of Engineers Australia 1987).

Peak flows for the 100 year average recurrence interval (ARI) storm event are compared in Table A-2, and the critical duration storm that resulted in the reported flow is provided in brackets where known. For the probabilistic Rational Method results, the time of concentration for Badgerys Creek, Cosgroves Creek and Duncans Creek were all approximately 2.5 hours.

The current study produced higher flow estimates than reported peak flows at the same locations in the Updated South Creek Flood Study. This was expected because the Updated South Creek Flood Study flows were for long duration storm events that were critical for the South Creek catchment as a whole, but the critical duration for the catchments in the current study were shorter. This may also be the case for the earlier South Creek flood study and floodplain management study, where South Creek was the watercourse of interest and the storm duration reported on was the one producing the largest flows in South Creek. A in 100-year ARI storm was simulated in the RAFTS model for comparison with the Updated South Creek Flood Study and the results are also indicated in the table at key locations.

The flows calculated in RAFTS in the current study compared well with rational method estimates for the 100 year ARI event, particularly for Badgerys Creek. Duncans Creek had the highest peak flow according to the RAFTS results, reflecting the higher impervious fraction for its catchment associated with large dams. The rational method calculation only considers differences in total area for catchments in the same region, and so Badgerys Creek, with the largest catchment area, was estimated to have the highest peak flow.

The RAFTS results correspond well with the 1991 Concept Design study, with peak flows from the two studies within 5% of one another.

For the purposes of comparison with the Updated South Creek Flood Study, a 100 year 36-hour storm went through simulation in the hydrology model. The results are shown in Table A-3.

Table A-3 Comparison of 100 year ARI design storm flow estimates

Location	100 year ARI peak flow (m^3/s) (critical duration)					
	RAFTS (current study)	Rational method (current study)	1990 South Creek Flood Study [1]	1991 South Creek Floodplain Mgmt. Study [1]	1991 Concept Design for Second Sydney Airport	2015 Updated South Creek Flood Study
Badgerys Creek at Elizabeth Drive	150.6 (6 hr) 125 (36 hr)	-	112	126	153 (2-6 hrs)	126 (36 hr [2])
Oaky Creek at Elizabeth Drive	37.6 (2 hr)	-	-	-	39 (2-6 hrs)	-
Badgerys Creek at South Creek	179.5 (6 hr) 136 (36 hr)	172	151	151	-	138 (36 hr [2])
Cosgroves Creek at South Creek	179.2 (6 hr) 136 (36 hr)	135	129	129	-	123 (36 hr [2])
Duncans Creek at Nepean River	181.8 (6 hr)	147	-	-	-	-

Table notes:

(1) This data was reported in the 2015 Updated South Creek Flood Study (Worley Parsons)

(2) This duration is not critical at these locations – but is for South Creek as a whole.

Sensitivity analysis of RAFTS model parameters

Sensitivity analysis was conducted by testing the impact of variations to the values of key model parameters, as follows.

- Initial loss: a higher initial loss of 35 mm was tested for pervious catchments, this being the upper limit in the range of recommended losses for this region provided in *Australian Rainfall and Runoff* (Institute of Engineers Australia 1987).
- Continuing loss: a higher continuing loss of 4.1 mm/hr for pervious catchments was tested in combination with both low and high initial losses (10 and 35 mm).
- Roughness: a higher roughness value of 0.05 was tested for pervious catchments.

- Lag times: the lag times assigned to lagging links between nodes in the model were adjusted to test a high velocity (2 m/s) and low velocity (0.5 m/s) scenario.
- BX: the storage coefficient multiplication factor was tested at 1.3, which was the value used in several previous flood studies (see Table A-3).

The sensitivity of the model results on the values of the input parameters has been assessed by comparing the hydrographs and peak flows for the 10 and 100 year ARI events at the downstream boundaries of the model. The peak flows at the end of Badgerys, Cosgroves and Duncans Creeks are compared for the base case (adopted parameterisation) and sensitivity analysis scenarios in Table A-4.

Table A-4 Sensitivity analysis results

	10 year ARI peak flow (m^3/s)			100 year ARI peak flow (m^3/s)		
Storm duration	*9 hr*	*6 hr*	*6 hr*	*6 hr*	*6 hr*	*6 hr*
	Badgerys Creek at South Creek	Cosgroves Creek at South Creek	Duncans Creek at Nepean River	Badgerys Creek at South Creek	Cosgroves Creek at South Creek	Duncans Creek at Nepean River
Base case	109	113	114	177	180	183
High initial loss	91	69	70	142	143	143
High continuing loss	97	106	106	167	172	175
High initial loss, high continuing loss	81	63	64	133	136	137
High pervious catchment roughness	91	92	91	148	155	154
Slow lagging links	77	76	74	119	124	120
Fast lagging links	138	135	136	218	214	221
Bx 1.3	101	104	103	164	170	171

The results were most sensitive to link lagging velocity, with a doubling in link lagging velocity corresponding to an approximate 20 % increase in peak flow, and a halving of link lagging velocity leading to an approximate 30 % decrease in peak flow. The timing of the peak was also impacted, as shown by the comparison of hydrographs for Badgerys Creek below.

A limitation of the model in terms of storage was that data was not available for the Leppington Pastoral site storage structure sufficient to appropriately estimate hydrology for this catchment. Results on Duncans Creek downstream of the site are considered indicative only.

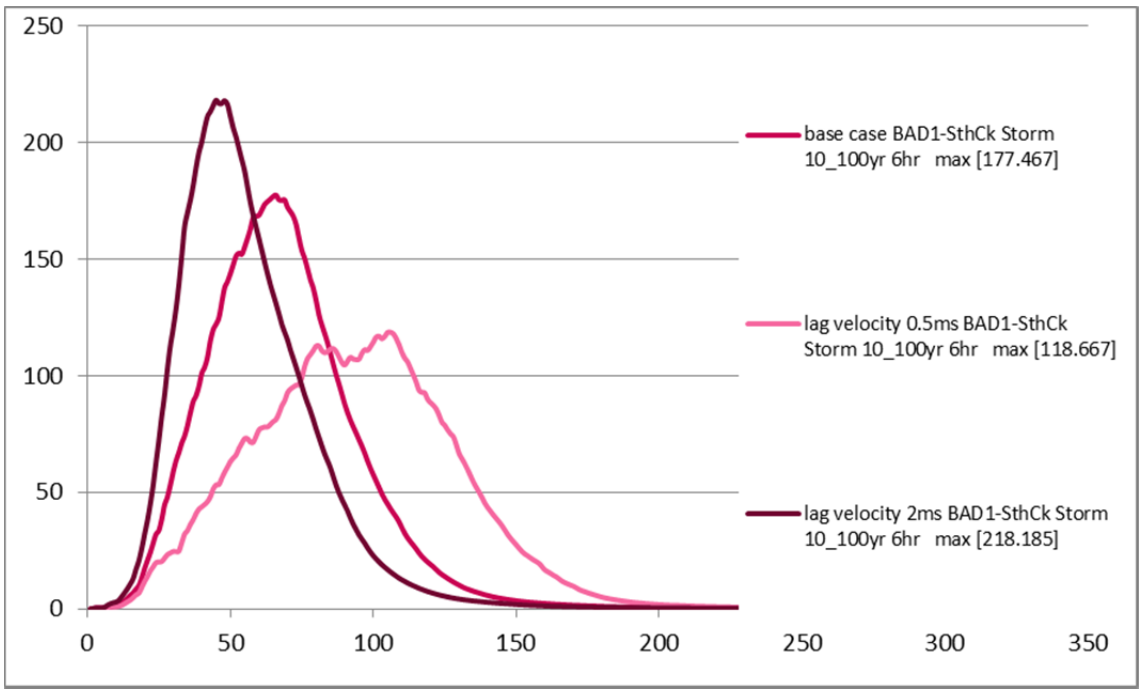


Figure A-2 Badgerys Creek at South Creek – sensitivity of lag velocity

The influence of the lagging assumption on impact assessment findings is expected to be limited. This is because flows for each subcatchment were explicitly routed in the MIKE 21 model rather than in the RAFTS model, meaning that the RAFTS lagging assumptions were not used within the extent of the hydraulic models.

Comparison of 1987 design rainfall IFD data with 2013 rainfall IFD data

Australian Rainfall and Runoff is currently undergoing revision and rainfall Intensity-Frequency-Duration (IFD) data has recently been revised from the 1987 published data to 2013 data. The 2013 data cannot currently be used for detailed studies as the associated temporal patterns and other information used to define the design storm events are still undergoing revision.

However, the 1987 data (used in this study) was compared with the 2013 data to understand the scale of expected change to rainfall because it is expected that, in the future, the airport site would need to be assessed against the revised data.

A comparison of the IFD curves is provided in Figure A-3.

It is important to note that the new data uses Annual Exceedance Probabilities (AEPs) as the probability measure rather than Average Recurrance Intervals (ARIs). ARIs of greater than 10 years are very closely approximated by the reciprocal of the AEP.

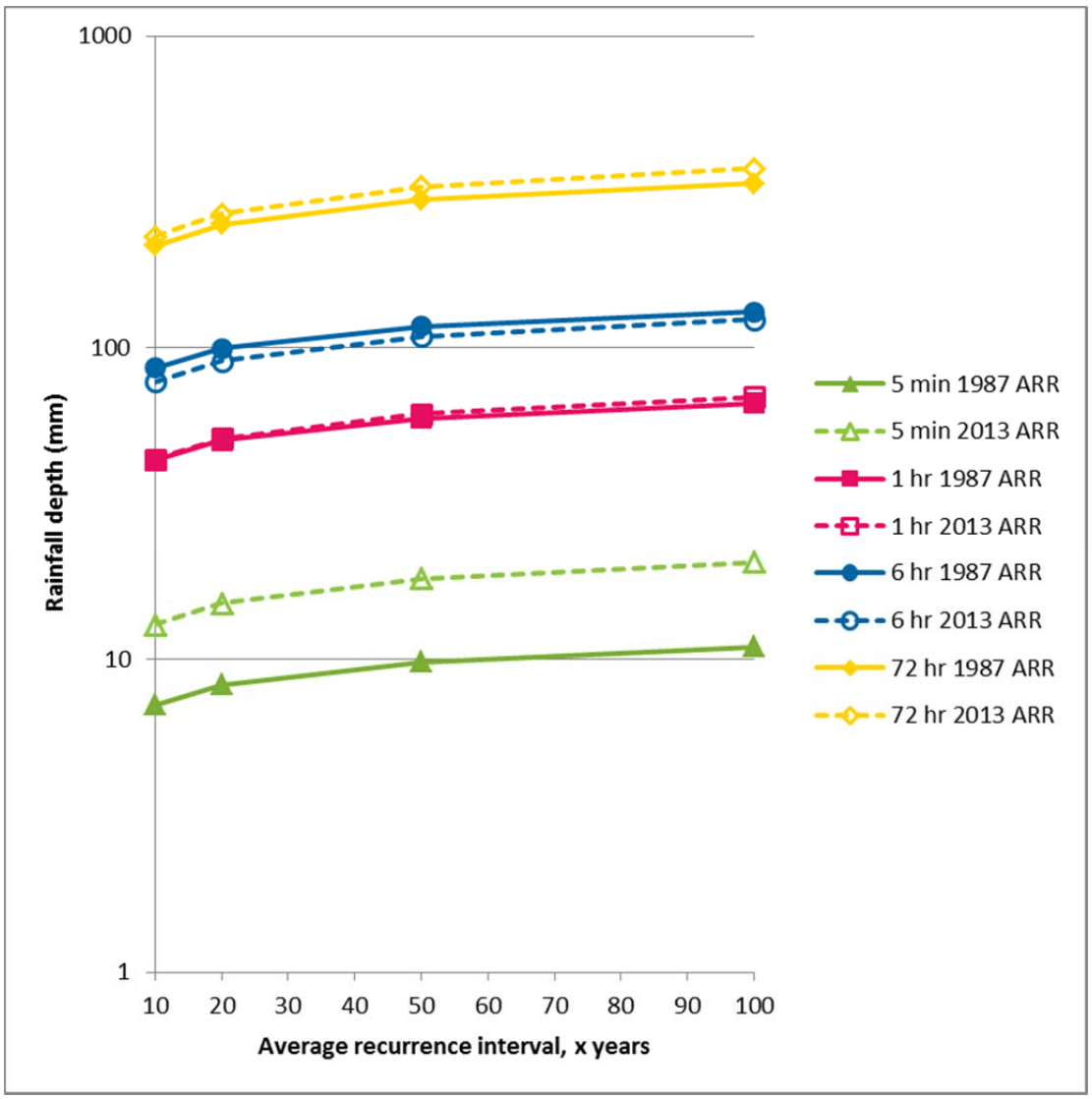


Figure A-3 Comparison of design IFD data for various durations

For very short duration storms, the 2013 IFD is much higher than the 1987 data. For longer duration storms, the rainfall is more closely aligned. On the basis of the available information it is not expected that the findings of the EIS would be materially altered due to the revised IFD data.

Hydraulic model

Photographs of key hydraulic structures from site inspection

Several key hydraulic structures are indicated in the following photographs. The photographs, together with onsite measurements, were used to define hydraulic structures in the MIKE 21 model.



Oaky Creek crossing at Elizabeth Drive



Badgerys Creek crossing at Elizabeth Drive



Badgerys Creek crossing at Badgerys Creek Road



Badgerys Creek crossing at the Northern Road

Hydraulic model verification

The accuracy of hydrologic and hydraulic modelling is influenced by a number of key factors, including:

- inherent uncertainty in the procedures documented in Australian Rainfall and Runoff (Engineers Australia, 1987) which are used to estimate peak flood flows, particularly for large flood events;
- the accuracy and resolution of the underlying data used to represent the model topography; and
- the uncertainty in hydraulic modelling methodology, in particular in estimating factors such as Manning's n which requires a significant amount of engineering judgement.

There was no detailed data available within the study area that could be used directly to calibrate the models, however model checks and validation was carried out on the basis of available information.

Comparison of results was made against those documented in the Updated South Creek Flood Study (WP, 2015). Levels were compared upstream of Elizabeth Drive and are shown in the following table.

Table A-1 Validation of model

Flood event	GHD existing case model, flood level (m AHD)	Updated South Creek Flood Study, flood level (m AHD)
100 year ARI event	47.0	46.6

The modelled water level was higher for the current study, which was expected as the value quoted for the Updated South Creek Flood Study was for a 36-hour duration flood event, which is not critical for the Badgerys Creek catchment. The value quoted for the current study is for a 6-hour storm duration event, which is critical for the catchment.

Other important points to note include:

- the representation of bridges and culverts in the Updated South Creek Flood Study is understood to be based on review of LiDAR rather than detailed information;
- the model validation undertaken for the Updated South Creek Flood Study was to the South Creek Flood Study (1991) which was calibrated to data on South Creek; and
- the focus of the Updated South Creek Flood Study was not Badgerys Creek, Cosgroves Creek or the airport site and it included only limited reaches of these creeks and the airport site within the study.

Whilst general agreement with the findings of the Updated South Creek Flood Study was considered appropriate, for the above reasons it was not considered appropriate to calibrate or otherwise amend the parameters used in this study to match exactly the findings of the Updated South Creek Flood Study.

Predicted water levels for number of model cross-sections of the streamline in a 1 year ARI event were checked against visual inspections on site of bank full levels and were considered generally reasonable.

Rainfall data from the Twin Creeks Golf Course and Country Club was provided for the event of the 21 April 2015 and 22 April 2015 (see section 3.2.3) and was compared to the data from the BOM AWS Badgerys Creek gauge. The gauge recordings are included in Table A-1-2.

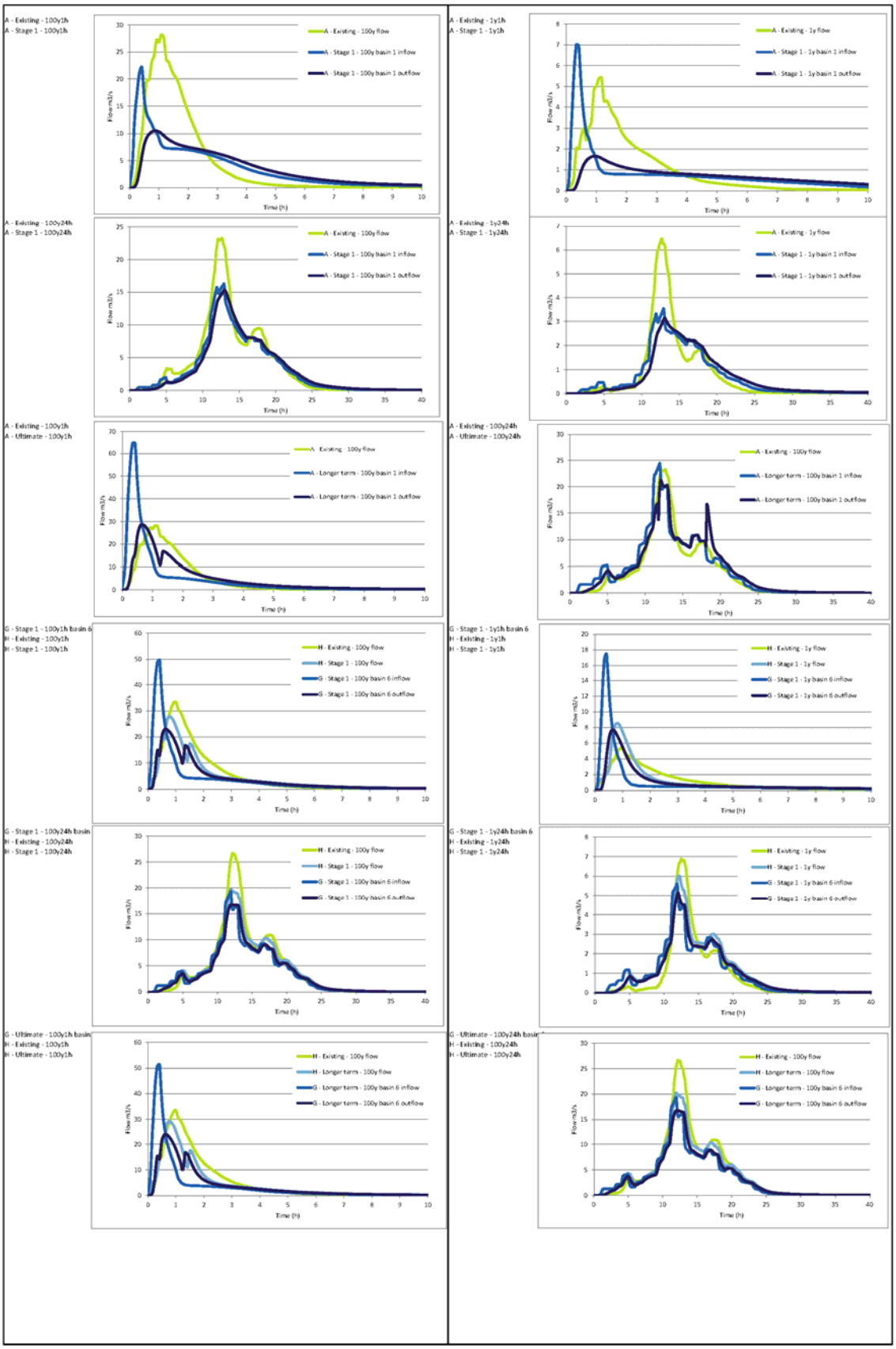
Table A-1-2 Rainfall totals for 21 and 22 April 2015

Gauge	Rainfall total (mm) in 24-hour period	Rainfall total (mm) in 48-hour period
Twin Creeks Golf Course and Country Club rainfall gauge	77	134
Badgerys Creek AWS	84	135

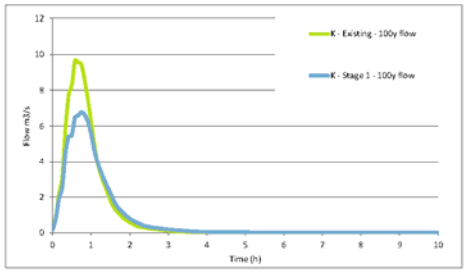
Compared to the BOM IFD for the airport site, these totals equate to around a 5 year ARI event or slightly larger.

Locations of debris marks observed on Badgerys Creek, believed to be from the recent flood events, were compared to modelled 5 year ARI flood events and agreement was found to be reasonable.

Appendix B – Hydrology results


A - Existing - 100y1h
A - Stage 1 - 100y1h
A - Existing - 100y flow
A - Stage 1 - 100y basin 1 inflow
A - Stage 1 - 100y basin 1 outflow
Flow m3/s
Time (h)
A - Existing - 1y1h
A - Stage 1 - 1y1h
A - Existing - 1y flow
A - Stage 1 - 1y basin 1 inflow
A - Stage 1 - 1y basin 1 outflow
A - Existing - 100y24h
A - Stage 1 - 100y24h
A - Existing - 1y24h
A - Stage 1 - 1y24h
A - Existing - 100y1h
A - Ultimate - 100y1h
A - Longer term - 100y basin 1 inflow
A - Longer term - 100y basin 1 outflow
A - Existing - 100y24h
A - Ultimate - 100y24h
G - Stage 1 - 100y1h basin 6
H - Existing - 100y1h
H - Stage 1 - 100y1h
H - Existing - 100y flow
H - Stage 1 - 100y flow
G - Stage 1 - 100y basin 6 inflow
G - Stage 1 - 100y basin 6 outflow
G - Stage 1 - 1y1h basin 6
H - Existing - 1y1h
H - Stage 1 - 1y1h
H - Existing - 1y flow
H - Stage 1 - 1y flow
G - Stage 1 - 1y basin 6 inflow
G - Stage 1 - 1y basin 6 outflow
G - Stage 1 - 100y24h basin
H - Existing - 100y24h
H - Stage 1 - 100y24h
G - Stage 1 - 1y24h basin 6
H - Existing - 1y24h
H - Stage 1 - 1y24h
G - Ultimate - 100y1h basin
H - Existing - 100y1h
H - Ultimate - 100y1h
H - Longer term - 100y flow
G - Longer term - 100y basin 6 inflow
G - Longer term - 100y basin 6 outflow
G - Ultimate - 100y24h basin
H - Existing - 100y24h
H - Ultimate - 100y24h

K - Existing - 100y1h
K - Stage 1 - 100y1h



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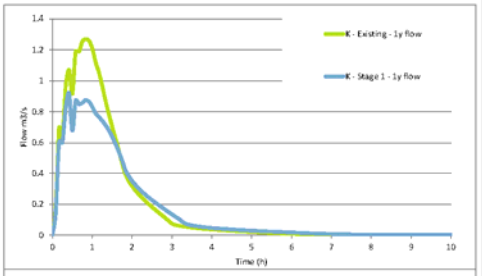
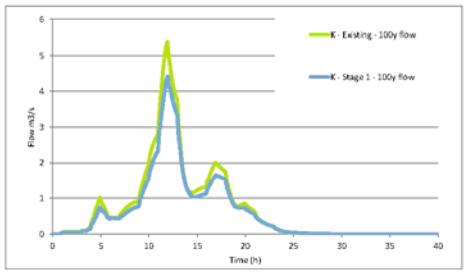
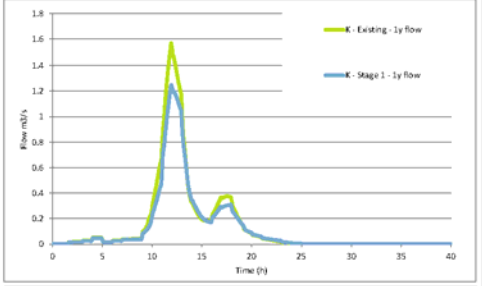
K - Stage 1 - 1y1h



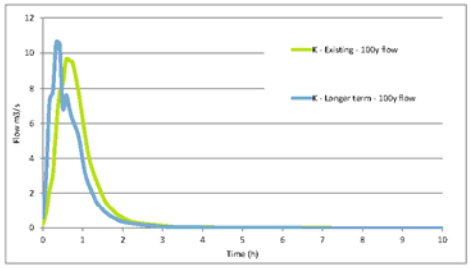
K - Existing - 100y24h
K - Stage 1 - 100y24h



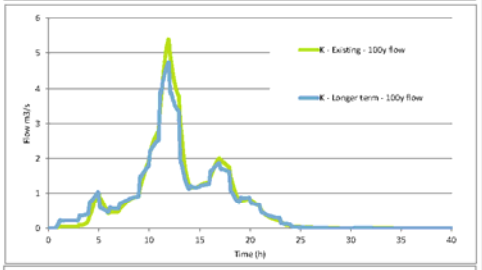
K - Existing - 1y24h
K - Stage 1 - 1y24h



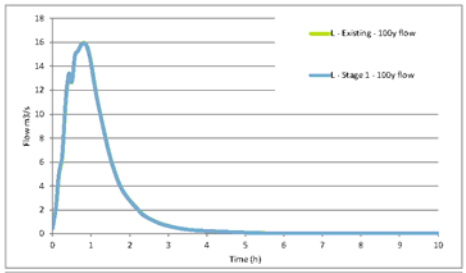
K - Existing - 100y1h
K - Ultimate - 100y1h



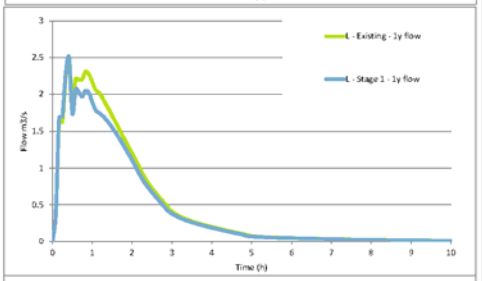
K - Existing - 100y24h
K - Ultimate - 100y24h



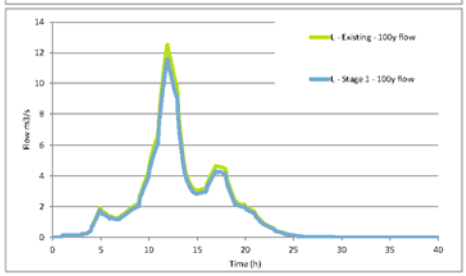
L - Existing - 100y1h
L - Stage 1 - 100y1h



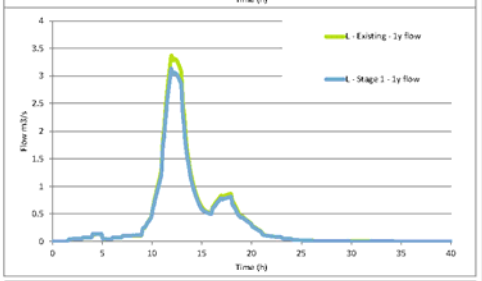
L - Existing - 1y1h
L - Stage 1 - 1y1h



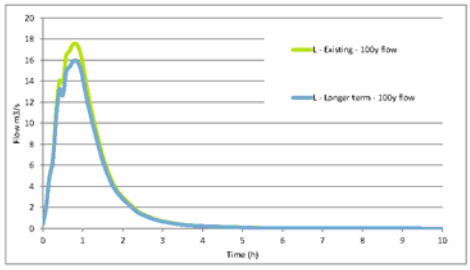
L - Existing - 100y24h
L - Stage 1 - 100y24h



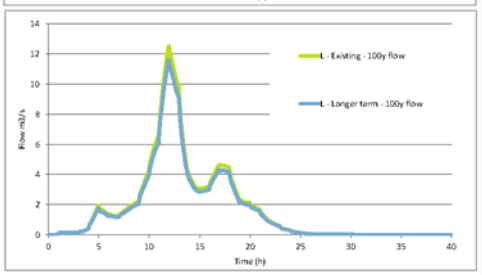
L - Existing - 1y24h
L - Stage 1 - 1y24h



L - Existing - 100y1h
L - Ultimate - 100y1h



L - Existing - 100y24h
L - Ultimate - 100y24h



Appendix C – Hydraulic model results



LEGEND

Airport site **NM²**

- 20 - 100
- 100 - 150
- 150 - 200
- >200

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Existing watercourse shear stress maps, 1-year ARI

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-1

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 42]

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Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site **NM²**

- 20 - 100
- 100 - 150
- 150 - 200
- >200

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Existing watercourse shear stress maps, 5-year ARI

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-2

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 43]

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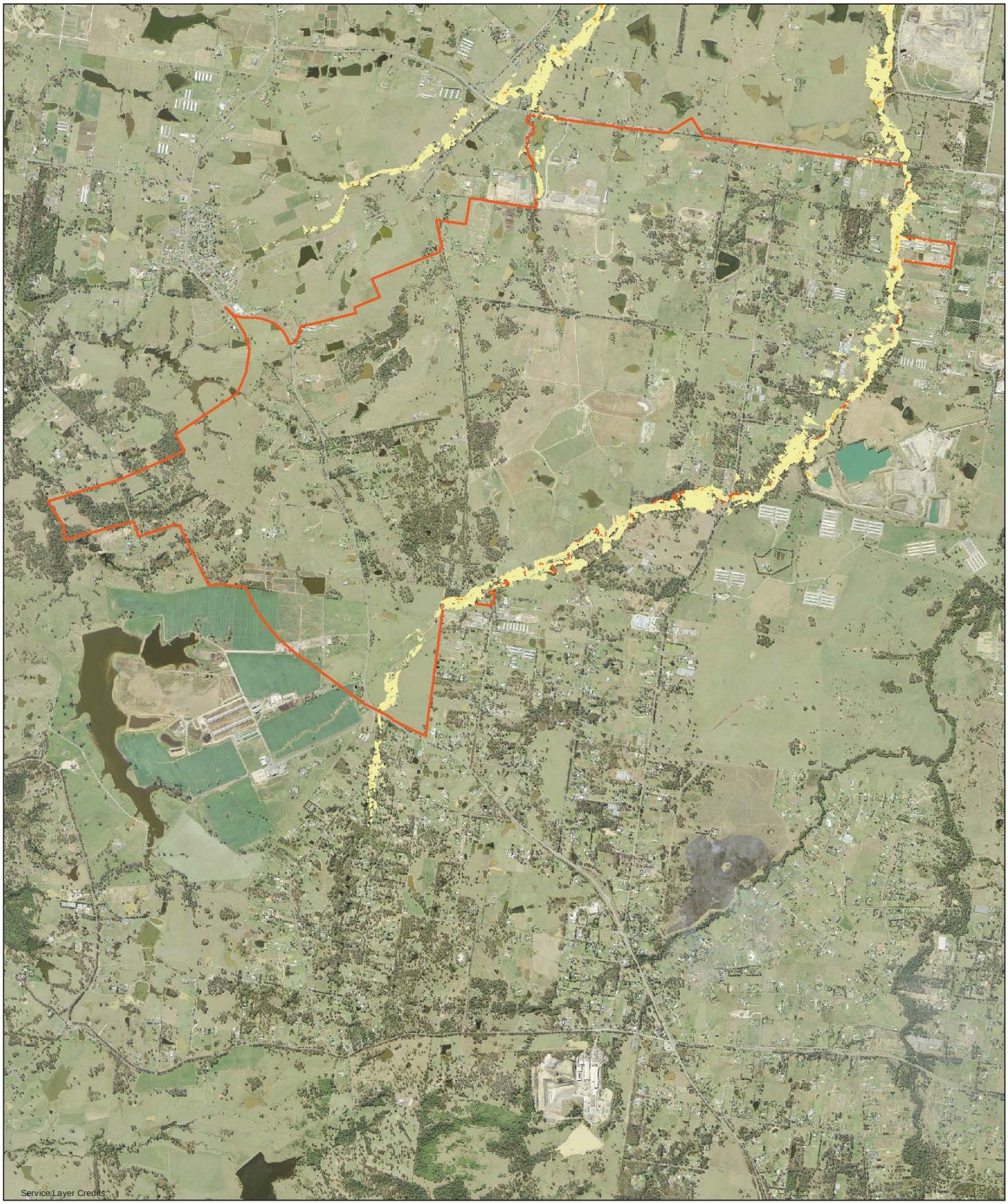

LEGEND

- Airport site NM²
- 20 - 100
- 100 - 150
- 150 - 200
- >200

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Existing watercourse shear stress maps, 100-year ARI

Figure C-3

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 44]

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Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Stage 1 flood depths
1-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-4

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 55]

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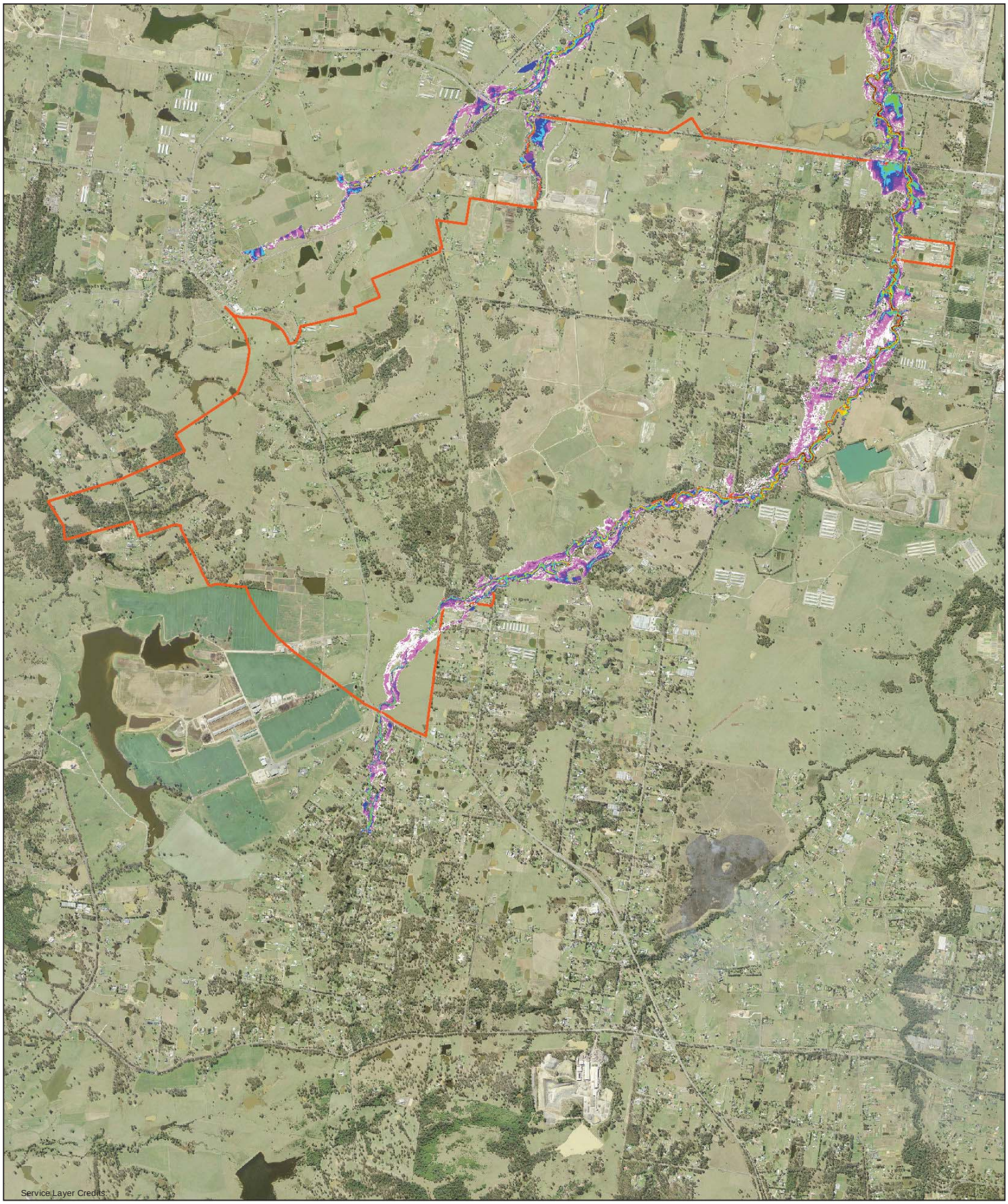
Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Stage 1 flood depths
5-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-5

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 56]

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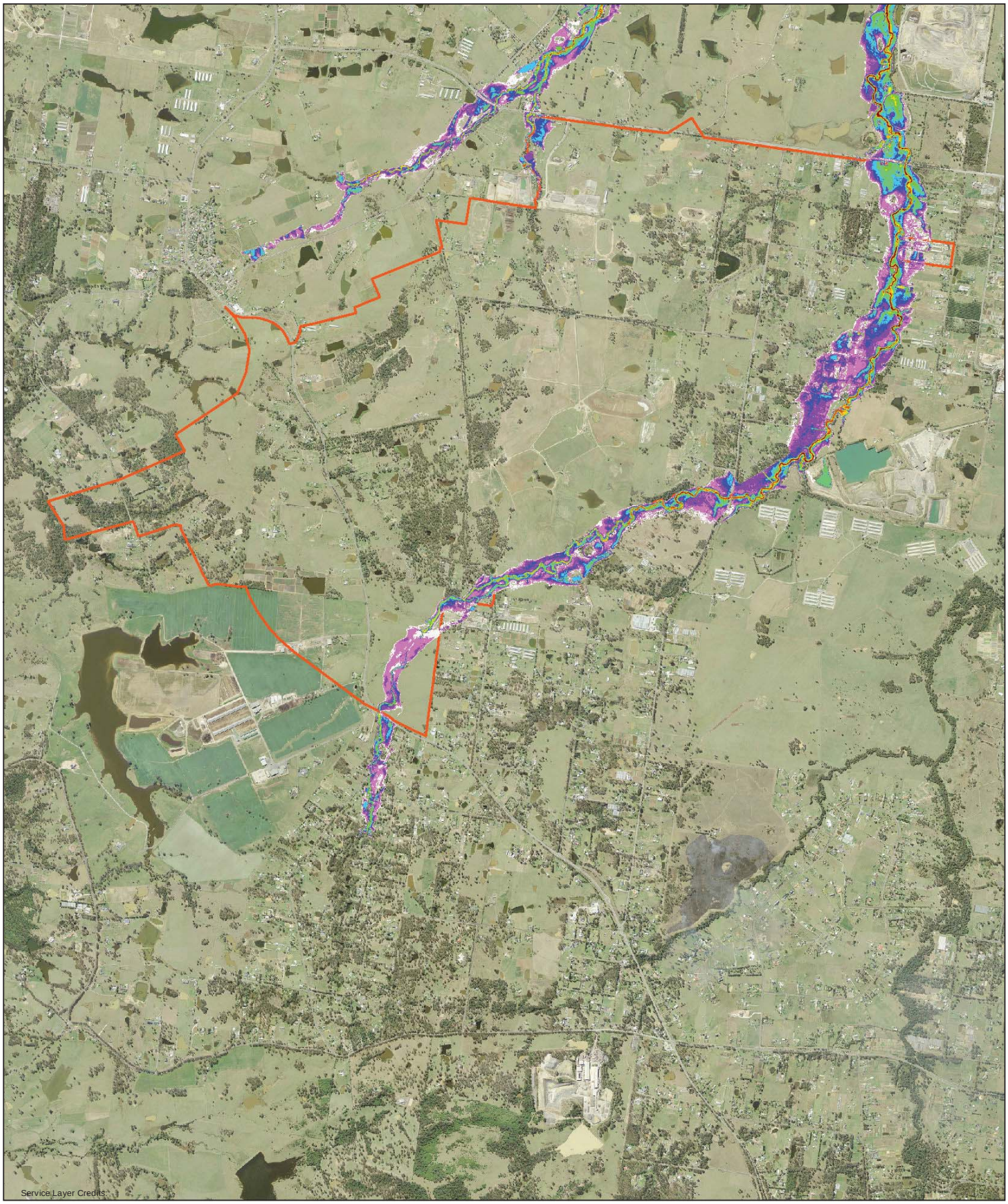
Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
	0.6 - 0.8	2 - 2.5

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Stage 1 flood depths
100-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-6

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 57]

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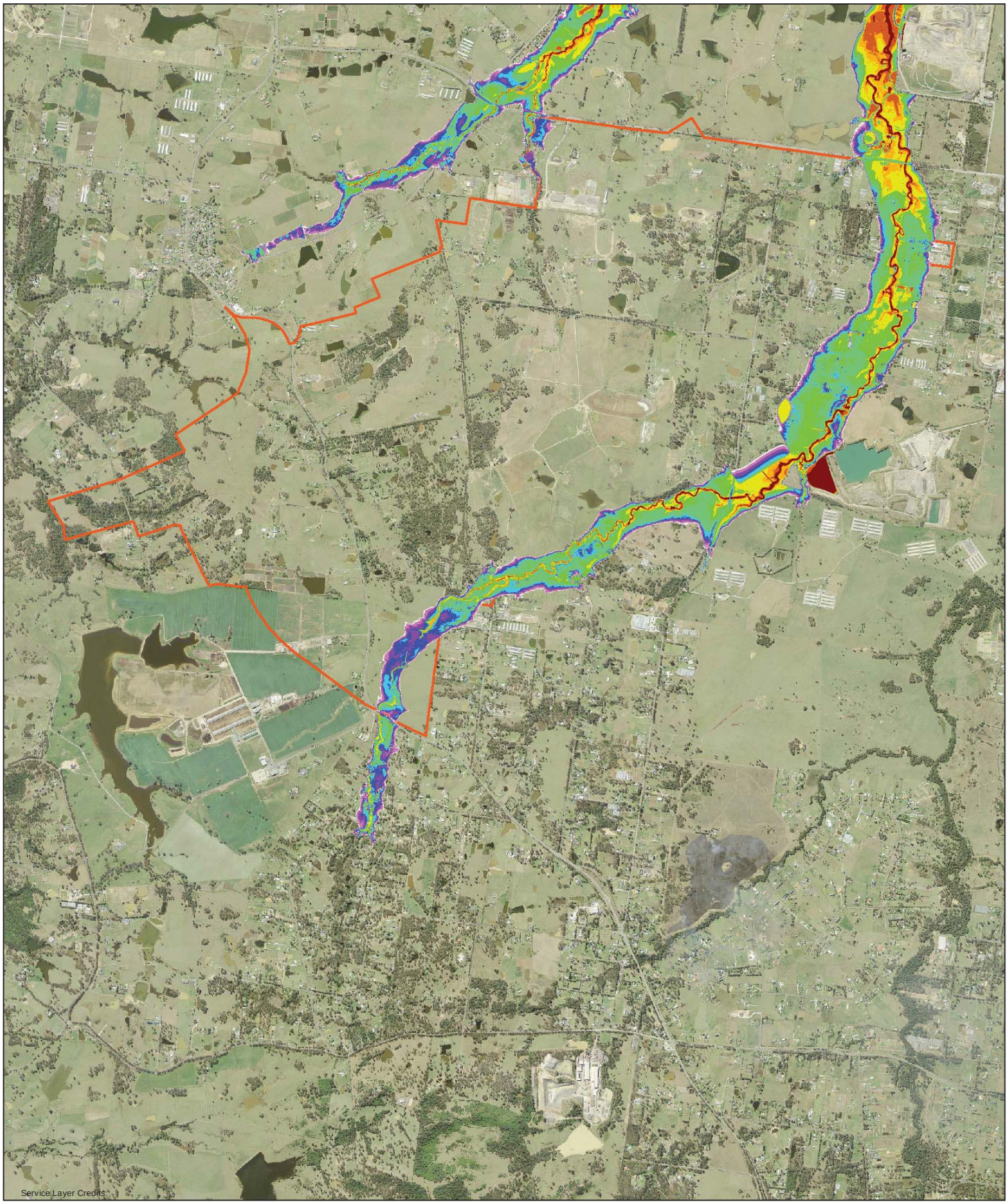
Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Stage 1 flood depths
PMF

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-7

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 58]

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Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site **NM²**

< -20	-5 to 5
-20 to -10	5 to 10
-10 to -5	10 to 20
	>20

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Change in shear stress, existing and Stage 1, 1-year ARI

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-8

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 45]

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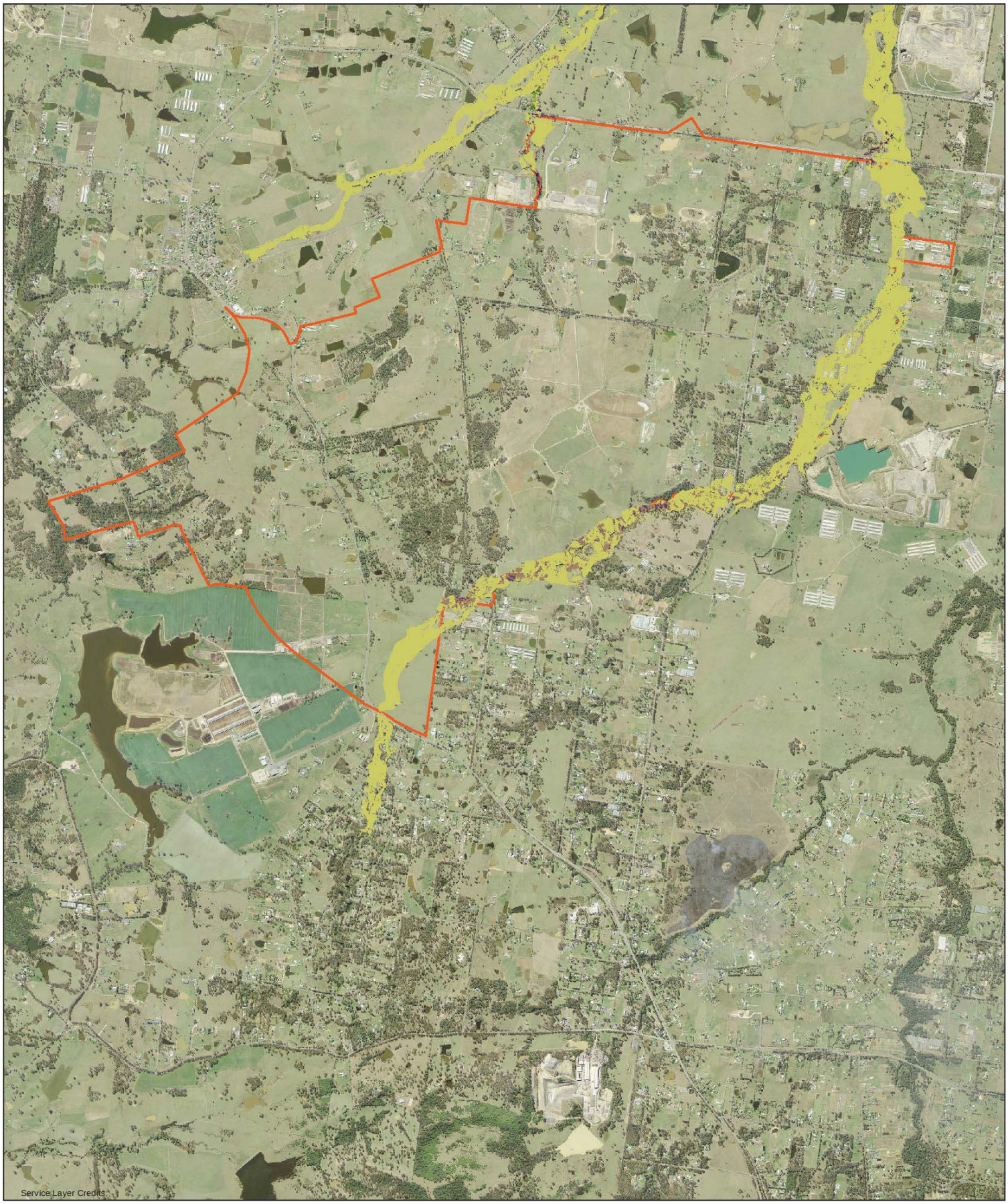
Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site **NM²**

< -20	-5 to 5
-20 to -10	5 to 10
-10 to -5	10 to 20
	>20

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Change in shear stress, existing and Stage 1, 5-year ARI

Figure C-9

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 46]

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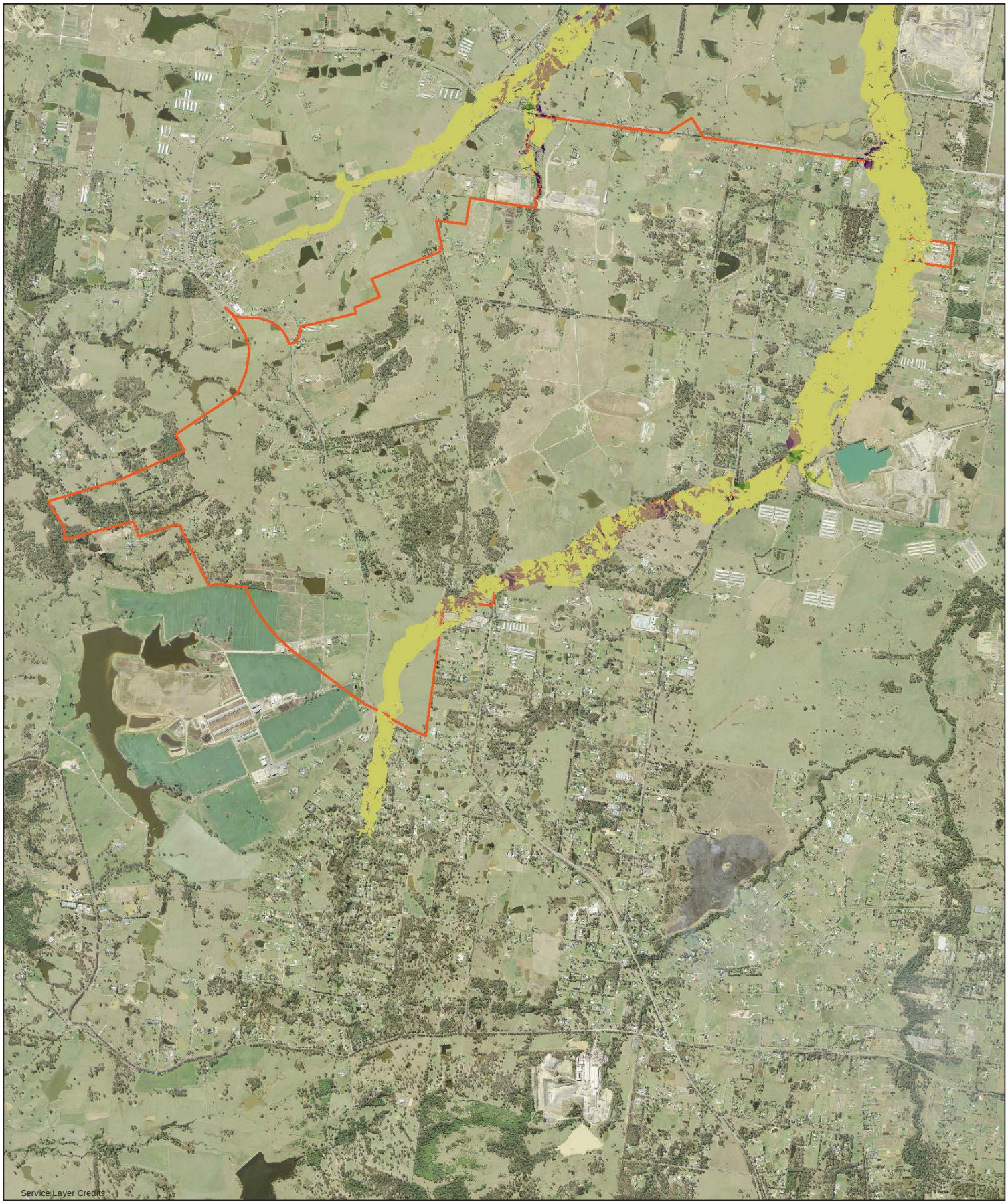
Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

- Airport site
- NM^2
- < -20
- -20 to -10
- -10 to -5
- -5 to 5
- 5 to 10
- 10 to 20
- >20

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Change in shear stress, existing and Stage 1, 100-year ARI

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-10

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 47]

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Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Longer Term flood results
1-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-11

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 62]

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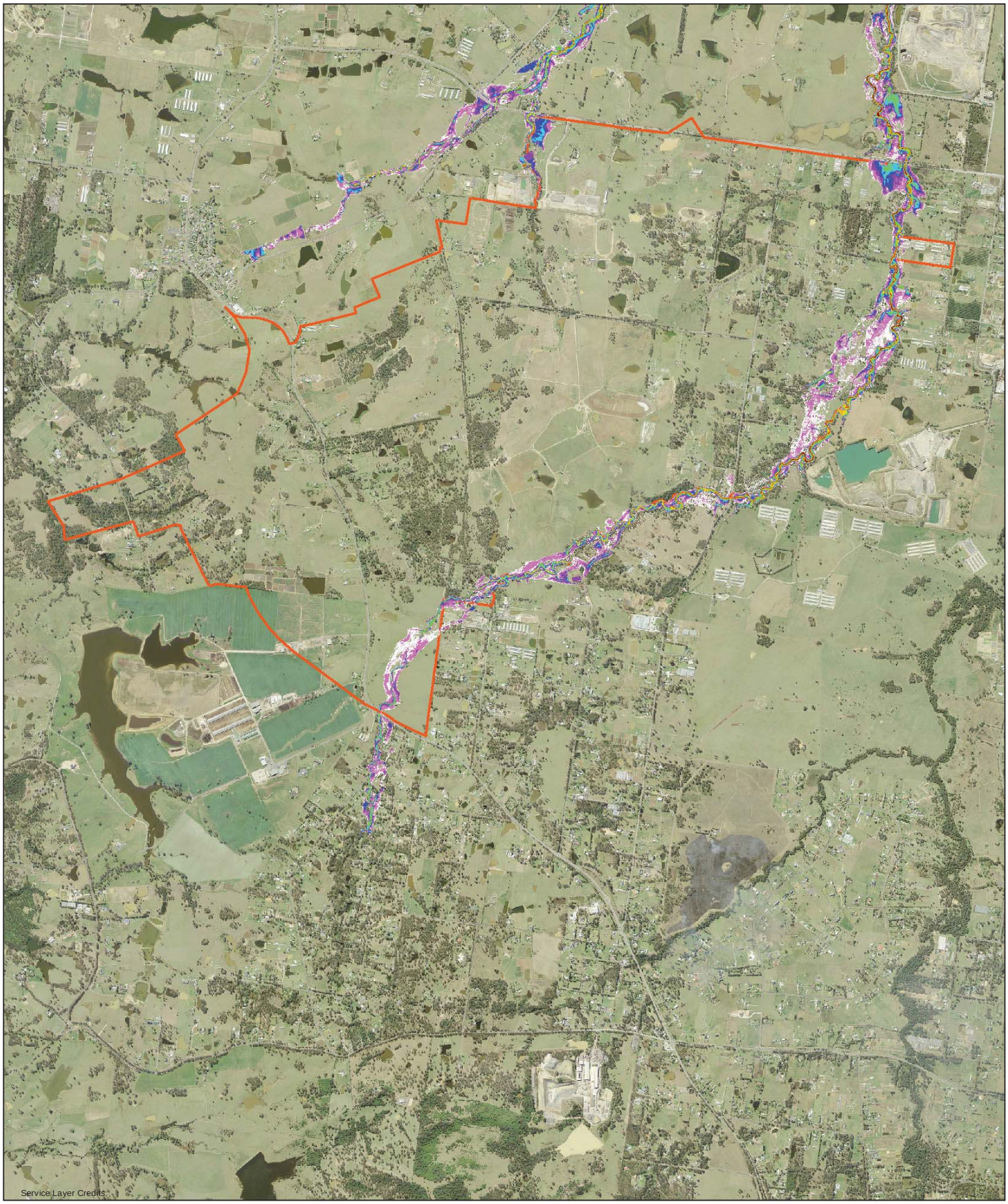
Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Longer Term flood results
5-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-12

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 63]

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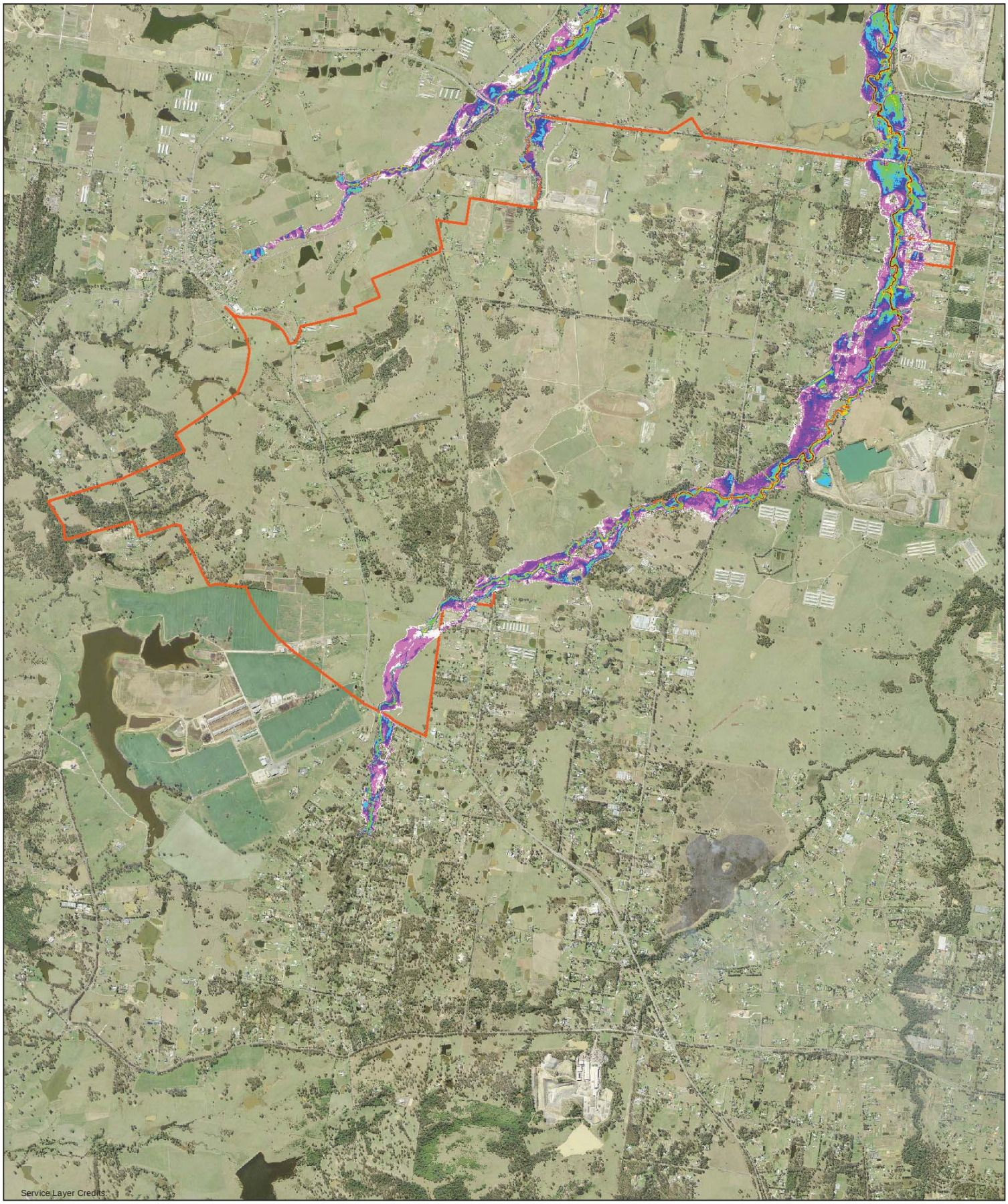
Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
	0.6 - 0.8	2 - 2.5

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Longer Term flood results
100-year ARI event

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-13

N:\AU\Sydney\Projects\21\24265\GIS\Maps\Deliverables\KBM.mxd [KBM: 64]

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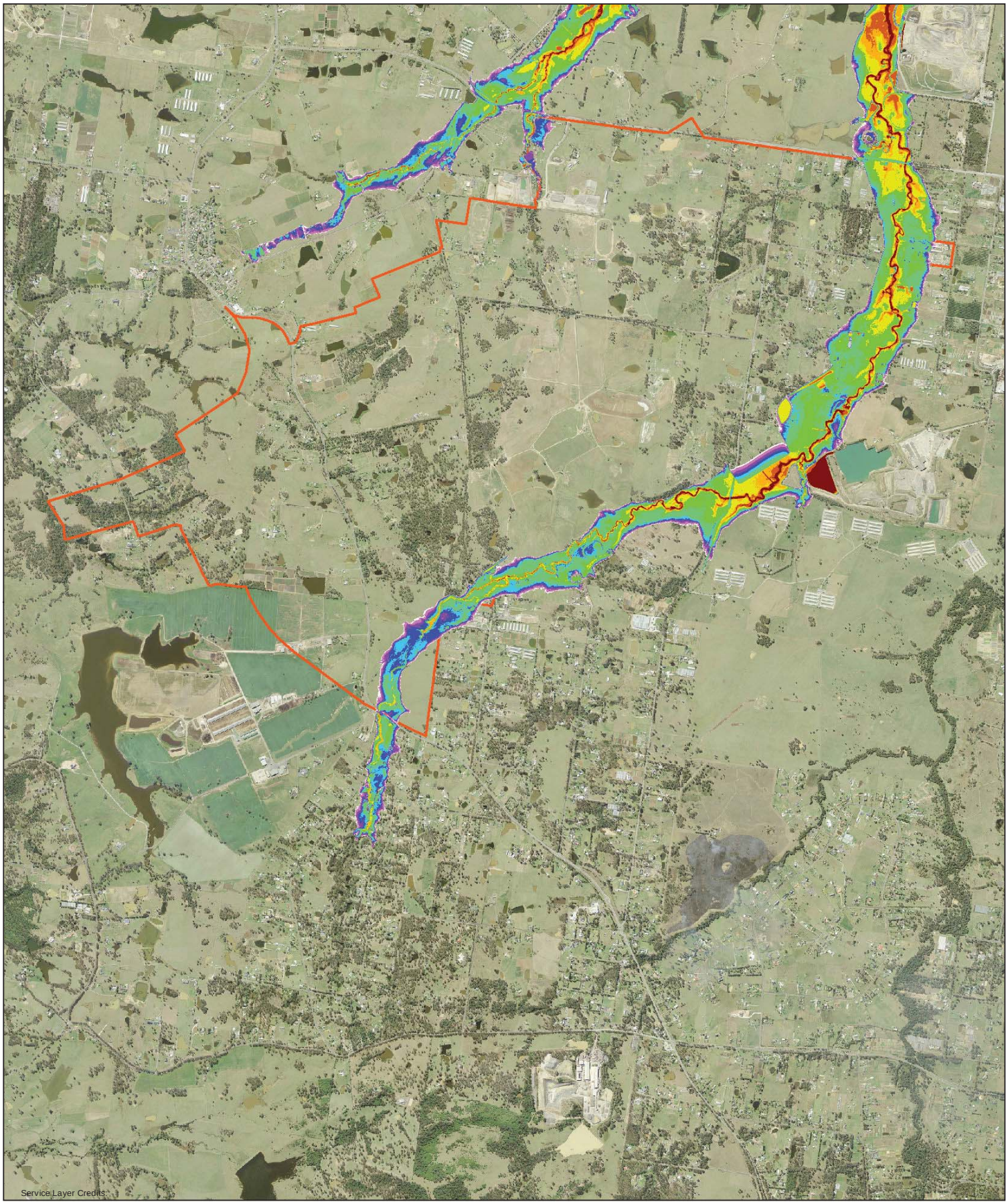
Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site

Flood depth (m)

0.1 - 0.2	0.8 - 1	2.5 - 3
0.2 - 0.4	1 - 1.5	3 - 4
0.4 - 0.6	1.5 - 2	>4
0.6 - 0.8	2 - 2.5	

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Longer Term flood results
PMF

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-14

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Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy



LEGEND

Airport site **NM²**

< -20	-5 to 5
-20 to -10	5 to 10
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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Job Number 21-24265
Revision A
Date 05 Aug 2015

Change in shear stress, existing and Longer Term, 1-year ARI

Figure C-15

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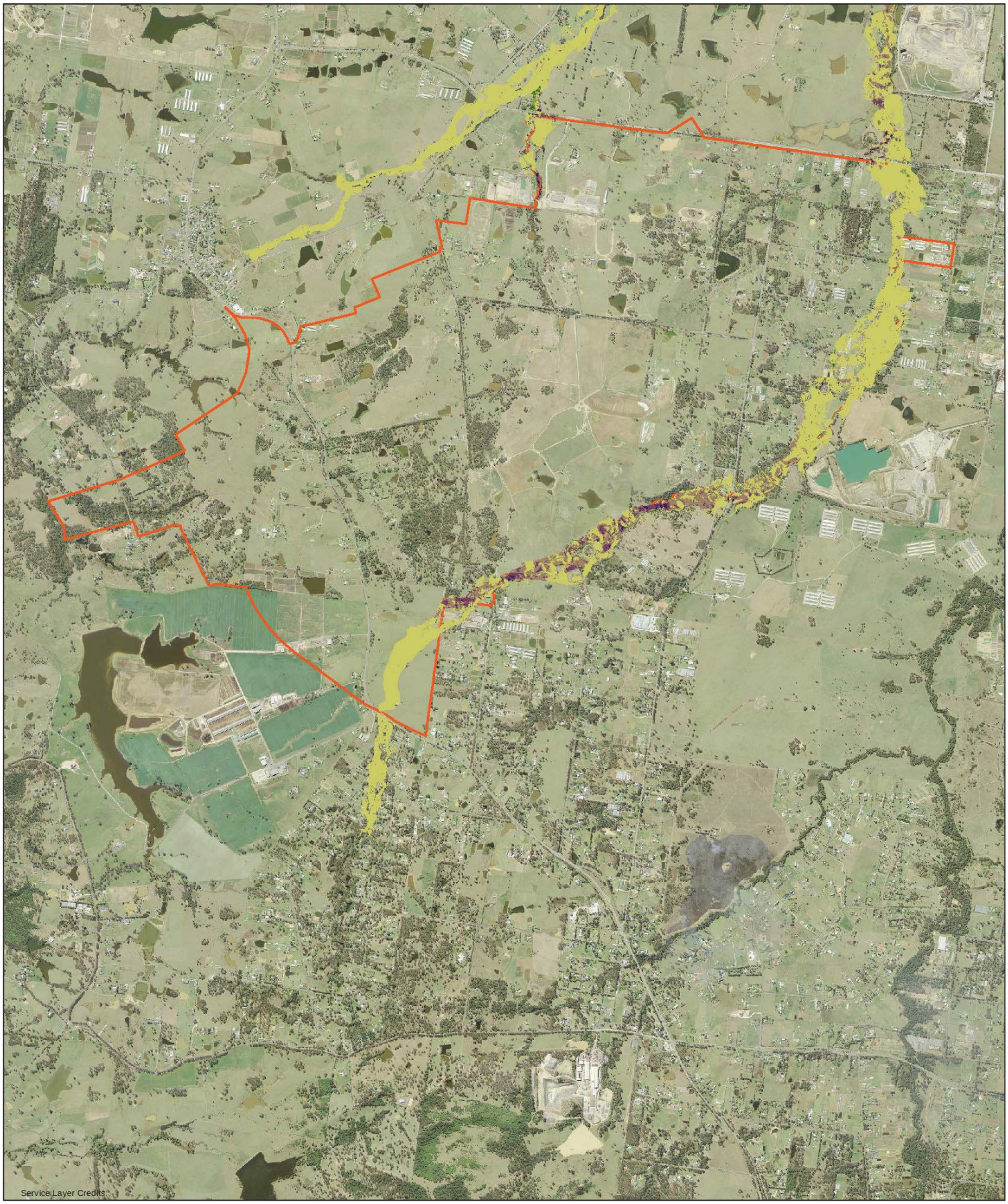

LEGEND

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Change in shear stress, existing and Longer Term, 5-year ARI

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Figure C-16

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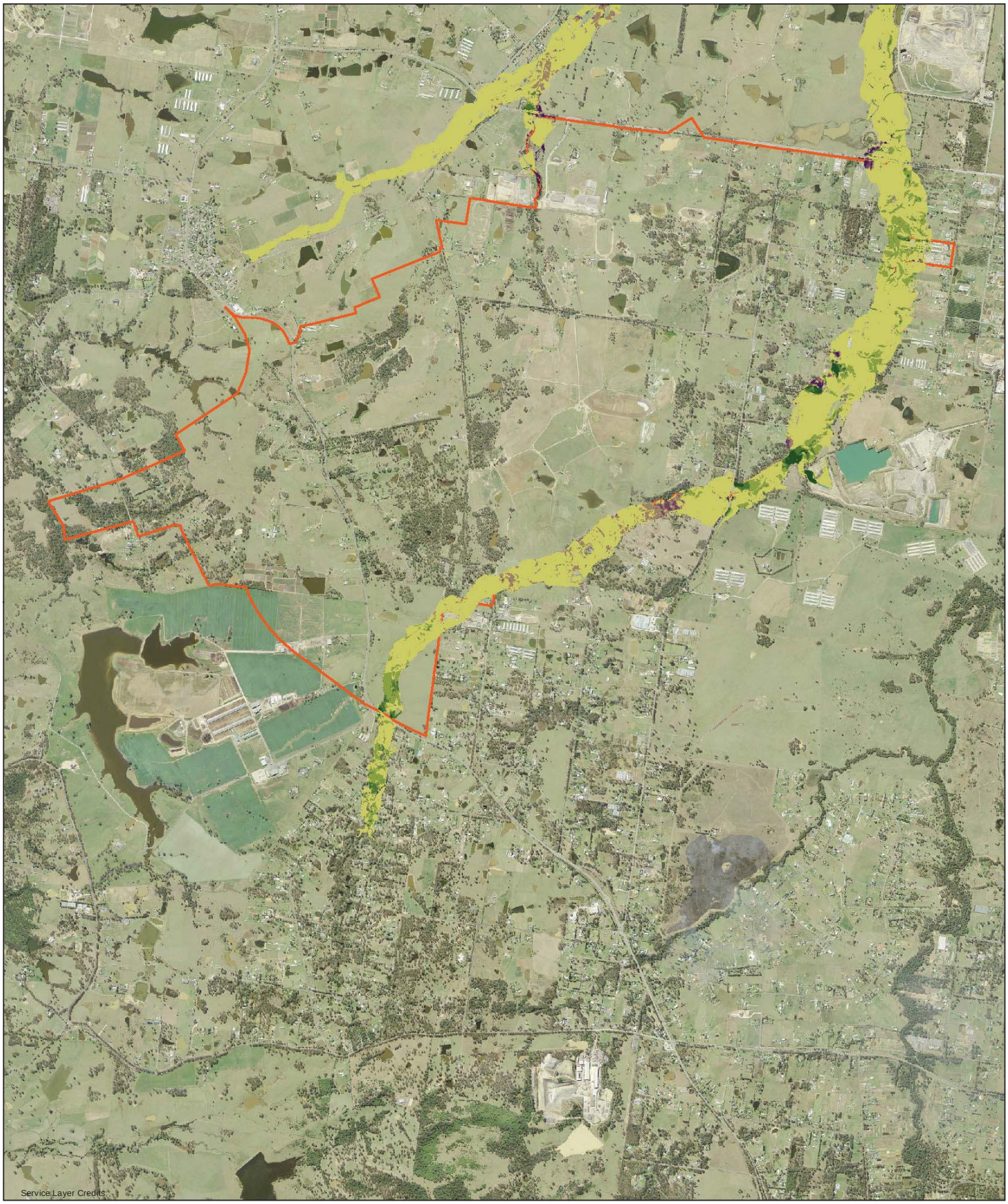

LEGEND

Airport site

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Grid: GDA 1994 MGA Zone 56

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Change in shear stress, existing and Longer Term, 100-year ARI

Job Number	21-24265
Revision	A
Date	05 Aug 2015

Figure C-17

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Appendix D – Hydrographs from hydraulic model

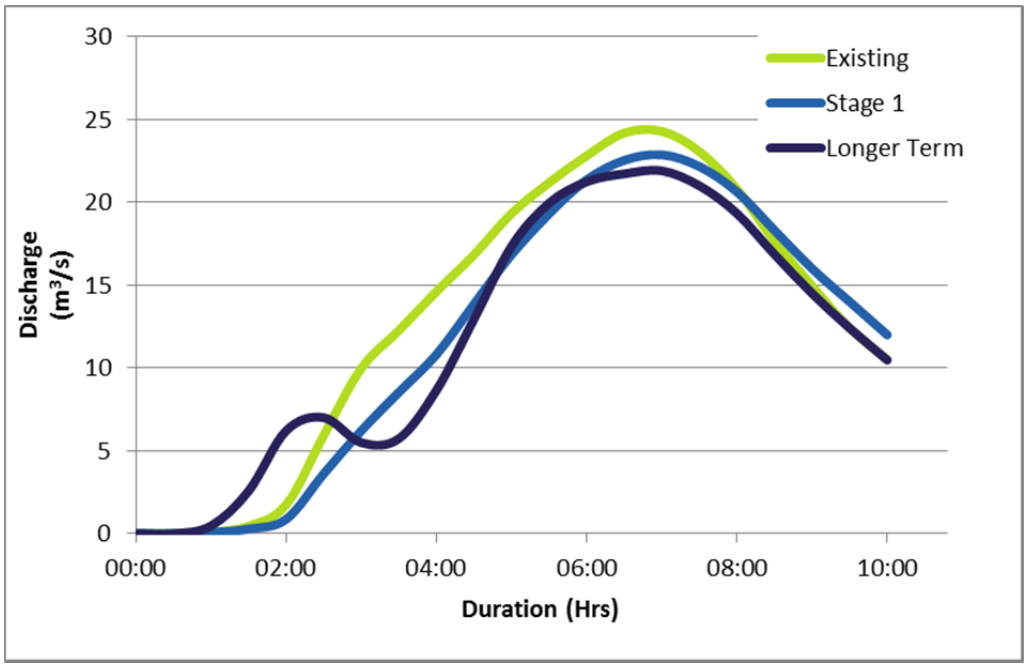

Figure D-1 Badgerys Creek 1 year ARI results downstream of Elizabeth Drive

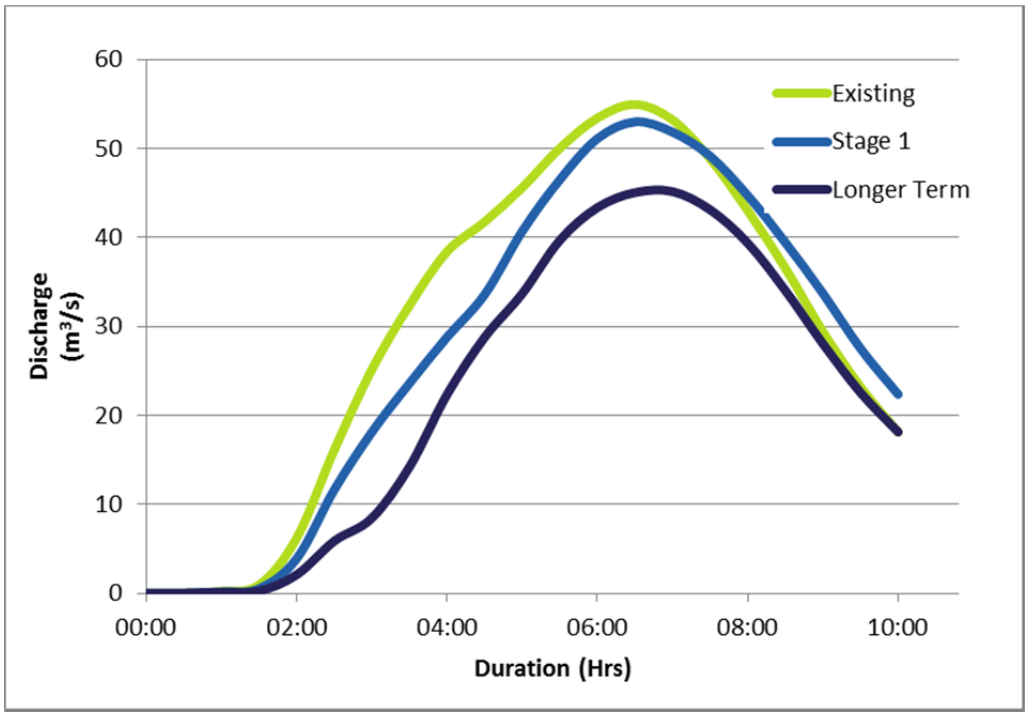

Figure D-2 Badgerys Creek 5 year ARI results downstream of Elizabeth Drive

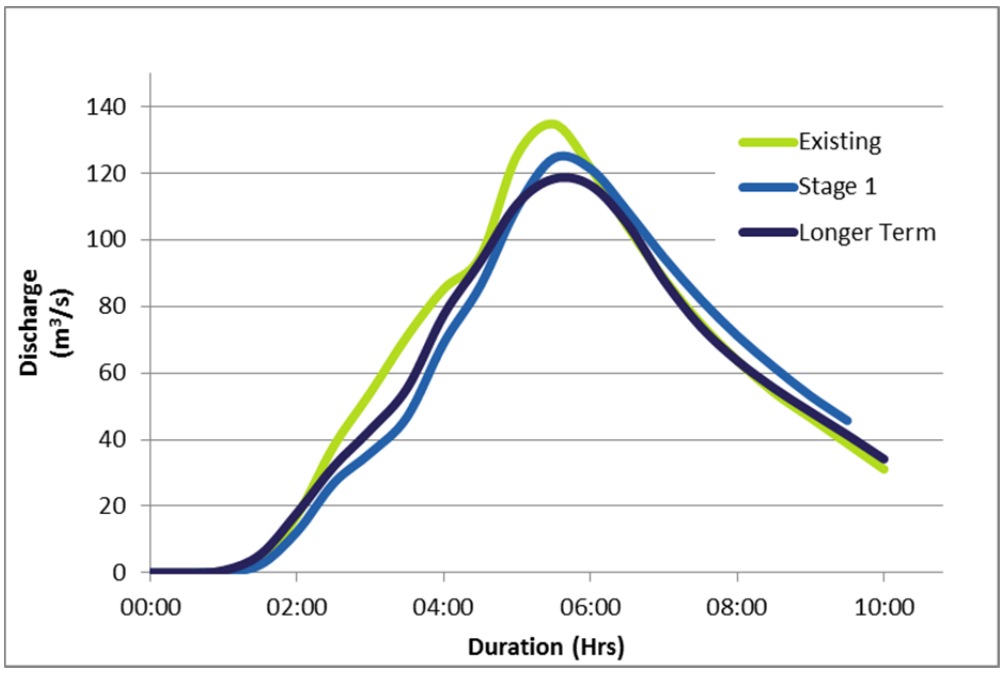

Figure D-3 Badgerys Creek 100 year ARI results downstream of Elizabeth Drive

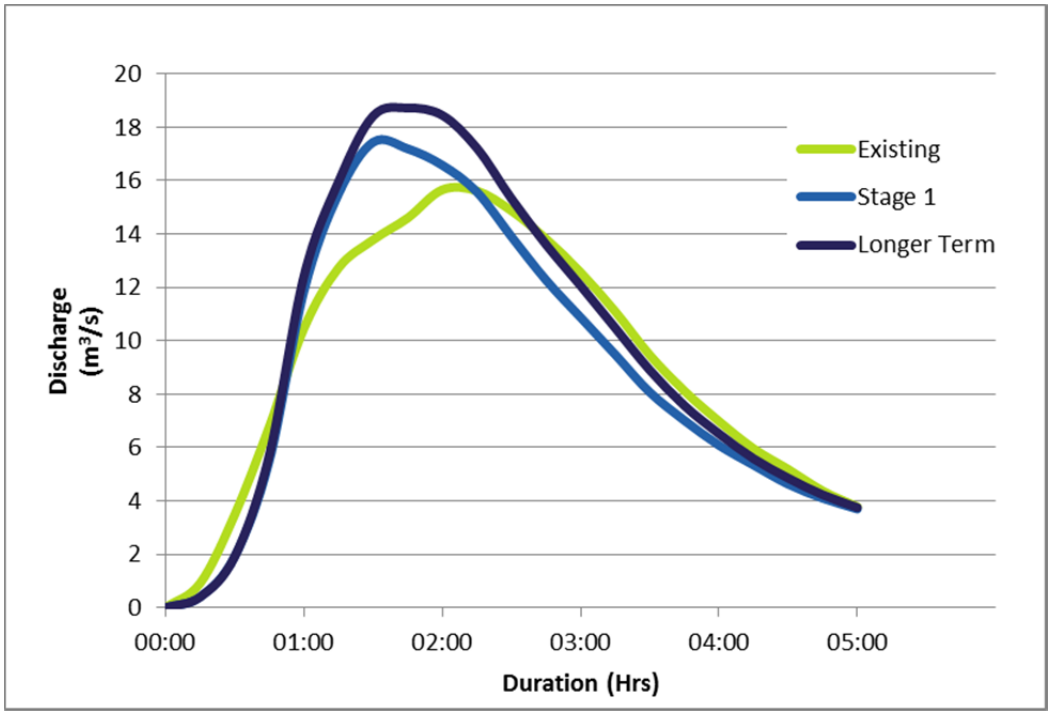

Figure D-4 Cosgroves Creek 1 year ARI results downstream of confluence with Oaky Creek

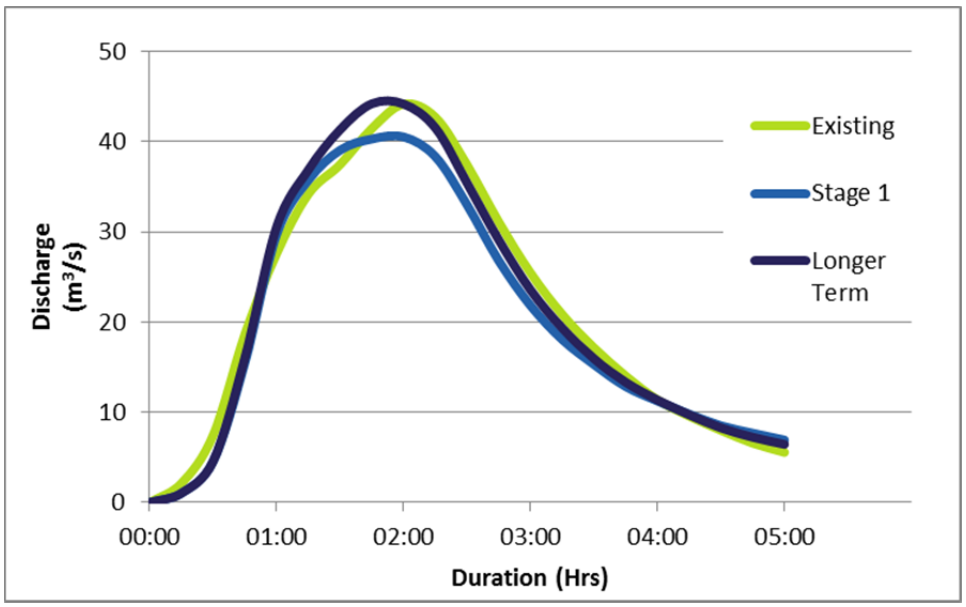

Figure D-5 Cosgroves Creek 5 year ARI results downstream of confluence with Oaky Creek

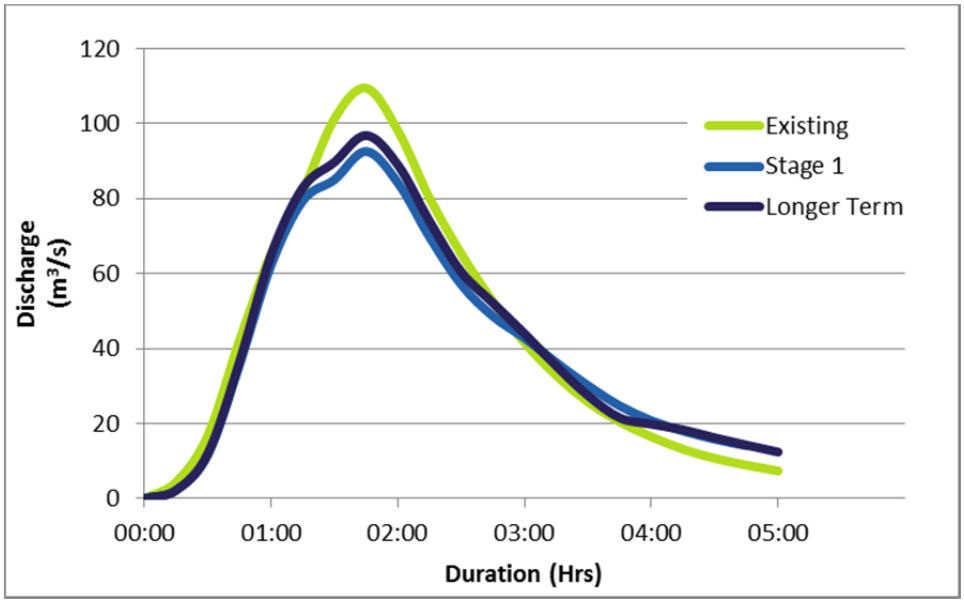

Figure D-6 Cosgroves Creek 100 year ARI results downstream of confluence with Oaky Creek

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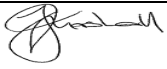
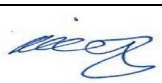
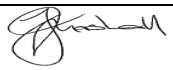
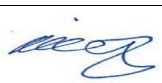
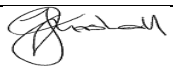
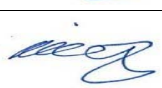
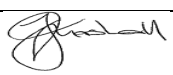
A Internal Draft	L Thomas G Lampert N Bailey	N Bailey		G. Marshall		17/05/2015
B	L Thomas G Lampert N Bailey	N Bailey		G. Marshall		22/07/2015
C	L Thomas G Lampert N Bailey	N Bailey		G. Marshall		13/08/2015
D	L Thomas G Lampert N Bailey	N Bailey		G. Marshall		28/08/2015

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VOLUME 4

Appendix L2
Surface water quality



Department of Infrastructure and Regional Development

Western Sydney Airport EIS

Surface Water Quality Assessment

October 2015

Limitations

GHD has prepared this report pursuant to the conditions in the Department of Infrastructure and Regional Development Deed of Standing Quotation (SON2030181), the Commonwealth RFQTS Number 2014/7540/001, the subsequent response accepted and referenced in the relevant Official Order (collectively the "Contract"):

In particular, this report has been prepared by GHD for the Commonwealth (and to the extent expressly stated in the Contract (and for the purposes stated therein) the parties referred to in the Contract ("Other Parties") and may only be used and relied on by the Commonwealth and the Other Parties in accordance with the Contract for the purpose agreed between GHD and the Commonwealth as set out in the Contract.

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Executive Summary

An assessment of the potential impacts of the proposed Western Sydney Airport (proposed airport) on surface water quality has been undertaken for both the Stage 1 and, at a preliminary level, for the longer term development. The assessment was undertaken on the basis of the Draft Airport Plan and concept design available for the study.

Available baseline water quality data for the airport site and surrounding areas have been reviewed. The results indicate that nutrient loads in the existing waterways are generally high and do not achieve Australian and New Zealand Environment and Conservation Council (ANZECC) water quality objectives for total phosphorus and total nitrogen. However, total suspended solids loads are generally low and below ANZECC Guideline levels.

A Model for Urban Stormwater Improvement Conceptualisation (MUSIC) water quality model was developed and calibrated to the available baseline data. Additional models were then developed to represent Stage 1 and the longer term development phases of the project and on which to identify potential impacts of the proposed airport.

Bio-retention basins proposed as part of the airport concept design were incorporated into the modelling. This consisted of eight bio-retention basins located along the perimeter of the airport site. Basins 1, 2, 3, 4, and 5 were placed along the southern boundary to provide water quality treatment of the stormwater flows prior to discharge to Badgerys Creek. Similarly, Basins 6 and 7 were situated along the northern boundary to manage the flows discharging into Oaky Creek and Cosgroves Creek, while Basin 8 was positioned to manage flows discharging into Duncans Creek. All the basins are proposed for construction during Stage 1 of the project, except for Basin 5, which would be constructed during the longer term development phase.

The calibrated MUSIC water quality models were simulated over an extended rainfall time series to assess the pollutant loads and potential impacts of the proposal. In evaluating the effectiveness of the proposed measures, the treatment targets for total suspended solids, total phosphorus, and total nitrogen were assessed on the basis of i) comparison with existing or pre-development pollutant loads (NORBE); ii) Water Sensitive Urban Design (WSUD) Guidelines; and iii) ANZECC Guidelines (2000).

The Neutral OR Beneficial Effect (NORBE) concept for water quality management compares pollutant loads derived under post-development conditions to those obtained under existing conditions and seeks to maintain or improve the existing loads, in order to minimise any downstream impacts. By comparison, the WSUD concept aims to manage water quality by reducing the post development pollutant loads by set percentage targets. It is noted that the WSUD approach does not explicitly take into account the water quality pollutant loads under existing conditions. ANZECC Guidelines provide water quality objectives with the aim to limiting the pollutant loads to those required to sustain the environmental health and assimilative capacity of receiving waterways. The Guidelines apply to both the existing and post-development environment.

Under the proposed Stage 1 development conditions, with the proposed bio-retention basins in place, the results indicate that reduction of the post-development loads to pre-development loads (NORBE) would not be achieved, except for suspended solids.

Similarly, the results indicate that Stage 1 of the development, with the bio-retention basins in place, would be unable to satisfy WSUD targets, except for flows discharging from the site into Oaky Creek and Cosgroves Creek. For Badgerys Creek where the percentage retention targets are not met, it is considered that additional design measures would be required, particularly in the residual catchment areas associated with Basin 2, Basin 4, and Basin 5.

The results indicate that for Stage 1 of the development, ANZECC water quality objectives would not be achieved, except for suspended solids. This is notwithstanding the general improvements in water quality concentrations relative to the existing environment, particularly in Badgerys Creek and South Creek.

Under the longer term development, the results indicate that reduction of the post-development loads to pre-development loads (NORBE) would not be achieved, except for suspended solids.

The results for the longer term development indicate that the WSUD percentage retention targets for total suspended solids, total phosphorus, and total nitrogen are generally satisfied for flows discharging from the site into Oaky Creek, Cosgroves Creek, and Badgerys Creek. However, at basin outlet locations for Basins 1, 5 and 6, where the targets are not satisfied, it is considered that supplementary design measures would be required during detailed design.

Under the longer term development conditions, the concentrations for suspended solids, total phosphorus and total nitrogen are found to generally improve, relative to existing conditions in Oaky Creek, Cosgroves Creek, Badgerys Creek, and South Creek. The exceptions are those at Duncans Creek for suspended solids, phosphorus and nitrogen, and at the Basin 2 and the Basin 3 outlets, for total phosphorus, where the concentrations are estimated to increase. The results also indicate that ANZECC water quality objectives would not be achieved, except for suspended solids. This is the case even with the general improvements in water quality relative to the existing environment.

Overall, the results indicate that the bio-retention basins currently proposed in the Draft Airport Plan and concept design would not be adequate in treating the water quality to NORBE, WSUD or ANZECC water quality targets or objectives for the proposed Stage 1 phase. For the longer term development, the bio-retention basins would also be inadequate for NORBE and ANZECC water quality objectives, but would generally be adequate in meeting WSUD targets.

It is considered that additional design measures would need to be assessed and designed for implementation during the detailed design phase. This includes the provision of enhanced bio-retention swales along the drainage lines, the provision of diversion drains to convey flows from residual sub-catchment areas to the proposed bio-retention basin, and enlarging some of the bio-retention basins, where necessary. Additional mitigation and management measures, including water quality monitoring, should also be implemented during the construction and operational phases of the project.

With the implementation of the above additional measures, it is expected that the proposed airport will have no adverse impact on downstream water quality.

Terms and abbreviations

Term	Usage
AEPR	Airport Environmental Protection Regulation (1997)
Airport	Western Sydney Airport
Airport site	The airport site is the total of all properties that may become part of Western Sydney Airport. The airport site includes existing Commonwealth land and land to be acquired by the Commonwealth, such as The Northern Road.
Airport features	Specific features of the proposed airport, such as runways, taxiways, terminal buildings or hangars.
Australian Height Datum (AHD)	A common national plane of level approximately equivalent to the height above sea level.
Badgerys Creek	Badgerys Creek is a suburb of Sydney about 50 kilometres west of the Sydney central business district, and the general locality of the airport. Badgerys Creek is also the name of a waterway which is referred to in this report.
Catchment	The area drained by a stream or body of water or the area of land from which water is collected.
Datum	A level surface used as a reference in measuring elevations.
DEM	Digital elevation model
Discharge	Quantity of water per unit of time flowing in a stream, for example cubic meters per second or megalitres per day.
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
Flood	For the purposes of this report, a flood is defined as the inundation of normally dry land by water which escapes from, is released from, is unable to enter, or overflows from the normal confines of a natural body of water or waterway such as rivers, creeks or lakes, or any altered or modified body of water, including dams, canals, reservoirs and stormwater channels.
Geomorphology	Scientific study of landforms, their evolution and the processes that shape them. In this report, geomorphology relates to the form and structure of waterways.
Groundwater	Subsurface water stored in pores of soil or rocks.
Hazard	The potential or capacity of a known or potential risk to cause adverse effects.
Hydraulic conductivity	The rate at which water at the prevailing kinematic viscosity will move under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow, usually expressed in metres per day (this assumes a medium in which the pores are completely filled with water).
Hydraulics	The physics of channel and floodplain flow relating to depth, velocity and turbulence.
Hydrology	The study of rainfall and surface water runoff processes.
Infiltration	The downward movement of water into soil and rock, which is largely governed by the structural condition of the soil, the nature of the soil surface (including presence of vegetation) and the antecedent moisture content of the soil.
Landform	A specific feature of the landscape or the general shape of the land.
Light Detection and Ranging (LiDAR)	LiDAR is a remote sensing method used to examine the surface of the Earth. LiDAR has been used in this study to define the topography of the airport site and surroundings.

Term	Usage
Longer term development	The longer term stage in the development of the proposed airport, including parallel runways and facilities for up to 82 million passengers annually (nominally occurring in 2063).
LPMA	New South Wales Land and Property Management Authority
Meteorology	The science concerned with the processes and phenomena of the atmosphere, especially as a means of forecasting the weather.
MIKE21 modelling	MIKE21 is a two dimensional hydraulic modelling software program used to simulate surface flow and estimate flood levels and flow velocities.
MUSIC modelling	Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is a software program used to estimate the performance of stormwater quality management systems.
NORBE	Neutral OR Beneficial Effect is a term used to describe the treatment of water quality pollutant loads to either maintain or improve those generated under existing conditions.
Permeability	The capacity of a porous medium to transmit water.
Pluviograph	A rain gauge with the capability to record data in real time to observe rainfall over a short period of time.
Reach	Defined section of a stream with uniform character and behaviour.
Riparian	Pertaining to, or situated on, the bank of a river or other water body.
Risk	The chance of something happening that will have an impact measured in terms of likelihood and consequence.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Salinity	The total soluble mineral content of water or soil (dissolved solids); concentrations of total salts are expressed as milligrams per litre (equivalent to parts per million).
Sediment	Material of varying sizes that has been or is being moved from its site of origin by the action of wind, water or gravity.
Stage 1 development	The proposed initial stage in the development of the airport, including a single runway and facilities for up to 10 million annual passengers (for assessment purposes 10 million annual passengers is assumed to be reached in 2030).
Surface water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Surface water features	These include waterways and wetlands and their attributes (water quality and geomorphology). The term is generally used in this report to describe natural resources, but may also extend to artificial surface water features including lakes, dams and man-made wetlands.
Study area	The subject site and any additional areas which are likely to be affected by the proposal, either directly or indirectly. The study area extends as far as is necessary to take all potential impacts into account.
Topography	Representation of the features and configuration of land surfaces.
Water quality	Chemical, physical and biological characteristics of water. Also the degree (or lack) of contamination.

Term	Usage
Water sharing plan	A legal document prepared under the Water Management Act 2000 (NSW) that establishes rules for sharing water between the environmental needs of the river or aquifer and water users and also between different types of water use.
Waterway	Generic term for a river, creek or waterway.
Western Sydney Airport	The proposed airport at the Commonwealth owned land at Badgerys Creek which is assessed in accordance with the Western Sydney Airport environmental impact statement

Table of contents

Limitations i

1. Introduction 1
   - 1.1 Background 1
   - 1.2 Scope of the assessment 2
   - 1.3 Study area 2
   - 1.4 Structure of this report 2
2. Methodology 5
   - 2.1 Legislation and guidelines 5
   - 2.2 Previous studies 10
   - 2.3 Historical surface water quality data 12
   - 2.4 Design and other relevant project information 13
   - 2.5 MUSIC water quality modelling approach 14
   - 2.6 Bio-retention basins sizing and treatment targets 20
3. Existing conditions 23
   - 3.1 Catchment description 23
   - 3.2 Major waterways 23
   - 3.3 Rainfall and evaporation 26
   - 3.4 Existing land uses 28
   - 3.5 Recent water quality sampling 31
   - 3.6 MUSIC modelling results under existing conditions 33
4. Assessment of operational impacts of proposal 37
   - 4.1 Changes in land use types and areas 37
   - 4.2 Treatment basins and residual catchment areas 37
   - 4.3 Stage 1 development 39
   - 4.4 Longer term development 43
   - 4.5 Fuel jettisoning 47
5. Assessment of construction impacts 49
   - 5.1 Overview 49
   - 5.2 Duration of construction works 49
   - 5.3 Erosion and Sedimentation 49
   - 5.4 Potential for spills 50
   - 5.5 Demolition and excavation works 50
6. Mitigation and management measures 51
   - 6.1 Operational Phase Measures 51
   - 6.2 Construction Phase Measures 52
7. Summary and conclusions 57
8. References 59

Table index

Table 2-1 Airport Environmental Protection Regulation (AEPR) Water Quality Guidelines (1997) 6

Table 2-2 ANZECC Guidelines Default Trigger Values for NSW Lowland Rivers 8

Table 2-3 Reduction Targets (WSUD Guidelines) 10

Table 2-4 Summary of Historical Surface Water Quality Data 12

Table 2-5 Key data sources for Western Sydney Airport 13

Table 2-6 Calibration of MUSIC model under existing conditions 16

Table 2-7 Adopted Model Parameters under Existing Conditions 16

Table 2-8 Adopted Base-flow and Stormflow Pollutant Concentrations 18

Table 2-9 Adopted Modelling Parameters for initial and longer term development 19

Table 2-10 Adopted Base-flow and Stormflow Pollutant Concentrations 20

Table 2-11 Bio-retention Basin Sizes Adopted 21

Table 3-1 Waterway Catchment Areas 23

Table 3-2 Rainfall Gauge at Badgerys Creek 26

Table 3-3 Existing Land use within the airport site and downstream catchments 28

Table 3-4 Land use within major waterway catchments 28

Table 3-5 Detailed breakdown of land use within airport site waterways 30

Table 3-6 Recent Surface Water Quality Data 33

Table 3-7 Average Annual Pollutant Loads under Existing Conditions 34

Table 3-8 Average Pollutant Concentrations under Existing Conditions 35

Table 4-1 Comparison of Waterway Catchment Areas for Existing and Development Conditions 37

Table 4-2 Land Use Types for Stage 1 and Longer Term Development 37

Table 4-3 Basin Catchment Areas for Stage 1 Development 38

Table 4-4 Basin Catchment Areas for Longer Term Development 38

Table 4-5 Stage 1 Average Annual Pollutant Loads 40

Table 4-6 Stage 1 Percentage Pollutant Load Reductions 42

Table 4-7 Stage 1 Pollutant Concentrations 43

Table 4-8 Longer Term Average Annual Pollutant Loads 45

Table 4-9 Longer Term Percentage Load Reductions 46

Table 4-10 Longer Term Development Concentrations at Key Locations 47

Figure index

Figure 1-1 Surface water quality study area and key features....3
Figure 2-1 Calibration of MUSIC model under Existing Conditions....17
Figure 2-2 Locations of Bio-Retention Basins (Stage 1 and longer term)....22
Figure 3-1 Catchments in vicinity of the airport site....24
Figure 3-2 Monthly rainfall statistics at Badgerys Creek AWS....26
Figure 3-3 Comparison of rainfall at Badgerys Creek and Sydney (Kingsford Smith) Airport....27
Figure 3-4 Evaporation data from Parramatta gauge....27
Figure 3-5 Map of Existing Land Use....29
Figure 3-6 Recent surface water quality sampling locations....32

Appendices

Appendix A – Water Quality Sampling Data
Appendix B – MUSIC Water Quality Results for Stage 1 Development
Appendix C - MUSIC Water Quality Results for Longer Term Development

1. Introduction

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The Draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The Draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Scope of the assessment

This study assesses the impact of the proposed airport on surface water quality. Hydrological, flooding, geomorphological, and groundwater impacts are assessed in separate reports.

The key aspects of this study were to:

- describe the existing environment with respect to surface water quality;
- assess the likely impact of the proposed airport on these features in the context of the Commonwealth legislation, EIS guidelines, national, regional and local industry practice and guidelines; and
- identify measures to mitigate or manage the proposed impacts.

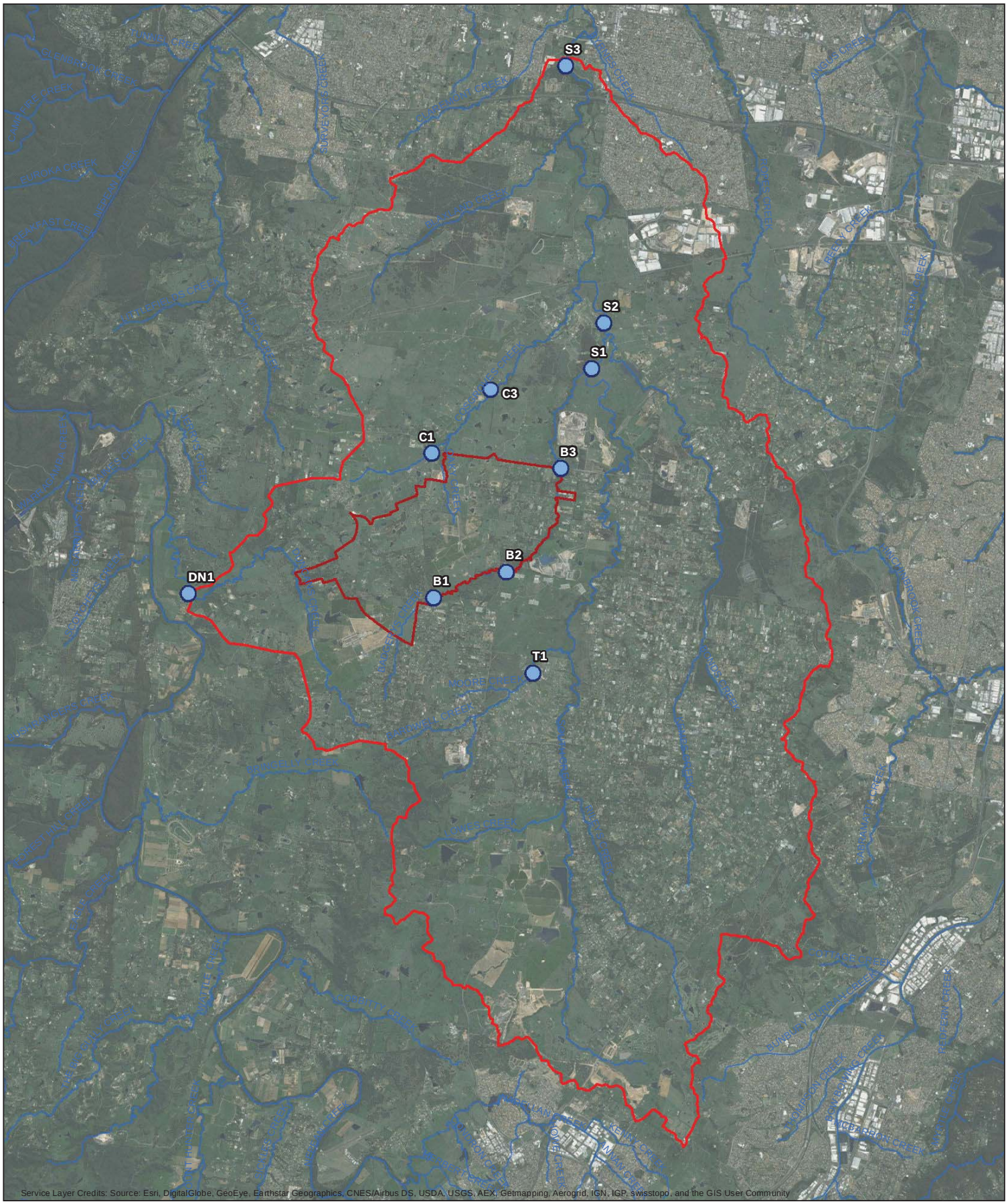
1.3 Study area

The study area for both Stage 1 and the longer term development scenarios consists of the airport site as well as the hydrological catchments of Duncans Creek, Cosgroves Creek, Oaky Creek, and Badgerys Creek. Duncans Creek discharges to the Nepean River. Oaky Creek discharges to Cosgroves Creek, while Cosgroves Creek and Badgerys Creek both discharge to South Creek. The study area is shown in Figure 1-1.

1.4 Structure of this report

The following summarises the content of the various sections of this report:

- **Section 2**: Describes the available data and reference legislations and documents;
- **Section 3**: Describes the existing surface water quality environment, including the existing land use and surface water quality pollutant export rates;
- **Section 4**: Describes the potential impacts of the airport proposal on surface water quality, including local and regional impacts;
- **Section 5**: Assesses the potential impacts during the construction phase;
- **Section 6**: Describes the mitigation and management measures to reduce the potential impacts; and
- **Section 7**: Summarises the findings and conclusions of the study.



LEGEND

- The airport site
- Water sampling site (Draft EIS)
- Watercourses
- Water Quality Study Area

Paper Size A3

0 800 1,600 3,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Surface water quality study area and key features

Job Number	21-24265
Revision	A
Date	14 Aug 2015

Figure 1-1

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2. Methodology

2.1 Legislation and guidelines

Key federal, state and local legislation, guidelines, and policies considered in this study include the following:

- *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act);
- *Airports Act 1996* (Cth) and *Airport (Environment Protection) Regulations 1997* (Cth);
- *Water Management Act 2000* (NSW) (WM Act);
- *National Water Quality Management Strategy* (ANZECC and ARMCANZ 1994) (NWQMS)
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality: Volume 1 – The Guidelines* (ANZECC and ARMCANZ 2000) (ANZECC Guidelines);
- Hawkesbury Nepean Catchment Action Plan (NSW Government 2014);
- Lower Hawkesbury-Nepean River Nutrient Management Strategy (NSW Government 2010);
- NSW Water Sharing Plans under the WM Act;
- Managing Urban Stormwater: Soils and Construction Volume 1(Blue Book, NSW Government 2004); and
- *Water Sensitive Urban Design Technical Guidelines for Western Sydney* (Upper Parramatta River Catchment Trust 2004) (WSUD Guidelines).

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The objective of the EPBC Act is to provide for the protection of the environment, especially those aspects of the environment that are matters of national environmental significance (MNES) and to promote the conservation of biodiversity.

MNES are relevant to surface water where:

- surface water features form part of the natural environment associated with a MNES; or
- a MNES is dependent on surface water features.

For the purposes of the EPBC Act, the proposed action is to be taken by the Commonwealth. The matter protected for actions taken by the Commonwealth under Part 3 of the EPBC Act is the environment. Under the Act, the definition of the environment is broad and includes ecosystems and their constituent parts, natural and physical resources, and qualities and characteristics of locations, places and areas. Surface water features are natural resources and are an integral part of the environment.

In response to a referral submitted by the Department in 2014, the Australian Government Department of the Environment has issued EIS guidelines which outline the matters that must be addressed in the EIS. *The Guidelines for the Content of a Draft Environmental Impact Statement, Western Sydney Airport* (Australian Government, 2015), identify that changes to water quality on site and downstream of the site need to be assessed as an impact on the environment.

This report has been prepared in accordance with the guidelines.

Other related surface and groundwater issues are addressed in separate reports.

2.1.2 Airports Act and Airports (Environment Protection) Regulations

Part 6 of the Airports Act deals with environmental management at airports. This Part will apply at the airport site after an airport lease is granted. It sets up a framework for making, monitoring and enforcing environmental standards at airports. Schedule 2 of Airports (Environment Protection) Regulations (AEPR) sets out acceptable limits for water pollution which apply to the exclusion of any state laws. AEPR guidelines for typical physical and chemical stressors are shown in Table 2-1. It is noted that the AEPR Guidelines are more stringent than ANZECC 2000 for total phosphorus and total nitrogen.

The regulations make provision for setting airport specific standards in certain circumstances.

Table 2-1 Airport Environmental Protection Regulation (AEPR) Water Quality Guidelines (1997)

Parameter	AEPR Guideline
Total phosphorus (TP)	< 0.01 mg/L
Total nitrogen (TN)	< 0.1 mg/L
Dissolved oxygen (DO)	80% of average level for a normal 24 hr period or < 6 mg/L
Total suspended solids (TSS)	change not more than 10% from seasonal mean
Turbidity	a reduction of 10% clarity in the euphotic zone from the seasonal mean
pH	6.5 – 9.0
Salinity	> 1000 mg/L or an increase of > 5%

2.1.3 Water Management Act 2000

The WM Act is administered by the NSW Department of Primary Industries (DPI) Water (formerly NSW Office of Water) and is intended to ensure that water resources are conserved and properly managed for sustainable use benefitting both present and future generations. The WM Act is also intended to provide a formal means for the protection and enhancement of the environmental qualities of waterways and their in-stream uses as well as to provide for protection of catchment conditions. The intent and objectives of the WM Act have been considered as part of this assessment.

2.1.4 National Water Quality Management Strategy

NWQMS has been developed by the Australian and New Zealand governments in cooperation with state and territory governments. The NWQMS aims to protect the nation's water resources, by improving water quality while supporting the businesses, industry, environment and communities that depend on water for their continued development. The NWQMS consists of three major elements: policy, process and guidelines.

The main policy objective of the NWQMS is to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development. The process strives to form a nationally consistent approach to water quality management through the development of high-status national guidelines. The guidelines provide the point of reference when issues are being determined on a case-by-case basis. These include guidance on regulatory and market-based approaches to managing water quality as well as regional water quality criteria.

2.1.5 ANZECC Guidelines (2000)

The ANZECC Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000) present numerical guidelines which can be used as a basis to assess the impact of the development of Western Sydney Airport against defined objectives or values for the receiving waters.

The core concept of the ANZECC Guidelines relates to managing water quality for environmental values. For each environmental value, the guidelines identify particular water quality characteristics or 'indicators' that are used to assess whether the condition of the water supports that value. The environmental values expressed as water quality objectives provide goals to assist in the selection of the most appropriate management options within a catchment. The guiding principles include that:

- where the environmental values are being achieved in a waterway they should be protected; and
- where the environmental values are not being achieved in a waterway, all activities should work towards their achievement over time.

The environmental values expressed as water quality objectives provide goals to assist in the selection of the most appropriate management options within a catchment. The ANZECC guidelines also advocate an 'issues-based' approach to assessing ambient water quality, rather than the application of rigid numerical criteria without an appreciation of the context. This means that the guidelines focus on:

- the environmental values we are seeking to achieve or maintain;
- the outcomes being sought; and
- the ecological and environmental processes that drive any water quality problem.

It should also be noted that the environmental values and respective numerical indicator values apply to ambient background water quality and are not intended to be applied to effluent quality or mixing zones associated with a release from a sewerage scheme. Discharges from the airport site therefore need to be considered on an individual catchment basis in recognition of other land uses within the catchment which also influence water quality.

The surface water features receiving water from the existing airport site and surrounding areas are located primarily within agricultural catchments and as such are considered to be "slightly modified fresh water systems". Based on this classification, a protection level of 95 per cent for freshwater ecosystems, as recommended in the ANZECC Guidelines, is considered to be suitable for toxicants. The airport site also has a 'lowland rivers' classification (NSW rivers, less than 150m in altitude).

Default ANZECC trigger values for physical and chemical stressors applicable to the airport site and adopted in this assessment are shown in Table 2-2. It is noted that these default trigger values are guideline values or water quality objectives only, and are not compliance standards.

Table 2-2 ANZECC Guidelines Default Trigger Values for NSW Lowland Rivers

Parameter	Default Trigger Value for Lowland Rivers
Chlorophyll a Chl a (mg/L)	0.005
Total phosphorus TP (mg/L)	0.05
Filterable reactive phosphate FRP (mg/L)	0.02
Total nitrogen TN (mg/L)	0.5
Oxides of nitrogen NOx (mg/L)	0.04
Ammonium NH4+ (mg/L)	0.02
Dissolved oxygen DO	85-110 %
pH	6.5 – 8
Salinity (µS/cm)	125-2200
Turbidity (NTU)	6 – 50

Source: ANZECC Guidelines (2000)

2.1.6 Hawkesbury Nepean Catchment Action Plan

The Hawkesbury-Nepean and Sydney Metropolitan Catchment Management Authority (CMA) regions were amalgamated in late 2012. Following this, a Catchment Action Plan (CAP) for the Hawkesbury-Nepean catchment was developed and later superseded by a *Greater Sydney Local Land Service Transition Catchment Action Plan* (NSW Government 2014).

Catchment Action Plans (CAPs) are ten-year plans to guide the management of water, land and vegetation by state government and local communities.

The catchments of Badgerys Creek, Oaky Creek, Cosgroves Creek and Duncans Creek fall within the *Greater Sydney Local Land Service Transition Catchment Action Plan*. The action plan has been considered with respect to any influence the proposed airport may have on the downstream catchments in relation to surface water and aquatic ecology.

Relevant strategies within the action plan include development of a more water sensitive city, promoting resilience through climate change adaptation and a number of strategies relating to the protection of aquatic ecosystems.

2.1.7 Lower Hawkesbury-Nepean River Nutrient Management Strategy

The *Lower Hawkesbury-Nepean River Nutrient Management Strategy* (NSW Government 2010) has been developed with the aim of reducing nutrient loads from existing sources and limiting the growth in nutrient loads from changing land uses (NSW Office of Environment and Heritage). The strategy includes development of a catchment-wide framework to coordinate and guide action on managing nutrients in the lower Hawkesbury-Nepean. The sources of nutrients identified as a priority are urban stormwater, agricultural practices, on-site sewage management systems, sewage treatment systems and overflows, and degraded land and riparian vegetation.

The nutrient management strategy report documents a number of mechanisms and related plans through which the strategy is proposed to be implemented.

2.1.8 NSW Water Sharing Plans

Water sharing plans are implemented under the WM Act and specify the rules for the sharing of water between the environment and water users and between water users themselves. Water sharing plans also specify rules for the trade and management of water access licences.

The Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources (the water sharing plan) commenced in 2011 and covers 87 management zones that are grouped into six water sources. The proposed airport is situated in the Hawkesbury and Lower Nepean Rivers catchment or source.

The Hawkesbury and Lower Nepean Rivers catchment is separated into management areas, which include amongst others the Upper and Lower South Creek Management Zones and the Mid Nepean River Catchment Management Zone. Badgerys, Oaky and Cosgroves Creeks are interpreted to be within the Upper South Creek Management Zone, and Duncans Creek is interpreted to be within the Wallacia Weir Management Zone (one of the Mid Nepean River Catchment Management Zones).

Extraction from these zones currently occurs for irrigation and town and industrial water supply.

The water sharing rules listed in the water sharing plan for the Upper South Creek and Wallacia Weir Management Zones are summarised below.

- Upper South Creek Management Zone:
  - access rules stipulate the flow rates at which users must cease to pump from the creek, based on A and B flow classes; and
  - trading is permitted within the management zone (subject to assessment) but is not permitted into the management zone.
- Wallacia Weir Management Zone:
  - environmental flow protection rules apply when inflows to the dams are greater than the 80th percentile, depending on the ability of the weir to pass flows released upstream;
  - trading is permitted within the management zone and is permitted into the management zone from upstream management zones (but not from other management zones);
  - limited access to very low flows is allowed for during water shortages depending on conditions that trigger a water shortage; and
  - lagoon rules prevent water trading onto a lagoon and application for new works on a lagoon.

Water sharing plans in relation to groundwater resources and groundwater recharge are discussed in the groundwater assessment report.

2.1.9 Managing Urban Stormwater: Soils and Construction – Volumes 1 and 2D

The NSW Government publishes the following documents about the management of erosion and sediment control during construction and other land disturbance activities.

- Managing Urban Stormwater: Soils and Construction – Volume 1 (Blue Book). The document provides guidance for local councils and practitioners on the design, construction and implementation of measures to improve stormwater management, primarily erosion and sediment control, during the construction phase of urban development.
- Managing Urban Stormwater: Main road construction – Volume 2D. The document provides guidelines, principles and recommended minimum design standards for managing erosion and sediment control during the construction of main roads. The construction of main roads and highways commonly involves extensive earthworks, with significant potential for erosion and sedimentation of waterways and the landscape, and the document therefore has been considered in the preparation of this report.

2.1.10 Water Sensitive Urban Design Technical Guidelines for Western Sydney

When urban development occurs, the change in land use and increased hardstand area due to development of the site may change the natural water cycle of the developed area. This typically results in increased runoff and increased contaminants flowing into the surrounding streams and waterways.

WSUD is increasingly being adopted by local and regional councils to provide water management strategy outcomes in urbanised environments in line with the various state planning instruments.

The objectives of WSUD policy are generally to maintain or replicate the predevelopment water cycle through the use of design techniques, with a particular focus on water quantity and quality. This is primarily achieved through the treatment of stormwater runoff through the use of on-site treatment measures that mitigate and limit the potential adverse effects on the downstream receiving waterways.

The WSUD Guidelines have been developed to assist the management of surface water quality attributed to the conversion of peri-urban and rural land use to urban land uses and residential development within the area. The document provides guidance on WSUD treatment measures as well as model parameters that may be adopted for the Western Sydney region.

It also specifies percentage reduction targets for total phosphorus, total nitrogen and total suspended solids for urban developments (Table 2-3). It is noted that these reduction targets are similar to those specified by the NSW Environment Protection Authority (EPA) Stormwater Management Handbook (1997). However the NSW EPA does not currently publish these targets.

Table 2-3 Reduction Targets (WSUD Guidelines)

	Total Suspended Solids (TSS)	Total Phosphorus (TP)	Total Nitrogen (TN)
% Reduction Targets	80%	45%	45%

Source: WSUD Technical Guidelines for Western Sydney (Upper Parramatta Trust 2004)

2.2 Previous studies

The following documents provide information on the state of the Hawkesbury-Nepean river system and its tributaries, including South Creek. It is noted that Duncans Creek, Badgerys Creek and Cosgroves Creek are also located within the upper reaches of the catchment. Key findings from these documents relevant to this study are summarised below.

2.2.1 Lower Hawkesbury-Nepean Nutrient Management Strategy (DECCW 2010)

This document analyses the major land uses within the catchment, and identifies a number of key pollutant sources within the catchment for which poor water quality could be attributed. The South Creek catchment was found to be a significant contributor of nutrients (phosphorus and nitrogen) into the overall river system. These nutrient loads were found to derive predominantly from grazing, urban environment, rural residential, intensive animal production and intensive horticulture land uses.

2.2.2 Hawkesbury-Nepean River Environmental Monitoring Program (DECCW 2009)

This technical report reviewed available water quality data in order to investigate long-term trends and biological patterns in the river ecosystem.

The report described many areas of the Hawkesbury-Nepean river system as being stressed, with some areas being eutrophic. Large amounts of water were found to be diverted from the water system for water supply and irrigation purposes and nutrient levels were often high, with algal blooms common.

A broad scale analysis of available water data was undertaken as part of this study and compared against ANZECC Guideline levels. The results for the South Creek catchment indicated that the minimum recorded values, for total phosphorus (TP) and total nitrogen (TN), generally do not achieve ANZECC water quality objectives and were identified as an important issue for the catchment.

Historical trends suggest that there may have been a reduction in pollutant loads in recent years due to possible changes in land management practices. However, extended monitoring data would be required before these results can be confirmed. It is intended that additional monitoring would be undertaken in the near future.

2.2.3 Water Management in South Creek Catchment (CRC 2007)

Similar to the Lower Hawkesbury-Nepean Nutrient Management Strategy, this study provides an analysis of land and water uses throughout the catchment and identifies a number of major environmental issues which are attributed to specific activities within the catchment.

A detailed breakdown of the estimated sources of phosphorus in the South Creek catchment indicated that 44 per cent was derived from agricultural land, 28 per cent from urban runoff, 18 per cent from unused or cleared lands, 9 per cent from sewage treatment plants and 1 per cent from natural runoff.

This report also commented that whilst a number of nutrient abatement strategies had been implemented, these measures had not been able to keep pace with continuing population growth and urban development.

2.2.4 Second Sydney Airport EIS (1997-1999)

In December 1997, the then Department of Transport and Regional Development exhibited a Draft EIS for the second Sydney airport proposal and a Supplementary EIS was completed in 1999. The EIS included Technical Paper 7 which focussed on geology, soils and water and contained a study of the effects on water quality of the proposed airport development. This included a limited water quality sampling programme, the results of which are summarised in section 2.3.

2.2.5 SMEC Environmental Field Survey (2014)

SMEC completed a report entitled *Environmental field survey of Commonwealth land at Badgerys Creek* (SMEC October, 2014), which included a review of both historical and more recent water quality sampling. The results of this survey by SMEC are included in Table 2-4.

A referral for the proposed airport was submitted by the Department of Infrastructure and Regional Development to the Department of the Environment in November 2014.

2.3 Historical surface water quality data

Historical water quality monitoring data available for the airport site and downstream areas include data from the Second Sydney Airport EIS and SMEC *Environmental Field Survey of Commonwealth Land at Badgerys Creek*. A summary of these data is presented in Table 2-4 for some key parameters. Figure 3-1 shows the locations where this monitoring was conducted.

In Table 2-4, ANZECC guideline default trigger values are also included for comparison. Both sets of data show that the nutrient loads (i.e. total nitrogen (TN) and total phosphorus (TP)) were elevated or significantly elevated above ANZECC water quality objectives for a number of the sampling locations. However, suspended solids, turbidity, and pH were found to be generally within acceptable values except for a few exceedances. Dissolved oxygen levels were found to be acceptable at the locations tested in Badgerys Creek, but were generally low for Cosgroves Creek, Thompsons Creek, and Duncans Creek. Full details of the data, including details of the sampling locations and other parameters sampled, are provided in the Appendices.

Table 2-4 Summary of Historical Surface Water Quality Data

Location	DO %S	pH	Turbidity NTU	TSS mg/L	TN mg/L	TP mg/L
ANZECC default values (2000)	**85-110%**	**6.5-8**	**6-50**	**<40***	**0.5**	**0.05**
Second Airport EIS (PPK 1997-1999)						
Badgerys Creek (B1, 1996)	63	6.9	1.1	2	-	<0.02
Badgerys Creek (B2, 1996)	150	7.3	7	33	-	1.2
Badgerys Creek (B3, 1996/1998)	13-107	6.7-7.2	5.1- 46	9-24	0.12-2.3	0.26-0.47
Cosgroves Creek (C1, 1996)	25	6.7	2.9	5	-	< 0.02
Cosgroves Creek (C3, 1996/1998)	2-65	6.7-7.4	2.9-16	5-12	1.23 – 1.7	0.02 – 0.07
Duncans Creek (D1, 1996/1998)	15-50	6.7-7.1	5.2-12	6-13	0.02 – 1.3	0.02 – 0.04
South Creek (S1, 1998)	83-105	7-7.2	15-65	9-56	0.49 – 1.6	0.01 – 0.14
South Creek (S2, 1998)	60-87	6.8-6.9	7-82	5-19	0.44 – 1.5	0.01 – 0.11
South Creek (S3, 1998)	39-79	6.9-7.4	12-40	4-14	0.8 – 1.52	0.05 – 0.5
Thompson Creek (T1, 1996/1998)	15-50	6.4-7.3	4.9-14	5-11	0.02 – 1.14	0.01 – 0.04
Badgerys Creek Environmental Field Survey (SMEC 2014)						
Cosgroves Creek (C1)			11	32	0.8	0.09
Badgerys Creek (B1)			3.2	10	2.8	1.6
Badgerys Creek (B2)			14	17	2.5	0.5
Badgerys Creek (B3)			11	16	2.6	0.5
Thompsons Creek (T1)			17	31	0.7	0.07
Duncans Creek (DN1)			35	30	1.5	0.1

TN: Total nitrogen TP: Total phosphorus TSS: Total suspended solids DO: Dissolved oxygen

* ANZECC Guidelines Professional judgement (aquaculture); 50 mg/L NSW Blue Book for Soils and Construction

Source: Collated from reports shown above

2.4 Design and other relevant project information

The following concept design information and other data were acquired or made available and reviewed and adopted for the purposes of this surface water quality study. These documents are summarised in Table 2-5.

Table 2-5 Key data sources for Western Sydney Airport

Document / dataset	Data source	Description	Date
Aerial imagery	NSW LPMA		2015
Airport Plan – Concept Plan - Longer Term	DIRD	Drawing of proposed longer term airport layout	May 2015
Airport Plan – Concept Plan - – Stage 1	DIRD	Drawing of proposed Stage 1 airport layout	May 2015
Airport Plan – Concept Plan - – Stage 1 Land Use Zoning Plan	DIRD	Drawing of proposed land use for Stage 1	May 2015
Airport Plan – Concept Plan - – Long Term Land Use Zoning Plan	DIRD	Drawing of proposed land use for longer term development	May 2015
Stage 1 Surface Water Management Layout Plan	DIRD / GHD design team	Drawing of proposed surface water management strategy for Stage 1	2015
Longer Term Surface Water Management Layout Plan	DIRD / GHD design team	Drawing of proposed surface water management strategy for the longer term development	2015
Draft Airport Plan	DIRD	Draft plan report as at the time of conducting the surface water assessment	May 2015
SMEC Environmental Field Survey of Commonwealth Land at Badgerys Creek	DIRD	Documentation of water quality sampling data collected by SMEC	2014
Hydrology models	DIRD / GHD design team	RAFTS model of the existing airport site and longer term development	2015
Hydraulic models	DIRD / GHD design team	MIKE 21 models of the existing airport site and longer term development	2015
LiDAR	NSW LPMA	Topographical LiDAR outputs at 1 metre and 5 metre intervals	2015
Updated South Creek Flood Study	Worley Parsons	Flood study of South Creek and its contributing catchments	2015
Water quality models	DIRD / GHD design team	Preliminary Model for Urban Stormwater Improvement Conceptualisation model of the Stage 1 airport site and longer term development. No existing site model was prepared as part of concept design.	2015
Western Sydney Airport – Airport Land Use Master Plan – Feasibility Design Version 0.01	DIRD	Draft report as at time of conducting surface water assessment	March 2015
Western Sydney Airport Climatological Review	Bureau of Meteorology	Report containing analysis of climatic data from Badgerys Creek gauge	2015
Western Sydney Airport Usability Report	Bureau of Meteorology	Report documenting the meteorological parameters affecting the usability of the airport site	2015

2.5 MUSIC water quality modelling approach

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) water quality model was used to estimate pollutant loads in the catchment under existing and proposed development conditions, including suspended solids, total phosphorus and total nitrogen. This model was chosen as it has the ability to estimate the quantity and quality of surface water generated at a site under a range of conditions, and to determine the effectiveness of potential mitigation measures.

MUSIC combines a rainfall-runoff and stochastic pollutant generation algorithm to estimate the quantity and quality of runoff generated, given the following inputs:

- a meteorological template which details rainfall and potential evapotranspiration inputs; and
- source nodes which define the catchment properties, including land use type (which in turn defines the water quality parameters), sub-catchment area, impervious fraction, and storage properties.

2.5.1 Meteorological template

The meteorological template specifies the rainfall and evaporation characteristics of the area. The rainfall input needs to be in the form of a time series, with a time-step representative of the smallest time of concentration for the catchment and/or the smallest notional detention time in treatment measures. Potential evapotranspiration data, on the other hand, can be in the form of a daily time-series or average monthly figures. These inputs were developed on the basis of available Bureau of Meteorology (BOM) data.

For this study, the rainfall gauge at Badgerys Creek (Station 067108, Figure 3-2) was adopted. This consisted of 1-minute data from December 1998 to May 2015. Monthly evaporation data were sourced from the Parramatta Gauge (Figure 3-4), which was the nearest station to Badgerys Creek that had evaporation data available.

2.5.2 Source nodes

MUSIC has three default land use types, namely Urban, Agricultural, and Forested Source Nodes. These source nodes differ only in their default base flow and stormflow pollutant concentrations. User defined source nodes may also be specified, which operates in exactly the same manner, but have no default water quality parameters included.

For this study, user-defined source nodes were adopted, in order to reflect the different types of land use within the catchment. This included nodes for rural residential, forest, horticultural, natural pastures and modified pasture areas.

2.5.3 MUSIC modelling under existing conditions

(a) Model set-up under existing conditions

The MUSIC model was initially set up to represent the existing airport catchment. A total of 39 individual sub catchments were delineated using 1 m contours generated for the site. Catchment boundaries were identified using hydro-line mapping of natural gullies and the Commonwealth land boundary in order to assess the site in isolation from the external catchment area.

Two additional external catchments were modelled to represent the area downstream of Elizabeth Drive down to the confluence of South Creek with Kemps Creek, and with Blaxland Creek respectively, in order to assess the impacts on downstream water quality at a more regional scale.

Each individual sub-catchment was broken down into five land use types to represent the existing land use. These were rural residential, forest, horticultural, naturalised pastures and modified pastures.

For convenience, junction nodes were also placed at all proposed bio-retention basin locations indicated in the Stormwater Management Plans provided by the Department of Infrastructure and Regional Development (see Table 2-5). Additional junction nodes were placed at known water quality monitoring locations for calibration purposes.

The parameters for rural residential source nodes were defined in accordance with the Draft NSW MUSIC Modelling Guidelines (Sydney Metropolitan CMA 2010). However, the default parameters for agricultural nodes in the NSW MUSIC Modelling Guidelines were not considered to be entirely appropriate for the range of land use within the catchment. Accordingly, guidance was also sought from the Technical Report "*A review of sediment and nutrient concentration data from Australia for use in catchment water quality models*" (E-Water CRC 2010). This document provides a statistical assessment of pollutant concentrations from some 750 records across 514 different geographical locations throughout Australia. This includes pollutant concentrations reported for catchments based on their Australian Land Use Mapping categorisations.

The MUSIC model set up for the existing catchment conditions was simulated for the full range of rainfall data available. A modelling time-step of six-minutes was found to be adequate and adopted for all modelling scenarios.

(b) Model calibration under existing conditions

The MUSIC model set up for the existing airport catchment was calibrated using recent sampling data obtained by SMEC 2014 (Table 2-4) and GHD 2015 (Table 3-6) at a number of locations along Badgerys Creek, Duncans Creek and Cosgroves Creek.

This was undertaken by making adjustments to the initial parameters defined in Section 2.5.2, and using an iterative process, until the modelled results were similar to the sampled data. The results of the calibration are presented in Table 2-6 and Figure 2-1.

In Table 2-6, the lower and upper range of results obtained from the MUSIC model is shown together with the sampled data. In general, the model results were found to be in good agreement with the sampled data, with the sampled concentrations generally falling within the range of results obtained. It is noted that the correlation was not particularly high at a number of locations. For example, at Badgerys Creek, the modelled total phosphorus concentrations are found to be relatively low compared to the field data.

Overall, however, the results were considered to be acceptable in view of the data and model limitations, and the inherent difficulties in water quality calibration. In particular, it is noted that the field data were discrete rather than continuous and little or no correlation to rainfall or flow conditions at the time of the sampling was available.

The MUSIC model parameters obtained from the above calibration process and adopted for the existing catchment environment are presented in Table 2-6 and Table 2-7.

Table 2-6 Calibration of MUSIC model under existing conditions

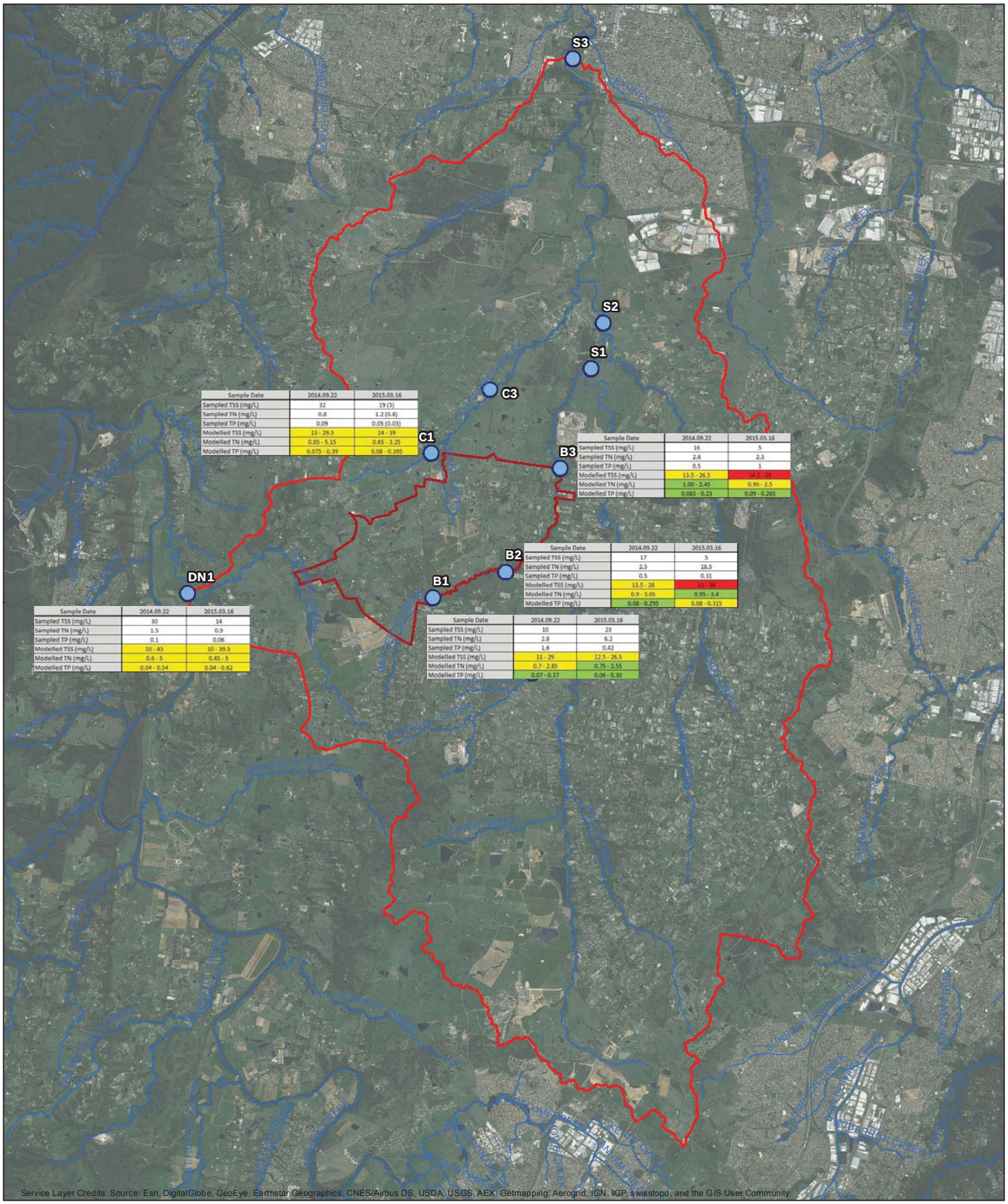
Location	Comparison of Sampled Data with Model Results (MUSIC)			
	Source	TSS (mg/L)	TN (mg/L)	TP (mg/L)
SMEC Data (22.9.2014)				
Badgerys Ck (B1)	Sampled Modelled	10 11-29	2.8 0.7-2.85	1.6 0.07-0.37
Badgerys Ck (B2)	Sampled Modelled	17 13.5-28	2.5 0.9-3.05	0.5 0.08-0.295
Badgerys Ck (B3)	Sampled Modelled	16 13.5-26.5	2.6 1-2.45	0.5 0.085-0.23
Cosgroves Ck (C1)	Sampled Modelled	32 13-29.5	0.8 0.85-5.15	0.09 0.075-0.39
Duncans Ck (DN1)	Sampled Modelled	30 10-43	1.5 0.6-5	0.1 0.04-0.54
GHD Data (16.3.2015)				
Badgerys Ck (BCUS)	Sampled Modelled	23 12.5-26.5	6.2 0.75-2.55	0.42 0.06-0.3
Badgerys Ck (BCMC)	Sampled Modelled	5 13-28	18.5 0.95-3.4	0.31 0.08-0.315
Badgerys Ck (BCDS)	Sampled Modelled	5 14.5-25	2.3 0.95-2.5	1 0.09-0.265
Cosgroves Ck (OCDS /CCUS)	Sampled Modelled	19 (5) 14-39	1.2 (0.8) 0.65-3.25	0.05 (0.03) 0.08-0.395
Duncan Ck (DCDS)	Sampled Modelled	14 10-39.5	0.9 0.45-5	0.06 0.04-0.62

Note: MUSIC model results are based on concentrations obtained at six-minute intervals over a 24-hour period

Table 2-7 Adopted Model Parameters under Existing Conditions

Parameters	Values
Impervious Area Parameters	
Daily Rainfall Threshold Values (mm)	1
Pervious Area Parameters	
Soil Storage Capacity (mm)	210
Initial Storage (% of capacity)	30
Field Capacity (mm)	80
Infiltration Capacity Coefficient – a	175
Infiltration Capacity Coefficient – b	3.1
Groundwater Properties	
Initial Depth (mm)	10
Daily Recharge Rate (%)	35
Daily Base flow Rate (%)	20
Daily Deep Seepage Rate (%)	0

Note: Parameter values are for non-urban source nodes > 10 Ha and mean annual rainfall <1000 mm



LEGEND

- The airport site
- Water sampling site (Draft
- Watercourses

LEGEND
range higher than sample
Sample in range
range lower than sample

Paper Size A3

0 800 1,600 3,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Calibration of MUSIC model under Existing Conditions

Job Number	21-24265
Revision	A
Date	23 Jul 2015

Figure 2-1

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Data source: Created by: afoddy

Table 2-8 Adopted Base-flow and Stormflow Pollutant Concentrations

Source Node	Pollutant Parameters mg/L (log_{10}) under Existing Conditions					
	TSS		TP		TN	
	Mean	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
Rural Residential[1]						
Base Flow	1.15	0.17	-1.22	0.19	0.05	0.12
Storm Flow	1.95	0.32	-0.66	0.25	0.30	0.19
Forest[1]						
Base Flow	0.78	0.13	-1.52	0.13	-0.52	0.13
Storm Flow	1.60	0.20	-1.10	0.22	-0.05	0.24
Horticultural[2]						
Base Flow	1.28	0.17	-0.70	0.30	0.01	0.30
Storm Flow	3.49	0.32	0.16	0.30	1.51	0.30
Naturalised Pastures[2]						
Base Flow	1.28	0.17	-1.18	0.30	0.01	0.30
Storm Flow	2.92	0.32	-0.32	0.30	0.20	0.30
Grazing/ Modified Pastures[2]						
Base Flow	1.28	0.17	-0.52	0.30	0.36	0.30
Storm Flow	2.41	0.32	-0.25	0.30	0.83	0.30

1: Based on NSW MUSIC Modelling Guidelines

2: Based on Drewry et al. (2006) and Bartley et al. (2010)

2.5.4 MUSIC modelling under Stage 1 and longer term conditions

(a) Modelling methodology under Stage 1 and longer term conditions

The Stage 1 analysis was undertaken on the basis of the land use plan, surface water management plan and design basis report provided as part of the Draft Airport Plan (refer to Table 2-5). Water quality models for Stage 1 were developed during the course of this study.

The surface water management plans provided were based on an earlier version of the land use plan. As a result, there were minor inconsistencies between the data sources characterising the airport site. Where necessary, assumptions in the assessment were made to manage those discrepancies.

The methodology adopted for modelling Stage 1 of the proposed airport development was similar to that adopted for modelling the existing environment, as described in Section 0. However, the model was modified in order to represent the catchment conditions for the development.

Sub-catchment areas for the proposed Stage 1 Development were delineated using the following information:

- Stage 1 Stormwater Management Plan, to identify the treatment of runoff and the extent of earthworks and proposed drainage network through the site;
- Stage 1 design contour information, to identify the proposed ridgeline separating the Stage 1 runway and longer term second runway and the extent of earthworks proposed; and
- existing contour information, to identify the residual areas not picked up by swales and internal drainage through which runoff would bypass the proposed basin locations.

Land use types were derived using the indicative concept design in the Draft Airport Plan. On this basis, the site was categorised into the following land use types, as detailed in the preceding section of this report:

- Grassed areas;
- Paved/Hardstand areas; and
- Roof areas.

All the model source nodes were updated to reflect the modified land uses and catchment areas within the airport site for the proposed Stage 1 Development. For modelling and comparison purposes, it was assumed that the catchments outside the airport site would remain the same as under existing conditions. Consequently, no changes were made to those external catchments.

The indicative longer term development model was developed using the same approach as that for the proposed Stage 1 Development, but using the relevant catchment and land use plans for the longer term development.

The same rainfall data set used to assess the existing environment was adopted in modelling for both the proposed Stage 1 and longer term development stages.

(b) Modelling Parameters for Stage 1 and longer term conditions

In assessing the proposed Stage 1 and longer term development phases of the project, it was considered that the site would effectively be urbanised as a result of the proposal. Consequently, urban parameters were considered to be appropriate and were adopted in configuring the source nodes within the site boundary. This included parameters for grassed, paved, and roofed areas which are shown in Table 2-9 and Table 2-10.

Table 2-9 Adopted Modelling Parameters for initial and longer term development

Parameters	Values
Impervious Area Parameters	
Daily Rainfall Threshold Values (mm)	1.5
Pervious Area Parameters	
Soil Storage Capacity (mm)	170
Initial Storage (% of capacity)	30
Field Capacity (mm)	70
Infiltration Capacity Coefficient – a	210
Infiltration Capacity Coefficient – b	4.7
Groundwater Properties	
Initial Depth (mm)	10
Daily Recharge Rate (%)	50
Daily Base flow Rate (%)	5
Daily Deep Seepage Rate (%)	0

Note: Parameter values are for non-urban source nodes >10 Ha and mean annual rainfall <1000 mm

Table 2-10 Adopted Base-flow and Stormflow Pollutant Concentrations

Source Node	Pollutant Parameters mg/L (log_{10})					
	TSS		TP		TN	
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Paved Areas						
Base Flow	1.2	0.17	-0.85	0.19	0.11	0.12
Storm Flow	2.43	0.32	-0.30	0.25	0.34	0.19
Roofed Areas						
Base Flow	n/a	n/a	n/a	n/a	n/a	n/a
Storm Flow	1.30	0.32	-0.89	0.25	0.30	0.19
Grassed Areas						
Base Flow	1.30	0.13	-1.05	0.13	0.04	0.13
Storm Flow	2.15	0.31	-0,22	0.30	0.48	0.26

Note: Above parameters are based on NSW Music Modelling Guidelines

2.6 Bio-retention basins sizing and treatment targets

The Draft Airport Plan for the airport (refer Table 2-5) included indicative sizes of bio-retention basins proposed for the site. These sizes were tested in the MUSIC model and assessed in terms of their effectiveness in managing the post-development water quality loads.

In evaluating the effectiveness of the proposed measures, three treatment targets were assessed, as follows:

- existing or pre-development pollutant loads for total phosphorus, total nitrogen, and suspended solids (NORBE);
- WSUD Guidelines; and
- ANZECC Guidelines.

The NORBE (Neutral OR Beneficial Effect) approach to water quality management requires that post development pollutant loads discharging from a site are managed such that the water quality is equal to or better than the pre-development or existing loads. The NORBE approach is described in *State Environmental Planning Policy (*SEPP*, Sydney Drinking Water Catchment)* 2011 and relates to development within Sydney Water's drinking water catchments. This approach is generally very difficult to comply with where the existing sites are pristine or of a rural nature, such as the airport site, but is relatively easy to comply with where the existing sites are already urbanised, semi-urbanised, or degraded. This is because the pristine or rural catchments generate much lower pollutant loads than those under urbanised conditions, thus requiring more extensive treatment measures in reducing the loads to pre-development levels.

It is noted that the NORBE approach to water quality management has been adopted in many development situations in Australia over the last 20 years prior to its inclusion in SEPP 2011. For example, it was also one of the design criteria adopted in the 1997 Airport EIS for Badgerys Creek.

The WSUD Guidelines specify pollutant reduction targets as a practical way of treating urban stormwater quality (refer Section 2.1.10). These targets recognise that, with most developments, pollutant loads are likely to increase, and the focus is therefore on managing the loads to acceptable levels, rather than maintaining the existing load levels. Consequently, these pollutant reduction targets apply only to urban or post-development pollutant loads, and do not take into account the existing or pre-development loads. The application of these

guidelines is generally less stringent than the NORBE approach where the existing catchments are of a rural nature, as in the case of the airport site.

The recommendations of the ANZECC Guidelines have been noted in Section 2.1.5. These guidelines take into account the relative health and assimilative capacity of the receiving waterways and aim to keep the pollutant loads exported from a site to levels that the receiving waterways can sustain. They are also intended to be site specific, with water quality trigger levels established on the basis of long-term water quality monitoring data and ecological studies. In this study, in the absence of detailed site monitoring data, default trigger levels provided in the ANZECC Guidelines have been adopted.

It is also noted that where ANZECC water quality objectives are not achieved for nutrient concentrations they are also not achieved for AEPR Guidelines, which are more stringent.

The bio-retention basin sizes included in the Draft Airport Plan and Concept Design were assessed in the MUSIC model. The adopted bio-retention basin sizes are shown in Table 2-11. The surface areas of these basins correspond to about 0.4% to 0.8% of the catchment areas discharging to them.

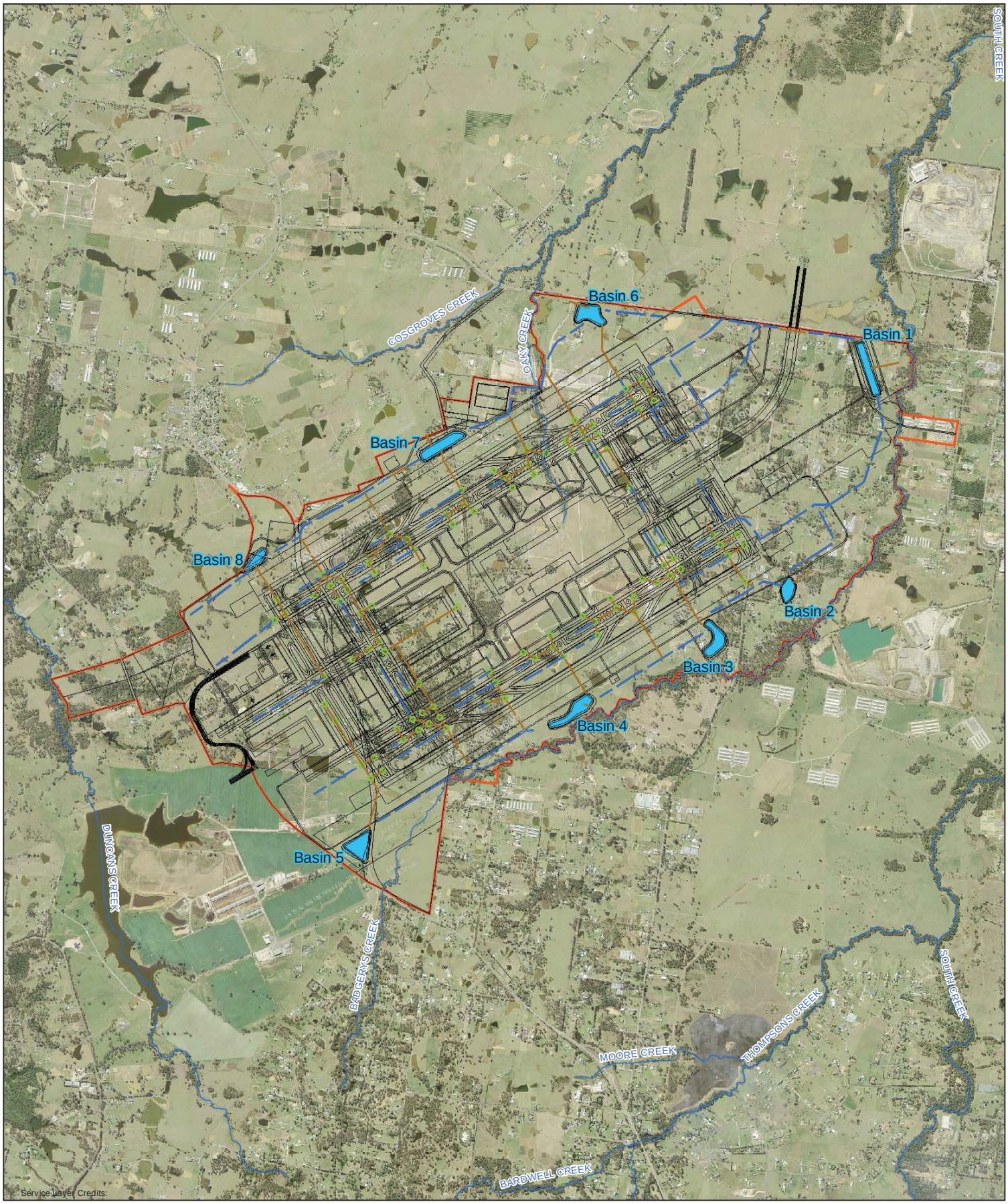
It is understood that the bio-retention sizes adopted in Table 2-11 in the Draft Airport Plan have been provided with the aim of satisfying WSUD Guidelines, rather than NORBE or ANZECC Guidelines. Accordingly, it is expected that supplementary design and management measures would be required during detailed design to further improve the water quality prior to downstream discharge (see Section 6).

Table 2-11 shows that all the bio-retention basins are proposed for construction in Stage 1 of the project, with the exception of Basin 5, which is only built in the longer term development phase. The locations of the proposed basins are shown in Figure 2-2.

Table 2-11 Bio-retention Basin Sizes Adopted

Parameter	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Basin 6	Basin 7	Basin 8
Surface Area (Ha)	1.8	0.6	1.2	1.2	1.4	1.6	1.8	0.9
Extended Detention Depth (m)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Surface Area as % of Catchment Area	0.5	0.6	0.7	0.4	0.8	0.6	0.8	0.5
Extended Detention Volume (m^3)	3600	1200	2400	2400	2800	3200	3600	1800
Filter Media Volume (m^3)	7200	2400	4800	4800	5600	6400	7200	3600
Proposed Construction Stage	1	1	1	1	longer term	1	1	1

Notes: 1) Filter area = surface area; 2) % catchment area = bio-retention surface area as percentage of catchment area



LEGEND

- Airport site
- Watercourses
- Longer term footprint
- Channel
- Culvert
- Pipe
- Pit
- Detention ponds

Paper Size A3

0 250 500 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Job Number	21-24265
Revision	A
Date	14 Aug 2015

Locations of Bio-Retention Basins (Stage 1 and longer term)

Figure 2-2

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Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: afoddy

3. Existing conditions

3.1 Catchment description

The airport site is situated in the Hawkesbury-Nepean basin. The Hawkesbury-Nepean catchment is one of the largest coastal basins in NSW with an area of 21,400 square kilometres. The airport site is located approximately 12.7 km east of Warragamba Dam in a part of the catchment termed the lower Hawkesbury-Nepean.

The airport site drains partially to the Nepean River and partially to the Hawkesbury River via South Creek and a system of tributaries. South Creek drains a catchment of approximately 414 square kilometres and flows in a northerly direction. It has its headwaters near Narellan and flows for a length of around 70 kilometres to its discharge point into the Hawkesbury River near Windsor.

The catchment is shale-based and is characterised by meandering streams. It is also highly disturbed due to increasing urbanisation and associated land clearing.

Land topography within the airport site is characterised by rolling hills dissected by a number of drainage lines. The ridge system trends north-west to south-east in the vicinity of The Northern Road and reaches elevations of just over 120 m AHD. There are some other isolated ridge lines in and around the Luddenham Dyke and The Northern Road at elevations of slightly more than 100 m AHD. The terrain generally slopes away from these ridgelines to the south and east into Oaky, Cosgroves and Badgerys Creeks as part the South Creek catchment and to the north-west into Duncans Creeks as part of the Nepean River Catchment. The lowest points of the site are where Badgerys Creek exits the north eastern extent of the site, at about 44 m AHD.

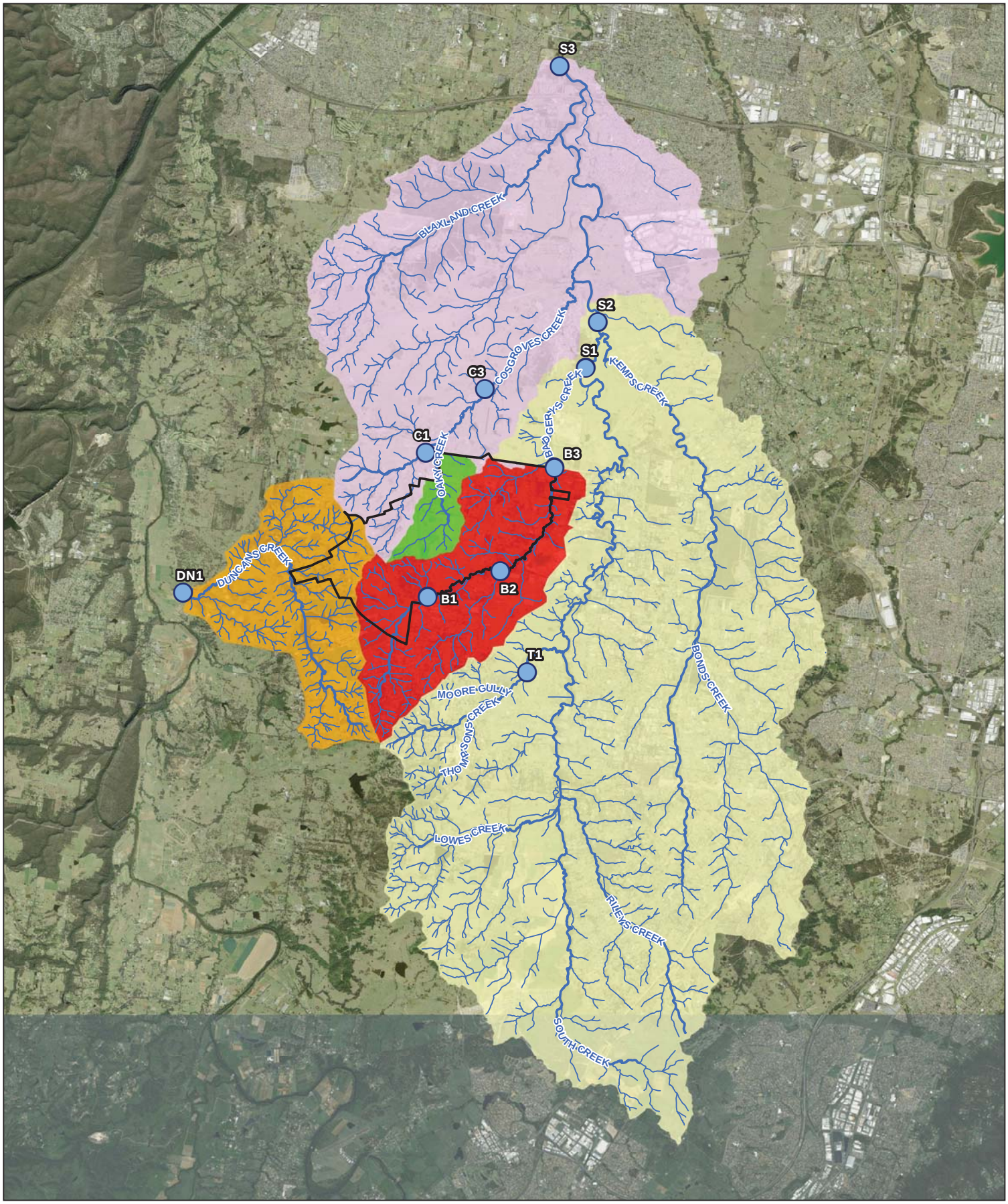
3.2 Major waterways

The major waterways within the airport site are Badgerys Creek, Cosgroves Creek, Oaky Creek and Duncans Creek. Oaky Creek is a tributary of Cosgroves Creek, while Badgerys Creek and Cosgroves Creek are tributaries of South Creek. South Creek is a tributary of the Hawkesbury River, while Duncans Creek is a tributary of the Nepean River. The catchments of Cosgroves and Oaky Creeks, Badgerys Creek, and Duncans Creek are shown in Figure 3-1. Sub-catchment areas located within and outside the airport site are presented in Table 3-1. Based on Table 3-1, the airport site has a total catchment area of about 1775 hectares.

Table 3-1 Waterway Catchment Areas

Waterway	Airport Catchment Area (Ha)	External Catchment Area (Ha)	Total Catchment Area (Ha)
Badgerys Creek (B3)	1056.1	1299.5	2355.7
Cosgroves Creek (C1)	514.7	406.9	921.6
Duncans Creek (DN1)	204.0	1851.9	2056.0
Badgerys Creek-Elizabeth Drive to South Creek confluence (S1)	0	16524.4	16524.4
South Creek confluence with Kemps Creek (S2)	0	6889.3	6889.3
Total	**1775**	**26972**	**28747**

Note: Distances between locations are as follows:
C1-C3 = 2.9 km; C1–S3 = 17 km; B3-S1 = 4 km; B3–S2 = 5.7 km; B3–S3 = 16.3 km



LEGEND

- Airport site
- Water sampling site (Draft EIS)
- Major waterways
- Minor waterways

Paper Size A3

0 800 1,600 3,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Job Number	21-24265
Revision	A
Date	08 Oct 2015

Catchments in vicinity of the airport site

Figure 3-1

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Data source: DCDB AND DTDB, Aerial Photography - NSW LPI, ESRI Imagery 2015. Created by:jrichardson

3.2.1 Badgerys Creek

Badgerys Creek has its headwaters in the vicinity of Findley Road, Bringelly approximately two kilometres upstream of the airport site. It flows in a north to north-east direction. It passes through the airport site at its southern extent and continues for a distance of approximately 1.2 kilometres before its course returns to the airport site boundary. The creek then forms the south-eastern boundary of the airport site as far as Elizabeth Drive. Downstream of the airport site, Badgerys Creek continues for a further four kilometres until its confluence with South Creek.

Between the airport site and the confluence with South Creek, Badgerys Creek passes a landfill site operated by SUEZ Environment (previously operating as SITA).

Land use within the Badgerys Creek catchment consists of agricultural, landfill, as well as residential uses. Ecologically sensitive riparian vegetation also exists within the catchment.

3.2.2 Oaky and Cosgroves Creeks

Oaky Creek has its headwaters located at the airport site. The creek flows in a north-westerly direction for around two kilometres before it reaches the airport site boundary. From this point, it meanders away from the airport site boundary, through the Blue Sky Mining site for several hundred metres, before re-joining the site boundary and continuing for 400 metres along its north-western boundary as far as the north-west corner of the site at Elizabeth Drive. Downstream of Elizabeth Drive, Oaky Creek continues for a further half a kilometre before discharging into Cosgroves Creek.

Cosgroves Creek then continues for another seven kilometres before joining South Creek. In the reach between Oaky Creek and South Creek, Cosgroves Creek passes through rural lots, the Twin Creeks Golf and Country Club site and beneath an above-ground Sydney Water Corporation water mains pipeline.

Oaky Creek has a catchment area of 382 hectares (3.82 square kilometres). The total catchment area of Cosgroves Creek at the confluence with South Creek is approximately 2163 hectares (21.63 square kilometres).

The catchments are largely rural and without residential development downstream of the site, with the exception of the Twin Creeks residential estate downstream of the site towards Cosgroves Creek's confluence with South Creek.

3.2.3 Duncans Creek

Duncans Creek has its headwaters in Bringelly and flows initially in a north-westerly direction. A number of unnamed tributaries of Duncans Creek are located on the airport site. A large water storage dam is located on the creek at the Leppington Pastoral Company site. Downstream of the dam, the creek continues, passing close to the southern tip of the airport site before turning sharply towards the south-west and later meandering north again before discharging into the Nepean River around nine kilometres downstream of the southern site extent. The Duncans Creek catchment downstream of the site is rural and zoned for primary production (plant or animal cultivation) according to the Liverpool City Council Local Environmental Plan.

The catchment area of Duncans Creek located within the airport site is 188.94 hectares (1.88 square kilometres).

3.3 Rainfall and evaporation

A rainfall gauge (Station No. 967108) operated by the Bureau of Meteorology (BOM) is located on the airport site. The data from this station have been analysed by the BOM (BOM 2015a) and the analysis is summarised in Table 3-2.

Monthly statistics, taken from Table 4-1 of the *Western Sydney Airport Usability Report, Meteorological Impacts* (BOM 2015b) are summarised in Figure 3-2. The BOM studies indicate that heavy rainfall events of probability 1 Exceedance Year (EY) and rarer are more likely to occur between the months of November and March.

It is noted that the median monthly rainfall at Badgerys Creek is significantly less than that at the existing Sydney Airport at Mascot (Figure 3-3).

Table 3-2 Rainfall Gauge at Badgerys Creek

Gauge name	Badgerys Creek AWS
Gauge Number	067108
Location	33.90^0 S, 150.73^0 E
Period of Data	December 1998 – Present
Data Set Completeness	93.9%
Data resolution	1 minute
Mean Annual Rainfall (mm)	676.4

Table 4-1 Rainfall climatology for Badgerys Creek

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Rainfall (mm)	77.4	108.0	77.3	43.2	40.1	52.1	23.0	35.9	33.9	52.7	74.5	63.6
Highest Monthly Rainfall (mm)	192.2	342.4	198.0	129.4	155.6	220.0	71.6	231.0	82.2	182.2	173.2	131.2
Lowest Monthly Rainfall (mm)	13.6	13.4	21.4	1.8	1.8	2.0	2.8	1.0	6.4	0.4	8.4	14.2
Highest Daily Rainfall (mm)	138.0	106.8	67.8	82.4	54.0	63.8	28.4	70.0	50.8	63.0	63.0	65.0

Figure 3-2 Monthly rainfall statistics at Badgerys Creek AWS

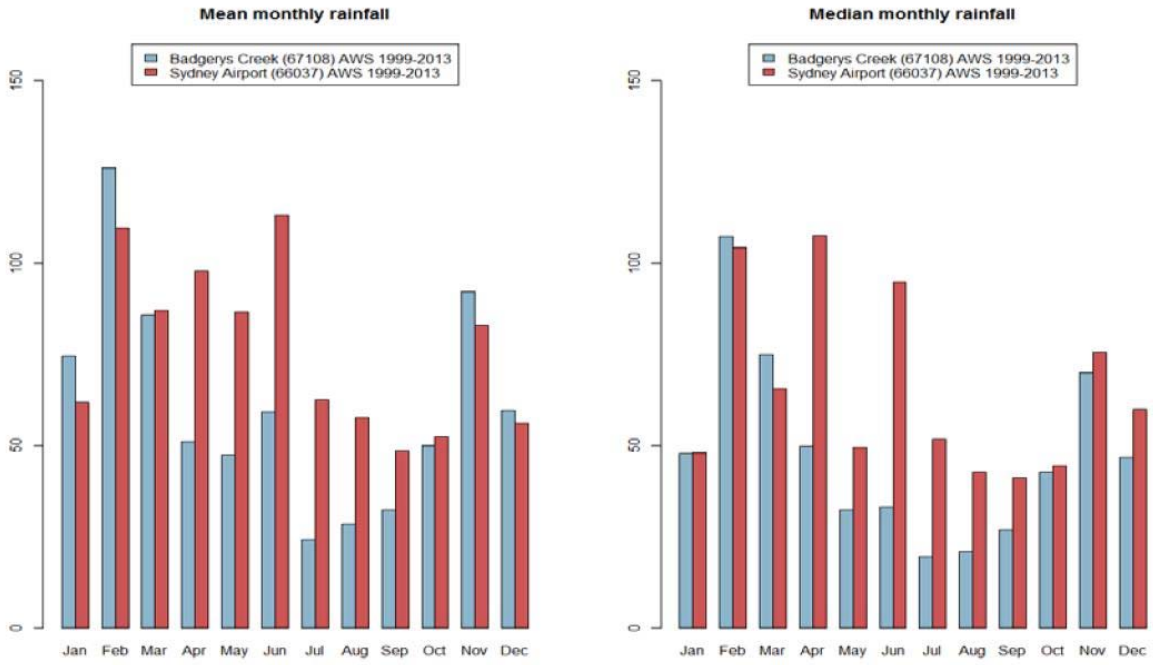


Figure 3-3 Comparison of rainfall at Badgerys Creek and Sydney (Kingsford Smith) Airport

Evaporation data is not collected at the Badgerys Creek automatic weather station. Data from the Parramatta gauge were instead adopted for the purposes of this study as Parramatta is the nearest representative location. The monthly evaporation data for Parramatta are shown in Figure 3-4.

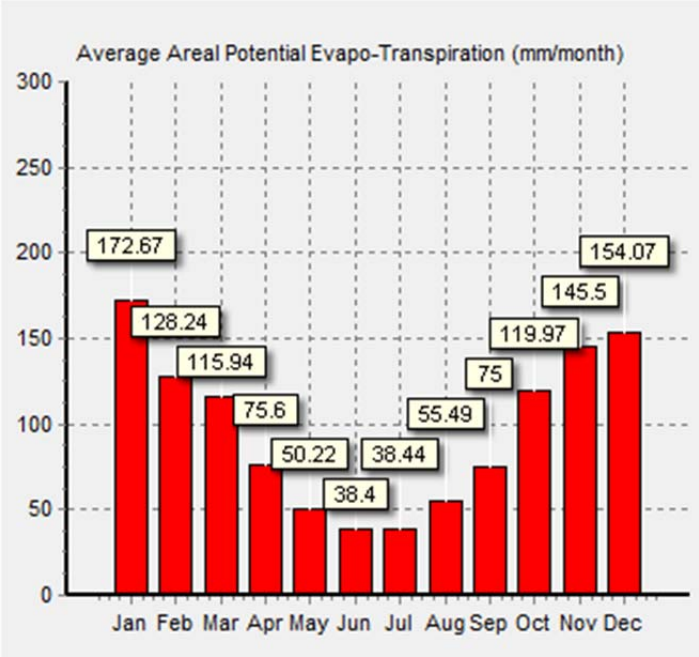


Figure 3-4 Evaporation data from Parramatta gauge

3.4 Existing land uses

Existing land use within the airport site is predominantly rural, with a mixture of pasture, agricultural, and rural residential areas. A large number of small farm dams are present across the airport site. Paved areas on the site are associated mainly with buildings and arterial and local roads.

Land use types within the airport site and downstream catchments are summarised in Table 3-3 and Figure 3-5. Overall, it can be seen that currently the airport site is approximately 68% pastures, 17% modified pastures, 11% rural residential, 4% forest, and the remaining 1% horticultural. Outside the airport site, within the South Creek catchment, residential land use is much higher with corresponding reductions in pasture and agricultural areas.

Land use within the catchments of Badgerys Creek, Cosgroves and Oaky Creek, and Duncans Creek are also summarised in Table 3-4. This table shows that rural residential areas tend to be concentrated within the Badgerys Creek catchment, while pastures and forests are fairly evenly distributed among the three major waterway catchments. A detailed breakdown of the waterway sub-catchment areas and land use types is presented in Table 3-5.

Table 3-3 Existing Land use within the airport site and downstream catchments

Catchment	Existing Land Use Types (Ha)					
	Rural Residential	Forest	Horticulture	Naturalised Pastures	Modified Pastures	Total
Airport Site	190 (11%)	64 (4%)	18 (1%)	1203 (68%)	299 (17%)	*1775*
External Site to S1	6539 (40%)	485 (3%)	1262 (8%)	6431 (39%)	1807 (11%)	*16524*
S1 to S2	3600 (52%)	51 (1%)	103 (1%)	2737 (40%)	398 (6%)	*6889*

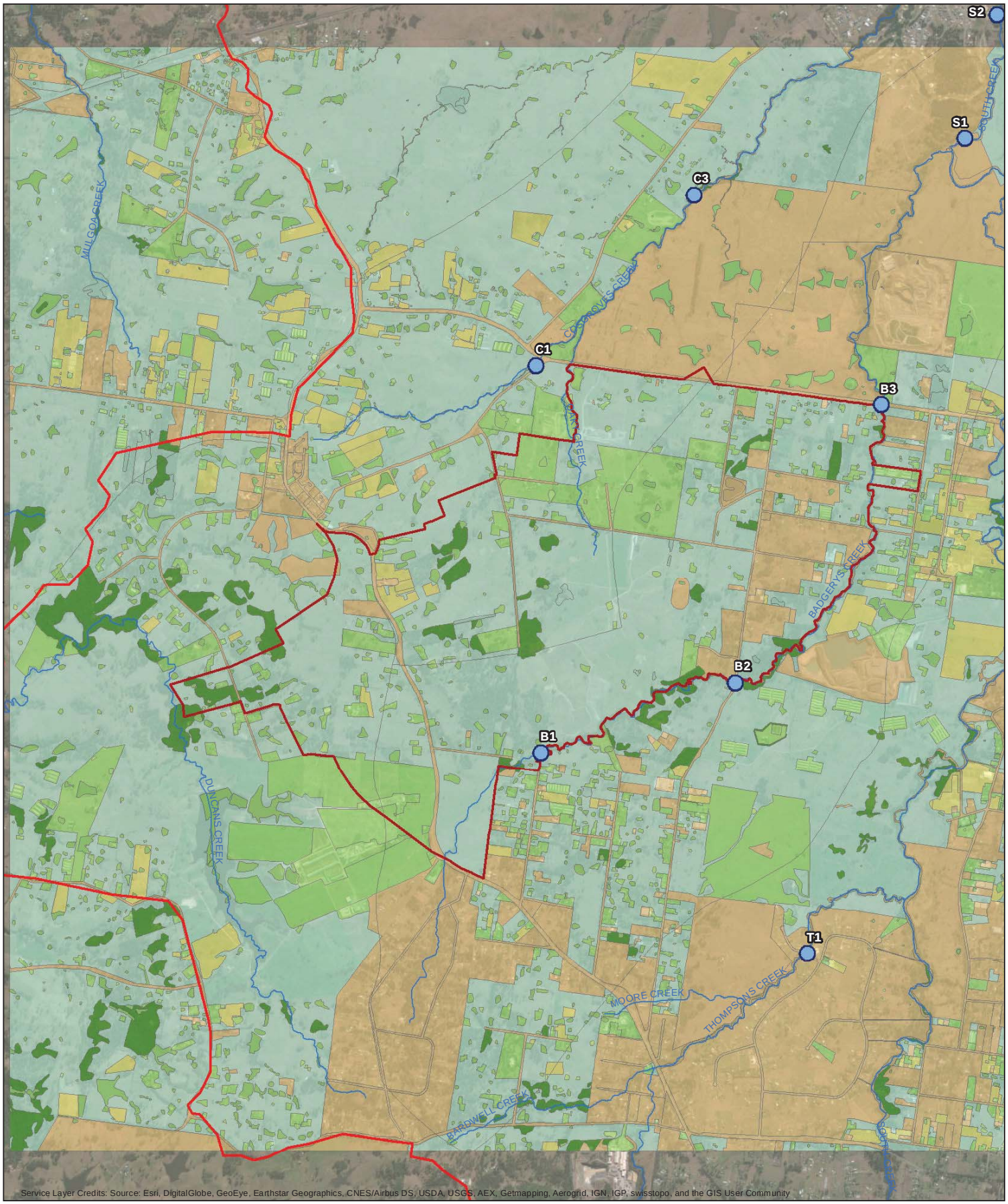
Note: Refer to Figure 3-1 for locations S1 and S2

External Site: South Creek catchment at location S1 excluding airport site

S1 to S2: South Creek catchment area between locations S1 and S2

Table 3-4 Land use within major waterway catchments

Waterway Catchment	Rural Residential (%)	Forest (%)	Horticultural (%)	Grazing (Naturalised Pastures) (%)	Grazing (Modified Pastures) (%)
Badgerys Creek					
- Airport Site	16	2	0	66	16
- External Site	33	2	3	44	19
- Catchment at B3	25	2	2	53	18
Cosgroves / Oaky Creek					
- Airport Site	3	5	3	69	20
- External Site	9	0	9	67	15
- Catchment at C1	6	3	5	68	18
Duncans Creek					
- Airport Site	4	7	0	75	14
- External Site	9	5	2	66	18
- Catchment at DN1	8	5	2	67	18



LEGEND

- The airport site
- Water sampling site (Draft EIS)
- Watercourses
- Rural Residential
- Intensive Agricultural
- Forest
- Horticulture
- Naturalised pastures

Paper Size A3

0 300 600 1,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Job Number	21-24265
Revision	A
Date	14 Aug 2015

Map of Existing Land Use Plan

Figure 3-5

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Data source: Created by: afoddy

Table 3-5 Detailed breakdown of land use within airport site waterways

Waterway	ID	Existing Land Use Types					
		Rural Residential	Forest	Horti	Naturalised Pastures	Intensive Agricultural Activities	Total
Duncans	0		2.0		6.2	0.8	9.0
Duncans	1	0.8	10.2		33.2	4.6	48.9
Duncans	2		0.1				0.1
Duncans	3		1.8		4.0	0.4	6.3
Duncans	4			0.6	49.3	9.2	59.1
Duncans	5	0.5			8.5	0.7	9.6
Duncans	6	6.6			26.4	5.9	38.9
Badgerys	7	11.9	1.0	1.6	154.7	65.2	234.3
Duncans	9					0.4	0.4
Duncans	10				1.4	1.5	3.0
Duncans	11				0.8	0.3	1.2
Duncans	12				10.5	1.6	12.0
Duncans	13	0.0			0.1		0.1
Duncans	14				13.1	2.5	15.6
Badgerys	16	54.6	0.6	0.9	15.6	1.0	72.7
Cosgroves	20	5.1	12.7	14.4	90.7	12.2	135.0
Cosgroves	21	1.3			4.0	10.9	16.2
Oaky Cosgroves	22	7.0	14.2		189.2	66.6	277.0
Badgerys	23	0.2	3.0		108.1	8.2	119.5
Badgerys	24				70.2	0.8	71.0
Badgerys	25	4.4	4.1		7.5	2.4	18.4
Badgerys	26	33.9	4.4	0.0	84.8	4.9	128.1
Badgerys	27	16.7		0.3	29.1	1.5	47.6
Badgerys	28	9.6		0.5	14.9	3.2	28.1
Badgerys	29	0.4	2.1		9.2	11.8	13.9
Badgerys	30	1.1	1.4	0.2	14.5	1.7	18.9
Cosgroves	31	2.0			10.5	1.1	13.6
Cosgroves	32	0.4			6.2	3.2	9.8
Badgerys	33	33.3	6.3		184.2	70.4	294.2
Cosgroves	34				2.3	0.9	3.2
Oaky Cosgroves	35	0.1			42.2	5.2	47.6
Oaky Cosgroves	36				12.0	0.4	12.4
Badgerys	37	83.5	19.1	8.4	303.4	77.5	491.8
Duncans	38	162.9	89.5	37.2	1230.2	332.2	1851.9
Badgerys	39	270.6	2.2	6.1	82.6	76.8	438.2

Waterway	ID	Existing Land Use Types					
		Rural Residential	Forest	Horti	Naturalised Pastures	Intensive Agricultural Activities	Total
Badgerys	40	74.2	2.5	24.2	179.4	89.2	379.2
Cosgroves	41	36.3		36.3	273.4	60.9	406.9
External site to S1	42	6538.9	485.0	1262.5	6430.9	1807.2	
S1 - S2	43	3600.1	51.1	103.1	2737.3	397.8	6889.3
Grand Total		***10956***	***713***	***1496***	***12440***	***3141***	***28747***

Note: Refer to Figure 3-1 for locations S1 and S2

Horti: Horticultural

External Site: Badgerys Creek (confluence with South Creek) at location S1 excluding airport site

S1 to S2: South Creek catchment area between locations S1 and S2

3.5 Recent water quality sampling

A limited scope of water quality sampling was undertaken by GHD during the aquatic ecology surveys on the 16 March 2015. Sampling results for some key parameters at sampling locations immediately surrounding the airport site are presented in Table 3-6 with the full results presented in Appendix A. The locations of the sampling points are shown in Figure 3-6.

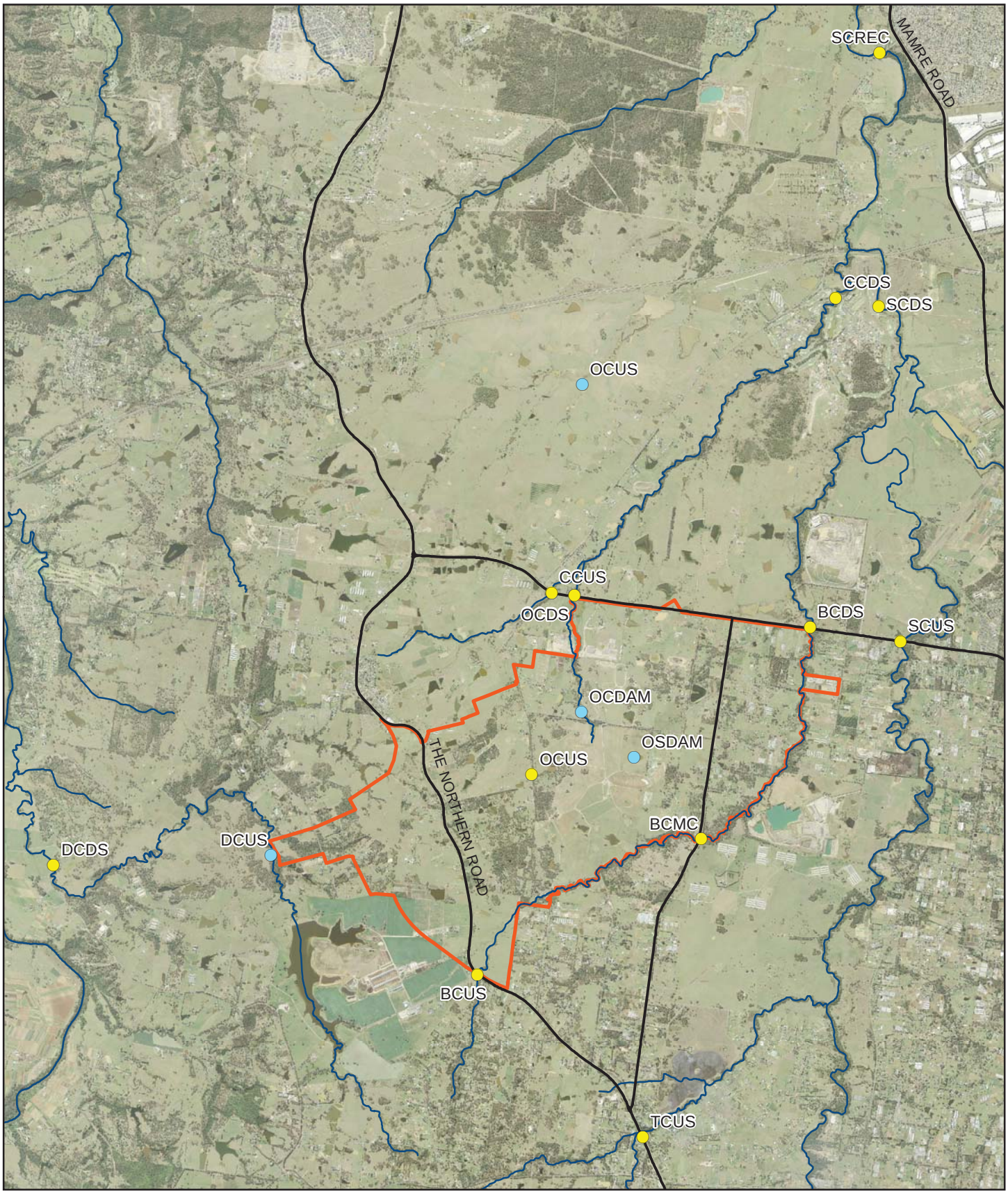
Table 3-6 indicates that the nutrient loads are generally high and elevated well above ANZECC water quality trigger values. Turbidity and total suspended solids were found to be generally within acceptable levels, while dissolved oxygen levels were found to be relatively low. These results are found to be fairly consistent with those obtained previously by PPK in 1997 and SMEC in 2014. The GHD data also indicate that conductivity levels were high and above those for typical lowland rivers.

Additional field visits to the airport site and surrounding areas were also conducted on the 6 May 2015 and 7 May 2015 by members of the surface water team. These field visits focused on the following:

- collection of details regarding key hydraulic structures (road bridge and culvert crossings);
- review of existing land use characteristics; and
- visual inspection of waterway condition at several locations.

There were limitations on accessibility to properties. This meant that full walkovers of all the waterway reaches on the site and downstream areas could not be undertaken.

The inspections confirmed that the majority of the airport site is currently used as farmland for various agricultural or grazing purposes, as indicated in Section 3.4. A number of the areas contained livestock and effluent irrigation also appeared to have been applied on some of the pastures. On this basis, it was considered not surprising that the water quality data sampled to date indicate typically high nutrient loads and low dissolved oxygen levels. Overall, the surface water quality data findings were considered to be consistent with the existing land use in the catchment.



LEGEND

- Airport site
- Monitoring Site
- Additional Monitoring Site
- Waterway
- Road

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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: Custom

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GHD

Recent surface water quality sampling locations

Job Number 21-2426508
Revision C
Date 14 Aug 2015

Figure 3-6

Level 7, 16 Marcus CLarke Street ACT 2601 Australia T 61 2 6113 3200 F 61 2 6113 3299 E cbrmail@ghd.com W www.ghd.com

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:afoddy

Table 3-6 Recent Surface Water Quality Data

Location	DO % sat	Conductivity uS/cm	Turbidity NTU	TSS mg/L	TN mg/L	TP mg/L
ANZECC Guidelines	85-110%	125-2200	6-50	<40	0.5	0.05
Badgerys BCUS	21.3	2710	12	23	6.2	0.42
Badgerys BCMC	36	3100	7.71	5	18.5	0.31
Badgerys BCDS	8.6	3050	13	5	2.3	1
Cosgroves OCDS (CCUS)	55.4 (73.6)	4320 (5020)	38.1 (4.25)	19 (5)	1.2 (0.8)	0.05 (0.03)
Duncans DCDS	52.5	847	89.2	14	0.9	0.06

DO: Dissolved Oxygen TN: Total nitrogen TP: Total phosphorus

Source: GHD March 2015

3.6 MUSIC modelling results under existing conditions

The results obtained from the MUSIC modelling for the existing environment are presented in Table 3-7 and Table 3-8 for key locations at and around the airport site. In Table 3-7, the results are presented for total phosphorus, total nitrogen, suspended solids and gross pollutants, in terms of annual loads, while the results in Table 3-8 are presented as concentrations.

The key locations selected include those where bio-retention basins have been proposed within the airport site (basin outlets 1 to 8) as part of the airport concept design (Table 2-5), as well as catchment locations downstream of the site. These locations are shown in Figure 1-1, Figure 3-1 and Figure 3-6.

Based on the results in Table 3.10, it is estimated that on average, the airport site (Basin Outlets 1 to 8) would contribute approximately 231,140 kg of suspended solids, 367 kg of phosphorus, and 3,303 kg of nitrogen each year to the downstream waterways. These loads are for the existing environment without the proposed bio-retention basins in place.

At the Elizabeth Drive crossing of Badgerys Creek (B3/BCDS), it is estimated that the average annual loads would be 316,000 kg for suspended solids, 557 kg for phosphorus and 5,230 kg for nitrogen. It is noted that these loads include those derived from catchment areas external to the airport site catchment.

Similarly, for Cosgroves Creek (C1), the average annual loads are estimated to be 171,100 kg for suspended solids, 325 kg for phosphorus and 3,050 kg for nitrogen.

At the downstream locations of Duncan Creek (DN1), South Creek confluence with Kemps Creek (S12), and South Creek confluence with Blaxland Creek, the estimated pollutant loads would be much higher. These downstream loads will be used to assess the potential impacts of the airport development proposal in the later sections of this report.

In Table 3.11, the estimated pollutant concentrations are also compared against ANZECC guideline default trigger values for lowland rivers. It can be seen from these results that the phosphorus and nitrogen concentrations modelled at all the locations do not achieve ANZECC objectives for water quality.

For total phosphorus, the mean concentrations are estimated to range from 0.06 to 0.38 mg/L, compared to an ANZECC guideline of 0.05 mg/L. Similarly, the mean concentrations for total nitrogen are estimated to range from 0.7 to 2.91 mg/L, compared to an ANZECC guideline level of 0.5 mg/L.

For total suspended solids, however, the estimated concentrations are estimated to achieve ANZECC water quality objectives at all the locations. The modelled concentrations are found to range from 10.3 to 23 mg/L, which are well below the ANZECC guideline level of 40 mg/L.

The above results are generally consistent with field measurements obtained by SMEC and GHD, as noted in Table 2-4 and Table 3-6. In terms of concentrations, the pollutant levels are found to be similar for both the airport site and downstream environment, with not a high degree of variation.

Table 3-7 Average Annual Pollutant Loads under Existing Conditions

Location	Average Annual Flow (ML/yr)	Average Annual Pollutant Loads (kg/yr)			
		TSS	TP	TN	Gross Pollutants
Basin 1 Outlet	505	59500	103	913	1050
Basin 2 Outlet	56.4	7280	8.68	82.9	178
Basin 3 Outlet	149	17900	23.5	218	361
Basin 4 outlet	77.9	4660	34.4	287	0
Basin 5 Outlet	260	34500	58.7	536	126
Basin 6 Outlet	372	58600	78.5	677	75.9
Basin 7 Outlet	171	30800	36.9	378	68.7
Basin 8 Outlet	120	17900	22.9	211	75.1
Total Basins 1 to 8 Outlets	**1711.3**	**231140**	**366.6**	**3302.9**	**1934.7**
Badgerys Creek B1 – BCUS	940	94800	182	1720	3010
Badgerys Creek B2 – BCMC	1600	171000	325	3050	3950
Badgerys Creek B3 – BCDS	2740	316000	557	5230	6330
Cosgroves Creek C1	999	171000	220	2060	532
Cosgroves Creek C3	1700	213000	367	3490	2450
Duncans Creek DN1	2300	308000	467	4240	1820
Kemps Creek Confluence S2	22500	2820000	4480	44000	76000
Blaxland Creek Confluence S3	31000	3640000	5820	57200	114000

Note: Refer toFigure 1-1, Figure 2-2 and Figure 3-1 for locations

S2: South Creek confluence with Kemps Creek

Blaxland Creek confluence S3: South Creek downstream of confluence with Blaxland Creek

Table 3-8 Average Pollutant Concentrations under Existing Conditions

Location	Average Pollutant Concentrations (mg/L)		
	TSS	TP	TN
Basin 1 Outlet	22.10	0.14	1.54
Basin 2 Outlet	22.10	0.09	1.25
Basin 3 Outlet	21.90	0.09	1.26
Basin 4 Outlet	20.70	0.38	2.91
Basin 5 Outlet	23.00	0.17	1.72
Basin 6 Outlet	22.50	0.15	1.60
Basin 7 Outlet	22.30	0.14	1.46
Basin 8 Outlet	23.20	0.13	1.51
Badgerys Creek B1 – BCUS	21.50	0.14	1.47
Badgerys Creek B2 – BCMC	21.80	0.15	1.54
Badgerys Creek B3 – BCDS	21.90	0.14	1.53
Cosgroves Creek C1	22.70	0.14	1.54
Cosgroves Creek C3	22.50	0.14	1.50
DN1	10.30	0.06	0.70
Kemps Creek Confluence S2	20.90	0.13	1.34
Blaxland Creek Confluence	20.80	0.12	1.31
ANZECC Guidelines	**< 40**	**0.05**	**0.5**

Note: Refer to Figure 1-1, Figure 2-2, and Figure 3-1 for locations

S2: South Creek confluence with Kemps Creek

Blaxland Creek confluence S3: South Creek downstream of confluence with Blaxland Creek

4. Assessment of operational impacts of proposal

4.1 Changes in land use types and areas

The proposed catchment and land use plans for the Stage 1 and longer term development are shown in the main document for the EIS. The waterway catchment areas within the airport site corresponding with the initial and longer airport development are shown in Table 4-1, for Badgerys Creek, Cosgroves Creek and Duncans Creek. Oaky Creek is included as part of Cosgroves Creek. It is estimated that, with the proposed development, the catchment of Badgerys Creek will increase by about 46 hectares, while those for Cosgroves Creek and Duncans Creek will reduce by about 31 hectares and 15 hectares, respectively.

Table 4-1 Comparison of Waterway Catchment Areas for Existing and Development Conditions

Waterway	Airport Site Catchment Areas (Ha)			Net Change (Ha)
	Existing Conditions	Stage 1	Longer Term	
Badgerys Creek	1056.12	1102.05	1102.05	+45.93
Cosgroves Creek	514.71	483.79	483.79	-30.92
Duncans Creek	204.01	189.00	189.00	-15.01
Total	**1775**	**1775**	**1775**	**0**

For the purposes of this study, the land use types for the proposed Stage 1 Development and longer term development have been classified into three main types, namely Grassed, Paved and Roofed. Essentially, they correspond to open space areas, paved areas and the roof surfaces of buildings. The results are shown in Table 4-2. These results show that the grassed areas will progressively decrease in each of the catchments, while the paved and roofed areas will increase, as development occurs.

Table 4-2 Land Use Types for Stage 1 and Longer Term Development

Waterway	Grassed (%)	Paved (%)	Roofed (%)	TOTAL (%)
Stage 1 Development				
Badgerys Creek	90.3	3.7	5.9	100
Cosgroves Creek	59.1	31.7	9.2	100
Duncans Creek	77.9	10.7	11.5	100
Longer Term Development				
Badgerys Creek	41.9	41.4	13.6	100
Cosgroves Creek	36.5	51.8	11.7	100
Duncans Creek	49.9	32.0	18.1	100

4.2 Treatment basins and residual catchment areas

As part of the Draft Airport Plan, a number of bio-retention basins have been proposed for water quality treatment purposes. The proposed locations of these basins are shown in Figure 3-6. The catchment areas and land use types discharging to these basins are shown in Table 4-3 for the Stage 1 development, and Table 4-4 for the longer term development.

Catchment areas discharging directly into these basins as well as residual areas are also included in both the above tables. The residual areas are those areas that cannot physically

discharge into the basins due to the proposed landform. For modelling purposes, the residual areas have been modelled to discharge to the outlet of the bio-retention basin, thus bypassing the treatment zone of the basin itself. This effectively represents what would occur in the field, and captures the total pollutant loads discharging from the airport site.

Overall, it is estimated that 81%, 12%, and 7% of the airport site will be grassed, paved and roofed, respectively, following Stage 1 of the development. This will be modified to 43%, 43% and 14%, respectively, for the longer term development. In other words, the pervious areas (grassed) will reduce from 81% to 43%, while the impervious areas (paved and roofed) will increase from 19% to 57%.

Table 4-3 Basin Catchment Areas for Stage 1 Development

Basin Name	Basin and Residual Catchment Areas (Ha)			
	Grassed	Paved	Roofed	Total
Basin 1	182.1	29.7	39.8	251.7
Basin 1 Residual	129.5	0.3	0.0	129.8
Basin 2	36.4	1.0	5.7	43.0
Basin 2 Residual	57.9	1.1	0.0	59.0
Basin 3	94.6	6.8	18.9	120.3
Basin 3 Residual	53.2	0.0	0.0	53.2
Basin 4	136.1	1.0	0.8	137.9
Basin 4 Residual	132.3	0.0	0.0	132.3
Basin 5 Residual	173.6	1.3	0.0	174.9
Basin 6	114.2	105.	28.8	248.1
Basin 6 Residual	2.4	0.00	13.2	15.6
Basin 7	152.2	40.9	0.6	193.7
Basin 7 Residual	17.0	7.3	2.0	26.4
Basin 8	107.3	18.6	0.7	126.5
Basin 8 Residual	39.9	1.6	21.0	62.5
Total	**1428.7 (81%)**	**214.6 (12%)**	**131.5 (7%)**	**1774.8 (100%)**

Notes: 1) Residual areas cannot physically discharge into the basins due to landform constraints but are assumed to discharge downstream of the basins for modelling purposes; 2) Basin 5 is not constructed in Stage 1 but in longer term.

Table 4-4 Basin Catchment Areas for Longer Term Development

Basin Name	Basin and Residual Catchment Areas (Ha)			
	Grassed	Paved	Roofed	Total
Basin 1	105.8	105.4	89.9	301.0
Basin 1 Residual	79.3	3.0	0.0	82.3
Basin 2	30.8	35.3	1.1	67.2
Basin 2 Residual	39.1	0.5	0.0	39.6
Basin 3	51.0	87.3	10.9	149.2
Basin 3 Residual	17.4	0.3	0.0	17.7
Basin 4	72.9	165.5	15.7	254.1
Basin 4 Residual	16.1	0.0	0.0	16.1
Basin 5	49.7	58.6	5.6	113.9
Basin 5 Residual	33.1	0.9	27.1	61.0
Basin 6	83.2	131.5	33.4	248.1
Basin 6 Residual	2.4	0.0	13.2	15.6

Basin Name	Basin and Residual Catchment Areas (Ha)			
	Grassed	Paved	Roofed	Total
Basin 7	74.0	111.8	7.9	193.7
Basin 7 Residual	17.0	7.3	2.0	26.3
Basin 8	54.4	58.8	13.3	126.5
Basin 8 Residual	39.9	1.6	21.0	62.5
Total	**766.1 (43%)**	**767.6 (43%)**	**241.1 (14%)**	**1774.8 (100%)**

Note: Residual areas cannot physically discharge into the basins due to landform constraints but are assumed to discharge downstream of those basins for modelling purposes

4.3 Stage 1 development

4.3.1 Average annual pollutant loads compared to existing conditions (NORBE)

The average annual pollutant loads resulting from Stage 1 of the proposed development are presented in Table 4-5 for suspended solids, total phosphorus, total nitrogen and gross pollutants. The percentage change in these pollutant loads compared to existing conditions (pre-development) is also shown in brackets for comparison. Both local and regional impacts are summarised in this table. The local impacts relate to those immediately downstream of the airport site, while the regional impacts relate to those up to 16 km downstream of the site (refer to Table 3-1 footnote). In Table 4-5, the percentage change in loads for gross pollutants has not been calculated due to the fact that in practice, gross pollutants are readily controlled through the use of gross pollutant traps and other standard stormwater devices.

(a) Local Impacts

The results in Table 4-5 indicate that the pollutant loads generated from the site would increase significantly as a result of the change in land use from a rural agricultural setting to an urban airport, particularly for total phosphorus and total nitrogen, and even with all the proposed bio-retention basins in place, except for Basin 5. As noted earlier, Basin 5 is not expected to be developed in Stage 1 but in the longer term development.

Based on these results, the total phosphorus loads at the basin outlets are estimated to increase by between +108% to +624% compared to existing loads. Similarly, the total nitrogen loads are estimated to increase by between +42% to +308% relative to existing conditions. For total suspended solids, four of the outlet locations are estimated to have load increases of between +8% to +497%, while the remaining outlets are estimated to have reductions of between -28% to -40%. In other words, the proposed bio-retention basins would generally be unable to attenuate the pollutant loads to pre-development levels. The exception is suspended solids, where a reduction in loads is achieved at some of the locations compared.

One reason for the increase in total phosphorus and total nitrogen loads, other than land use change, is that due to the change in catchment areas associated with the proposed topography, it has not been possible to direct much of the flows to the proposed basin locations. While the flow paths are much improved in the longer term development, this is not the case for Stage 1.

It is concluded that the bio-retention basins proposed for Stage 1 for water quality management are not adequate in satisfying the NORBE or pre-development load targets. This is not surprising, considering that the NORBE targets are particularly difficult to comply with for rural sites, as noted earlier. It is considered that the NORBE targets may not be achievable without sterilising large sections of the airport site. Nevertheless, it is expected that there will be further improvements in water quality relative to NORBE targets with the implementation of additional design and management measures.

(b) Regional Impacts

In Table 4-5, the results indicate that despite the significant increase in pollutant loads generated and discharged at the bio-retention basins, the downstream regional impacts would be much smaller by comparison. This is evident at the downstream locations of Badgerys Creek at Elizabeth Drive (B3), Badgerys Creek at South Creek confluence (S1), South Creek at Kemps Creek confluence (S2), South Creek downstream of Blaxland Creek (S3), Cosgroves Creek at Elizabeth Drive (C1), Cosgroves Creek downstream of Oaky Creek confluence (C3), and Duncans Creek at downstream location DN1.

Badgerys Creek, on leaving the airport site at Elizabeth Drive (B3) is estimated to have increases of +38% (annual flows), -5% (reduction in suspended solids), +71% (total phosphorus), and +27% (total nitrogen) compared to pollutant loads under existing conditions. The impacts are then estimated to reduce to +4% (annual flows), -2% (suspended solids), +5% (total phosphorus), and +2% (total nitrogen) by the time the flows arrive at the South Creek - Kemps Creek confluence (S2). At South Creek downstream of Blaxland Creek (S3), the impacts would be further reduced to +3% (annual flows), -0.4% (suspended solids), +4% (total phosphorus), and +1% (total nitrogen).

It is noted, however, that the reduction in impacts further downstream of the airport is due to the larger loads derived from the other catchments outside of the airport site, rather than any additional treatment that has occurred in the waterways downstream of the site. This is not surprising due to the relatively large catchment areas associated with the downstream locations as well as the urbanised nature of those areas.

At the Elizabeth Drive crossing of Cosgroves Creek (C1), the increases of +104% (annual flows), -31% (reduction in suspended solids), +67% (total phosphorus), and +39% (total nitrogen) are observed to dissipate to +59% (annual flows), -22% (reduction in suspended solids), +36% (total phosphorus), and +20% (total nitrogen) by the time the flows arrive a short distance downstream at C3.

By comparison, at Duncans Creek at DN1, the results indicate that the airport development would result in an increase in annual flows of +11%, a reduction of 5% for suspended solids, a +14% increase for total phosphorus, and a +9% increase for total nitrogen.

Overall, the above results indicate that the NORBE targets are not fully achieved at the downstream regional locations assessed with the bio-retention basins in place. However, it is expected that these regional impacts would progressively decrease at locations further downstream of the airport due to the increasing loads derived from catchments outside the airport at those downstream locations.

Table 4-5 Stage 1 Average Annual Pollutant Loads

Location	Annual Flow (ML/yr)	Average Annual Loads (kg/yr)			
		TSS	TP	TN	Gross Pollutants
Local Impacts					
Basin 1 Outlet	919 (+82%)	35500 (-40%)	214 (+108%)	1300 (+42%)	3910
Basin 2 Outlet	195 (+246%)	13800 (+90%)	62.8 (+624%)	338 (+308%)	1910
Basin 3 Outlet	385 (+158%)	12100 (-32%)	82.2 (+250%)	493 (+126%)	1590
Basin 4 outlet	437 (+461%)	27800 (+497%)	145 (+322%)	805 (+180%)	3940
Basin 5 Outlet	300 (+15%)	35800 (+4%)	142 (+142%)	756 (+41%)	5390

Location	Annual Flow (ML/yr)	Average Annual Loads (kg/yr)			
		TSS	TP	TN	Gross Pollutants
Basin 6 Outlet	1040 (+180%)	18400 (-69%)	164 (+109%)	1240 (+83%)	2770
Basin 7 Outlet	538 (+215%)	22100 (-28%)	104 (+182%)	593 (+57%)	2160
Basin 8 Outlet	487 (+306%)	19400 (+8%)	107 (+367%)	800 (+279%)	5730
B1 – BCUS	849 (-10%)	77400 (-18%)	246 (+35%)	1720 (0%)	8280
B2 – BCMC	1850 (+16%)	176000 (+3%)	497 (+53%)	3530 (+16%)	13100
B3 – BCDS	3770 (+38%)	301000 (-5%)	953 (+71%)	6630 (+27%)	21300
Regional Impacts					
Cosgroves Creek C1	2040 (+104%)	118000 (-31%)	368 (+67%)	2860 (+39%)	5310
Cosgroves Creek C3	2710 (+59%)	213000 (-22%)	505 (+36%)	4190 (+20%)	7200
Duncans Creek DN1	2560 (+11%)	293000 (-5%)	531 (+14%)	4620 (+9%)	7470
Kemps Creek Confluence - S2	23500 (+4%)	2750000 (-2%)	4720 (+5%)	44700 (+2%)	91000
Blaxland Creek Confluence – S3	32000 (+3%)	3625000 (-0.41%)	6030 (+4%)	57800 (+1%)	129000

Notes: 1) Values in brackets show percentage increase (+) or decrease (-) in loads compared to existing conditions 2) The results at the location of Basin 5 are those without the basin being constructed, as Basin 5 is developed only in the longer term.

4.3.2 WSUD Technical Guidelines for Western Sydney

The potential impacts of the proposed Stage 1 Development, measured against the requirements of the WSUD Guidelines, are presented in Table 4-6. The targets are that 80% of suspended solids, 45% of total phosphorus, and 45% of total nitrogen should be retained on the airport site. In Table 4-6, it is noted that basin outlet flows and loads include areas that discharge directly into the basins as well as residual areas that cannot physically discharge into those basins. In addition, Basin 5 is not expected to be constructed in Stage 1 but in the longer term development.

It is noted that as the above WSUD Guidelines specify only the reduction targets that should be achieved on-site at the basin outlets, they cannot be meaningfully applied within the context of downstream regional impacts where there are no additional bio-retention basins or treatment measures constructed at those locations as part of this project.

In Table 4-6, the eight basin outlets effectively represent the locations where the pollutant loads generated from the proposed airport would discharge into the downstream environment. The results show that, in terms of suspended solids, only Basins 6 and 7 satisfy the 80% reduction target. For total phosphorus, Basins 1, 3, 6, 7 and 8 are close to or satisfy the 45% reduction target. For total nitrogen, Basins 3, 6 and 7 satisfy the 45% reduction target. The remaining basins do not satisfy the retention targets. As noted earlier, this is due to land areas modified for the proposed airport development, or residual areas, that cannot physically discharge into the basins under Stage 1 of the development. However, as the landform for the longer term is modified, a much higher rate of percentage retention would be achieved. This will be discussed in Section 4.4.2.

Other locations listed in Table 4-6 are situated outside the airport site, and therefore predictions for these locations include flows from large untreated catchment areas external to the proposed airport. Consequently, the net percentage retentions achieved at these locations are relatively low by comparison. The exception is Cosgroves Creek at C1. This is due to the high percentage retention achieved at Basins 6 and 7, and because, for modelling purposes, the outflows from Basins 6 and 7 both discharge into C1.

Overall, the results indicate that the WSUD Guidelines percentage retention targets are met for flows discharging from the site into Oaky Creek and Cosgroves Creek. For Badgerys Creek where the percentage retention targets are not met, it is considered that additional land management may be required, particularly in the residual areas associated with Basin 2, Basin 4 and Basin 5. This includes the provision of additional diversion drains, as discussed in Section 6.

Table 4-6 Stage 1 Percentage Pollutant Load Reductions

Location	% Reduction of Pollutant Loads		
	TSS (%)	TP (%)	TN (%)
Western Sydney Guidelines	**80%**	**45%**	**45%**
Basin 1 Outlet (to Badgerys Creek)	77.2	44.8	44.4
Basin 2 Outlet (to Badgerys Creek)	40.1	28.3	33.4
Basin 3 Outlet (to Badgerys Creek)	73.0	48.7	51.4
Basin 4 Outlet (to Badgerys Creek)	47.2	34.6	31.8
Basin 5 Outlet (to Badgerys Creek)	0	0.00	0
Basin 6 Outlet (to Oaky/ Cosgroves Creek)	92.4	66.7	51.5
Basin 7 Outlet (to Cosgroves Creek)	83.1	65.5	58.3
Basin 8 Outlet (to Duncans Creek)	73.7	49.0	34.8
Cosgroves Creek at Elizabeth Drive C1	73.8	58.8	42.9
Badgerys Creek B1	0	0	0
Badgerys Creek B2	12.4	13.3	9.59
Badgerys Creek B3	34.6	27	24.1
Cosgroves Creek at Elizabeth Drive C1	73.8	58.8	42.9
South Creek Kemps Creek Confluence S2	5.48	4.49	7.00
South Creek Blaxland Creek Confluence S3	4.15	3.51	5.56

Notes: 1) Basin 5 is not constructed in Stage 1 but rather in the longer term development. 2) Basin outlet loads include those from residual areas that cannot physically discharge to basins. 3) The treated loads from Basins 6 and 7 have been modelled to both discharge into Cosgroves Creek at C1.

4.3.3 ANZECC Guidelines pollutant concentrations

The results of the MUSIC modelling for Stage 1 are summarised in Table 4-7 for suspended solids, total phosphorus and total nitrogen, together with ANZECC guideline default trigger levels for slightly disturbed ecosystems in lowland rivers. Detailed results showing the pollutant concentrations obtained under Stage 1 conditions are presented in the Appendices.

(a) Local Impacts

Following the Stage 1 Development, the concentrations for suspended solids, total phosphorus and total nitrogen are found to generally improve, relative to those obtained under existing conditions. This can be seen in the results at the basin outlet locations in Table 4-7. The exceptions are those at Basin 3, where total phosphorus increases from 0.09 mg/L to 0.12 mg/L and at the Basin 5 location (without the basin), where suspended solids are estimated to increase slightly.

Overall, the results indicate that ANZECC objectives would not be achieved in Stage 1, with the exception of total suspended solids. This is notwithstanding the general improvements in water quality relative to the existing environment.

(b) Regional Impacts

The regional downstream impacts are similar to the local impacts. Most of the locations assessed were found to have improvements in water quality concentrations for suspended solids, total phosphorus and total nitrogen relative to existing conditions.

The exceptions are at Duncans Creek (DN1) where the concentrations are estimated to increase for all the three pollutants. At Duncans Creek, the impacts are a result of the proposed development along the western perimeter of the site.

As in the case of local impacts, the regional results indicate that ANZECC water quality objectives would not be achieved, despite the general improvements in water quality, with the exception of the level for suspended solids.

Table 4-7 Stage 1 Pollutant Concentrations

Location	Pollutant Concentrations (mg/L)					
	Existing			Stage 1		
	TSS	TP	TN	TSS	TP	TN
ANZECC Guidelines (2000)	**40**	**0.05**	**0.5**	**40**	**0.05**	**0.5**
Local Impacts						
Basin 1 Outlet (to Badgerys Creek)	22.10	0.14	1.54	12.90	0.11	0.91
Basin 2 Outlet (to Badgerys Creek)	22.10	0.09	1.25	16.50	0.11	0.99
Basin 3 Outlet (to Badgerys Creek)	21.90	0.09	1.26	12.20	**0.12**	0.88
Basin 4 Outlet (to Badgerys Creek)	20.70	0.38	2.91	15.90	0.11	1.00
Basin 5 Outlet (to Badgerys Creek)	23.00	0.17	1.72	**23.70**	0.10	1.19
Basin 6 Outlet (to Oaky/ Cosgroves Creek)	22.50	0.15	1.60	6.99	0.12	0.76
Basin 7 Outlet (to Cosgroves Creek)	22.30	0.14	1.46	10.60	0.12	0.81
Basin 8 Outlet (to Duncans Creek)	23.20	0.13	1.51	11.90	0.11	0.90
Badgerys Creek B1	21.50	0.14	1.47	**22.50**	0.11	1.21
Badgerys Creek B2	21.80	0.15	1.54	18.10	0.11	1.10
Badgerys Creek B3	21.90	0.14	1.53	14.80	0.12	1.00
Regional Impacts						
Cosgroves Creek at C1	22.70	0.14	1.54	10.20	0.12	0.88
Cosgroves Creek at C3	22.50	0.14	1.50	10.90	0.12	0.88
Duncans Creek at DN1	10.30	0.06	0.70	**13.20**	**0.11**	**0.96**
South Creek Kemps Creek Confluence S2	20.90	0.13	1.34	15.40	0.11	1.03
South Creek Blaxland Creek Confluence S3	20.80	0.12	1.31	15.50	0.11	1.02

Note: Locations where the mean concentrations have increased are shown in bold.

4.4 Longer term development

4.4.1 Average annual pollutant loads compared to existing conditions (NORBE)

The average annual pollutant loads obtained for the longer term development are presented in Table 4-8 for suspended solids, total phosphorus, and total nitrogen and gross pollutants. The percentage change in these pollutant loads compared to those for existing conditions is shown in brackets for comparison. Both local and regional impacts are summarised in this table. The local impacts relate to those immediately downstream of the airport site, while the regional impacts relate to those further downstream from the airport site. Gross pollutants are readily

controlled through the use of gross pollutant traps and other standard stormwater devices and are not considered in this comparison, as noted earlier.

(a) Local Impacts

The results in Table 4-8 indicate that, under longer term development conditions, the annual loads for total phosphorus and total nitrogen will generally increase, compared to existing conditions. The average annual loads for total phosphorus are estimated to increase by 113% to 703% at the various basin outlet locations assessed. Similarly, the average annual total nitrogen loads are estimated to increase by 86% to 420%. For total suspended solids, the results indicate that some locations will be impacted by an increase of up to 306% in the average annual load, while other locations will have a reduction of up to 64%. Similar to the Stage 1 Development, the proposed bio-retention basins will generally be unable to attenuate most of the loads to pre-development or existing levels.

It is noted that the longer term development has less residual catchment areas than the Stage 1 Development (Table 4-3 and Table 4-4), resulting in more areas being directed to the bio-retention basins for water quality treatment. However, this is also offset by increases in pollutant loads attributed to additional areas being urbanised by the airport.

(b) Regional Impacts

As in the case of Stage 1, the regional impacts for the indicative longer term development, compared to existing conditions, are predicted to be much smaller.

Badgerys Creek, on leaving the airport site at Elizabeth Drive (B3) is estimated to have increases of +114% (annual flows), -10% (reduction in suspended solids), +96% (total phosphorus), and +61% (total nitrogen) compared to pollutant loads under existing conditions. These impacts are estimated to reduce to +14% (annual flows), -4% (suspended solids), +8% (total phosphorus), and +7% (total nitrogen) by the time the flows arrive at the South Creek - Kemps Creek confluence (S2). At South Creek downstream of Blaxland Creek (S3), the impacts are further reduced to +10% (annual flows), -1% (suspended solids), +6% (total phosphorus), and +5% (total nitrogen).

Similarly, at the Elizabeth Drive crossing of Cosgroves Creek (C1), the increases of +149% (annual flows), -26% (reduction in suspended solids), +96% (total phosphorus), and +63% (total nitrogen) are observed to reduce to +86% (annual flows), -21% (suspended solids), +56% (total phosphorus), and +35% (total nitrogen by the time the flows arrive at C3.

By comparison, at Duncans Creek at DN1, the results indicate that the proposed airport development will result in an increase in annual flows of +21%, an increase of +8% for suspended solids, a +20% increase for total phosphorus and a +18% increase for total nitrogen.

Overall, it is assessed that the regional impacts will progressively dissipate downstream of the airport site. The implementation of additional design and management measures during the detailed design phase is expected to further improve the water quality and result in a reduction of any potential impacts.

Table 4-8 Longer Term Average Annual Pollutant Loads

Location	Annual Flow (ML/yr)	Average Annual Loags (kg/yr)			
		TSS	TP	TN	Gross Pollutants
Local Impacts					
Basin 1 Outlet	1490 (+195%)	56900 (-4%)	312 (+203%)	2070 (+127%)	2860
Basin 2 Outlet	317 (+462%)	11400 (+57%)	69.7 (+703%)	431 (+420%	1250
Basin 3 Outlet	663 (+345%)	10500 (-41%)	102 (+334%)	692 (+217%)	571
Basin 4 outlet	1180 (+1415%)	18900 (+306%)	174 (+406%)	1300 (+353%)	479
Basin 5 Outlet	668 (+157%)	19100 (-45%)	125 (+113%)	995 (+86%)	6660
Basin 6 Outlet	1170 (+215%)	21300 (-64%)	182 (+132%)	1430 (+111%)	2770
Basin 7 Outlet	862 (+404%)	25400 (-18%)	147 (+298%)	910 (+141%)	2160
Basin 8 Outlet	713 (+494%)	27000 (+51%)	152 (+564%)	1130 (+436%)	5730
B1 – BCUS	1220 (+30%)	62500 (-34%)	226 (+24%)	1970 (+15%)	9540
B2 – BCMC	2950 (+84%)	146000 (-15%)	506 (+56%)	4290 (+41%)	10900
B3 – BCDS	5850 (+114%)	284000 (-10%)	1090 (+96%)	8440 (+61%)	16400
Regional Impacts					
Cosgroves Creek C1	2490 (+149%)	126000 (-26%)	431 (+96%)	3350 (+63%)	5310
Cosgroves Creek C3	3170 (+86%)	217000 (-21%)	574 (+56%)	4710 (+35%)	7200
Duncans Creek DN1	2790 (+21%)	333000 (+8%)	560 (+20%)	4990 (+18%)	7470
South Creek Kemps Creek Confluence - S2	25600 (+14%)	2710000 (-4%)	4820 (+8%)	47000 (+7%)	86100
South Creek Blaxland Creek – S3	34100 (+10%)	3590000 (-1%)	6180 (+6%)	60100 (+5%)	124000

4.4.2 WSUD Technical Guidelines for Western Sydney

The potential impacts of the longer term airport development, measured against the requirements of the WSUD Guidelines, are presented in Table 4-9. The targets are 80% for suspended solids, 45% for total phosphorus and 45% for total nitrogen to be retained on site. As previously noted, the basin outlet flows and loads include areas that discharge directly into the basins as well as residual areas that cannot physically discharge into those basins.

The WSUD Guidelines specify only the reduction targets that should be achieved on site at the proposed basin outlets, and as such cannot be meaningfully applied within the context of downstream regional impacts where there are no additional bio-retention basins or treatment measures constructed at those locations.

In Table 4-9, the eight basin outlets represent the locations where the pollutant loads generated from the proposed airport would discharge into the downstream environment. The results show

that, in terms of suspended solids, all the discharges from the basins satisfy the 80% reduction target. The 79% achieved at Basin 1 is considered to be acceptable and within the limits of modelling error. Similarly, for total phosphorus, all the basins satisfy the 45% reduction target. For total nitrogen, all the basins satisfy the 45% reduction target, except for Basin 1, Basin 5, and Basin 8. This is due to a combination of factors, including residual areas that cannot physically discharge into the basins, as well as the development constraints.

The other locations listed in Table 4-6 are situated outside of the airport site, and include large untreated catchment areas. Consequently, the net percentage reductions achieved at these locations are relatively low by comparison. The exception is Cosgroves Creek at C1, which also satisfies the three reduction targets. This is due to the high percentage reductions achieved at Basins 6 and 7.

Overall, the results indicate that the WSUD Guidelines, in terms of reduction targets, are generally satisfied for flows discharging from the airport site into Oaky Creek, Cosgroves Creek and Badgerys Creek. At the basin outlet locations, where the targets are not satisfied, it is considered that additional land management may be required, particularly in the residual areas associated with Basin 1, Basin 5 and Basin 8. This includes the provision of additional diversion drains as discussed in Section 6.

Table 4-9 Longer Term Percentage Load Reductions

Location	% Reduction in Pollutant Loads		
	TSS (%)	TP (%)	TN (%)
Western Sydney Technical Guidelines	**80**	**45**	**45**
Basin 1 Outlet	**79**	49.0	**42.5**
Basin 2 Outlet	86.7	61.2	46.9
Basin 3 Outlet	94.6	71.8	58.3
Basin 4 Outlet	94.6	72.8	55.2
Basin 5 Outlet	86.6	58.4	**39.9**
Basin 6 Outlet	92.6	67.4	50.2
Basin 7 Outlet	90.2	70.1	58.6
Basin 8 Outlet	81.6	51.9	**35.5**
B3	66.4	43.7	25.2
B2	75.8	56.0	34.6
B1	76.6	54.7	37.9
C1	80.0	62.5	44.9
DN1	26.5	22.7	11.0
Kemps Creek Confluence S2	25.6	9.89	21.40
Blaxland Creek Confluence S3	20.70	7.90	17.6

4.4.3 ANZECC Guidelines pollutant concentrations

The results for the longer term development are summarised in Table 4-10 for suspended solids, total phosphorus and total nitrogen, together with ANZECC guideline default trigger levels for slightly disturbed ecosystems in lowland rivers. Detailed results showing the pollutant concentrations obtained under longer term development conditions are presented in the Appendices.

(a) Local Impacts

The concentrations for suspended solids, total phosphorus and total nitrogen are found to generally improve, relative to existing conditions. This can be seen in the results at the basin outlet locations in Table 4-7. The exceptions are those at Basin 2 and Basin 3, where total phosphorus increases marginally from 0.09 mg/L to 0.11 mg/L.

However, despite these improvements, the results indicate that ANZECC water quality objectives would not be achieved, except for suspended solids.

(b) Regional Impacts

The regional downstream impacts are found to be similar to the local impacts. Most of the locations assessed are found to have improvements in water quality concentrations for suspended solids, total phosphorus and total nitrogen relative to existing conditions. This is particularly the case in Cosgroves Creek, Badgerys Creek and South Creek.

The exception is Duncans Creek (DN1), where concentrations are estimated to increase for all the three pollutants. At Duncans Creek, the impacts are a result of the proposed development along the western perimeter of the site.

As in the case of local impacts, the regional results for the downstream areas indicate that ANZECC water quality objectives would not be achieved, despite the general improvements in water quality, except for suspended solids.

Table 4-10 Longer Term Development Concentrations at Key Locations

Location	Existing Conditions (mg/L)			Longer Term Development (mg/L)		
	TSS	TP	TN	TSS	TP	TN
ANZECC Guidelines	**40**	**0.05**	**0.5**	**40**	**0.05**	**0.5**
Basin 1 Outlet	22.10	0.14	1.54	12.40	0.11	0.90
Basin 2 Outlet	22.10	0.09	1.25	14.70	**0.11**	0.96
Basin 3 Outlet	21.90	0.09	1.26	10.50	**0.11**	0.84
Basin 4 Outlet	20.70	0.38	2.91	8.24	0.12	0.78
Basin 5 Outlet	23.00	0.17	1.72	13.20	0.11	0.94
Basin 6 Outlet	22.50	0.15	1.60	7.43	0.12	0.77
Basin 7 Outlet	22.30	0.14	1.46	10.90	0.12	0.83
Basin 8 Outlet	23.20	0.13	1.51	12.80	0.11	0.92
B1	21.50	0.14	1.47	14.40	0.11	1.02
B2	21.80	0.15	1.54	11.40	0.12	0.93
B3	21.90	0.14	1.53	12.00	0.12	0.94
C1	22.70	0.14	1.54	11.00	0.12	0.91
DN1	10.30	0.06	0.70	**13.60**	**0.11**	**0.98**
South Creek Kemps Creek Confluence S2	20.90	0.13	1.34	13.20	0.12	0.98
South Creek Blaxland Creek Confluence S3	20.80	0.12	1.31	13.40	0.12	0.97

4.5 Fuel jettisoning

The issue of potential adverse effects from fuel dumping (fuel jettisoning) has been addressed with reference to the regulations on fuel dumping (*Air Navigation (Fuel Spillage) Regulations 1999)* and the procedures for fuel dumping in Australia (Aeronautical Information Package (AIP) (Airservices Australia, 2014). The cause, frequency and volume of fuel jettisoned, as well as results from a prior scientific study on fuel dumping are outlined below.

Fuel jettisoning generally only occurs during an emergency, as a safety precaution when a plane must land prematurely. At take-off, aircraft are heavier than they are at landing due to the unburned fuel that is to be used during the flight. As aircraft can only safely land when the specified maximum landing weight is reached, weight must sometimes be removed from the plane during flight prior to an emergency landing. This occurs in the form of an expulsion of fuel from the plane's wing tips, tail or fuselage (Aerospaceweb, 2005).

There are specific protocols in place to regulate fuel dumping in Australia in accordance with the *Air Navigation (Fuel Spillage) Regulations 1999*. The Aeronautical Information Package (AIP) (Airservices Australia, 2014) indicates that where possible, a pilot should obtain authority from Air Traffic Control (ATC) before commencing a fuel dump and receive instruction on where the fuel dump is to be performed. Fuel dumps are required to occur in clear air at 6,000 ft. (approximately 2,000 m) above ground level, and in an area nominated by the ATC to ensure that all fuel is vaporised before reaching the ground. The AIP also requires that reasonable precautions must be taken to ensure the safety of persons and property in the air and on the ground. There are currently no recorded cases of fuel from civil aircraft reaching the ground.

The amount of fuel that is dropped will vary with the size of the aircraft, the amount of fuel carried at the time, and the amount required to be jettisoned in order to reach their maximum landing weight. Data for annual frequency and amounts of fuel dumped near Australian airports is unavailable, however in total, it is estimated that up to 6800 tonnes of fuel was released over oceans in the 1990s (Aerospaceweb, 2005). The significant cost of fuel means that fuel dumps only occur when necessary. It is in the airlines' best interest to conserve fuel and consider alternate options prior to fuel dumping.

Fuel dumping events are extremely rare worldwide. For example, All Nippon Airways (Japan's largest airline by revenues and passenger numbers in 2012) experienced only three cases of fuel dumping during 2013. All of these occurred off the east coast of Japan away from urban areas (ANA Holdings, n.d). As fuel jettisoning is usually only a safety feature of new, large, long-range aircraft, most planes are forced to either burn excess fuel prior to landing by circling in the air or land overweight. In Australia, common aircraft such as the Airbus A320 and Boeing 737 are not capable of fuel jettisoning and thus fuel dumping is likely to be a rare occurrence.

Civilian aircraft generally use Jet-A1 grade fuel which contains up to approximately 20% by volume aromatic hydrocarbons (including benzene) and approximately 2% by volume of naphthalene's (including Polycyclic Aromatic Hydrocarbons) (IARC, 1989). This aircraft fuel is a source of volatile organic compounds (VOCs) and carbon dioxide (CO_2) when unburnt fuel droplets are released. Although all dumped fuel is vaporised before reaching the ground, it may have an impact on local air quality. This is particularly significant for pollutants with long residence times. For example, VOC's such as benzene can occur in a predominantly vapour phase with a residence time of between one day and two weeks depending on climate and other pollutant concentrations (Harrison et al, 2010). This may cause concern due to the known carcinogenic effect of benzene over long-term exposure (Harrison et al, 2010). However, since fuel dumping is a rare event and protocols are in place to ensure the safety of persons and property on the ground, fuel dumping is not likely to have significant impacts on local air quality or human health.

Due to improvements in fuel efficiency and lightweight aircraft material, the amount of fuel dumped from aircraft under emergency situations has decreased substantially, with this trend anticipated to continue. As fuel efficiency, technology and airspace management continue to improve, volumes of fuel required to be carried on planes will steadily decline in the future. Major Australian airlines already have goals in place to implement these improvements. Qantas, for example, is currently aiming to improve its fuel efficiency by 1.5 per cent per year until 2020 (Department of Resources, Energy and Tourism, 2013). The Qantas Group Fuel Optimisation Program also has strategies in place to reduce travel distance and unnecessary aircraft weight. These strategies will help to reduce the volume of fuel carried by aircraft and reduce the amount of fuel dumped in event of an emergency.

Based on the above considerations, fuel jettisoning is not expected to have any measurable impacts on surface water quality discharging from the airport site.

5. Assessment of construction impacts

5.1 Overview

The proposed airport has the potential to impact on surface water quality during both the proposed Stage 1 and the longer term construction phases of the project. Land clearing, the removal of existing vegetation, buildings and structures, major earthworks, the laying of airport services, and the movement of construction vehicles within the site would be expected to result in extensive disturbance to the existing soils. Rainfall events during the construction period may therefore lead to increased erosion and sediment deposition of the disturbed soils. This has the potential to result in the release of pollutants into the downstream waterways, including suspended solids, nutrients and other toxicants which may impact on the environment. There is also the risk that chemical or hydrocarbon spills may occur during the construction activities, which may discharge into the waterways, particularly during rainfall events.

Notwithstanding the above risks, potential construction impacts would mostly be mitigated through the implementation of a Soil and Water Management Plan (SWMP) and a Construction Environmental Management Plan (CEMP). A water quality monitoring plan would also be developed and implemented as part of these plans to monitor any potential impacts during the construction phases of the project. Management measures that would be expected to be included in these plans are highlighted in Section 6.

With the management plans in place, construction is not expected to have any significant impact on existing water quality concentrations in the receiving waters downstream of the site. Any exceedances would likely be localised and short term. In particular, it is noted that ANZECC water quality objectives are not achieved under existing conditions, but water quality would be improved substantially once the construction works are completed. Additional information on some of the potential impacts during construction of the project is noted below.

5.2 Duration of construction works

It is possible that a large rainfall event may occur during the extended construction phase for the proposed airport. Impacts from poor management of surface water on site could result in increased mobilisation of soils, flooding of equipment and increased risks associated with constructing in wet and muddy soils. There is also the potential for large quantities of sediments to be directed into the stormwater network, potentially resulting in siltation and blockage during the construction period. Where the construction period can be reduced, the risks would also be reduced.

5.3 Erosion and Sedimentation

Soil erosion and sedimentation are risks posed to surface water quality throughout the construction phase where earthworks, vehicle access and alterations to drainage lines and connections can lead to increased sediment loads entering downstream environments.

Disturbed areas with surface grades greater than 2.5 per cent and vehicle access tracks where the surface is frequently disturbed by traffic are typically high risk areas during construction. The locations of disturbed areas with grades greater than 2.5 per cent could change throughout construction and would need to be identified in the CEMP. Stockpiled soils can also erode during rainfall events and high winds and require careful on-site management. Other disturbed areas with exposed soils are also susceptible to erosion during rainfall events.

Construction of the longer term airport involves the disturbance of additional land surfaces as well as the installation of new connections between proposed drains and existing pits. During

the construction of these connections there is an increased risk that disturbed soil will enter drainage lines and waterways.

Stormwater control and treatment measures would need to be located immediately downstream of the construction footprint. However, overland flow from the construction site may still enter the downstream waterways if not managed carefully. In the event that runoff from the site is permitted to leave the site in an uncontrolled manner and discharge into downstream waterways, localised scour could occur at the points of discharge.

With the provision of appropriate construction stage erosion and sediment controls, nutrient loads would be unlikely to increase significantly during the construction phase, however particulate phosphorous is likely to increase where erosion and scour is allowed to propagate.

5.4 Potential for spills

The release of potentially harmful chemicals and other substances in the environment may occur during construction. This would have the potential to impact on water quality in receiving waters downstream of the airport site. These potentially contaminating substances would include acids and chemicals from washing processes, construction fuels, oils, lubricants, hydraulics fluids and other chemicals. Release of these substances could occur due to spills, as a result of equipment refuelling, malfunction and maintenance, via treatment and curing processes for concrete, as a result of inappropriate storage, handling and use of the substances or from the disturbance and inappropriate handling of contaminated soils. These substances have the potential to be taken up in surface water runoff and transported downstream from the proposed works locations. Water quality and associated ecological impacts could result if these contaminants are transported into waterways downstream of the site.

5.5 Demolition and excavation works

The major civil construction works would require the demolition of existing buildings and infrastructure within the project site, though it is understood that much of the demolition works would be conducted separately to the works proposed as part of the proposed Stage 1 and the longer term development. Excavation works also have the potential to unearth contaminated land.

Examples of sources of pollutants that could affect water quality from demolition and excavation works are as follows:

- asbestos and other building materials;
- toxic or pollutant laden soils including fertilisers and pesticides;
- heavy metals;
- chemicals including hydrocarbons and fluids associated with demolition processes and machinery; and
- dust and airborne pollutants.

Typical impacts on the waterways would be through mobilised dust, litter and other building materials being deposited and picked up by surface water runoff, waterways or stormwater management infrastructure thereby degrading the quality of the natural receiving environment. The transportation of building waste from the demolition sites could potentially impact on the quality of the waterways through accidental spills/material drops. As identified above, some materials that are typically found in building demolition such as lead-based paints and chemicals can be easily transported from the demolition site through off-site stormwater runoff. There is also potential for pollutants to be ingested by aquatic fauna or terrestrial fauna.

6. Mitigation and management measures

6.1 Operational Phase Measures

During the operational phases of the project for both Stage 1 and the longer term, key water quality management measures proposed as part of the management strategy include the following:

(a) Design based measures

- During detailed design, additional water quality treatment measures, consisting of bio-retention swales, would be provided along all the drainage flow lines to cater for additional polishing of water quality prior to discharging to the bio-retention basins. Where necessary, the effectiveness of the swales would be enhanced with increased infiltration properties.
- During detailed design, diversion drains would be designed to convey flows from “residual areas” into the proposed basins. These residual areas are those areas that do not currently discharge to the basins due to topographical constraint. These diversion channels would be designed to have non-erosive velocities to minimise stream erosion.
- During detailed design, the proposed bio-retention basins would be increased in size where necessary, depending on the effectiveness of the above supplementary measures.
- During detailed design, the bio-retention basins would be separated from the flood control basins. The bio-retention basins would be designed to be offline such that design flows larger than the capacity of the bio-retention basins would bypass the system and discharge directly into the flood control basins. This would ensure that the pollutants within the bio-retention system are not re-suspended during large flow events.

(b) Management based measures

- Surface water quality would be maintained by implementing safeguards and procedures to prevent contaminants entering the drainage system and by treating all surface water in sediment basins prior to downstream discharge;
- The use of herbicides, pesticides and fertilisers would be controlled and the disposal of any unacceptable substances such as paint and oils into the drainage system would be prohibited;
- Pollutant traps would be provided at strategic locations to prevent debris and coarse sediment entering the drainage system. Inspections and monitoring activities of pollutant traps would be undertaken at regular intervals and after large storm events to check accumulation of material and evidence of overflows and blockages. Accumulated sediment and debris would be regularly removed from traps. Access to all structures would be provided for maintenance vehicles;
- Fuel storage, chemical facilities and any other similar storage or handling facilities with the potential to contaminate stormwater would be provided with perimeter bunds. Procedures should also be established to clean up spills as quickly as possible to reduce the potential for groundwater or surface water impacts;
- An operation and maintenance plan would be prepared for the sediment and water quality basins to ensure performance meets requirements;
- Operation and management activities would involve stream bank maintenance to prevent erosion, periodic trash, sediment removal, and monitoring of water quality indicators;

- Water quality basins would be inspected at regular intervals and after high flow events. The inspections would ensure that all components of the basins are functioning correctly and to determine the need for erosion control or sediment removal procedures;
- Sediment would be removed as required to restore basin operational depth using earth moving equipment. Testing for contamination would be carried out before any sediment is used in landscaping works around the site or transported to a suitable landfill;
- Regular monitoring of inflow and outflow water quality parameters would be carried out to provide information to assess the performance in meeting water quality objectives. An airport lessee company would undertake water quality monitoring in accordance with the *Airport (Environmental Protection) Regulations 1997*;
- Spillage control and containment areas would be provided to reduce the risk of spills discharging onto adjacent land, watercourses, or the bio-retention basin areas;
- Structures would be designed to limit potential for infiltration to the underlying groundwater system (i.e. they would be appropriately lined);
- Suitably sized temporary holding tanks would be included in the discharge lines to capture the expected volumes from cleaning activities and spills;
- A strategy would be implemented for off-site removal of the captured contaminated water by a licensed waste contractor; and
- Cleaning and spill response procedures would be documented in a site management plan to ensure that impacted water is contained, collected and managed appropriately.

6.2 Construction Phase Measures

Both the initial and longer term developments would face the same challenges in relation to mitigation and management of construction impacts. However, the airport site would become more constrained as construction progresses around existing infrastructure. Facilities constructed as part of the proposed Stage 1 Development of the site including bio-retention basins and open swale drains would bisect the construction site and these structures would need to be considered so that construction activities did not adversely impact their performance.

A Soil and Water Management Plan (SWMP) would be prepared and implemented in order to cater for the construction activities across the airport site. These measures would also be documented within the CEMP and approved by the relevant regulatory authorities. This should include procedures to minimise the risk of contamination.

The primary focus of the SWMP is erosion and sediment control during the land disturbance phases of the project. The SWMP should be prepared in accordance with the following guidelines:

- Soils and Construction, Managing Urban Stormwater series, including:
  - Volume 1 (Blue Book, Landcom, 2004);
  - Volume 2A (Installation of services, DECC 2008); and
  - Volume 2D (main roads construction, DECC 2008).

Important and additional considerations in surface water management and preparation of the SWMP are discussed below. These include potential site constraints and considerations for both the construction and operational phases of the project. Overall implementation of the above measures is expected to minimise any adverse impacts on the existing environment.

6.2.1 Sediment and Erosion Control

Sediment and erosion control measures that reduce the amount of sediment leaving the site should be included and implemented on-site before, during and after construction until the site conditions have settled and operational measures are established.

Erosion and sediment control measures, aimed at minimising the volume of sediment transported from disturbed areas and discharging from the site, are required. Potential measures include:

- careful design of the drainage system to minimise the lengths of drainage paths or watercourses that have to be filled, diverted and replaced;
- identification and implementation of temporary diversion channels and bunding, where necessary to prevent concentrated flow from causing scour of disturbed surfaces;
- identification of highly erodible soils and avoidance of activities involving disturbance of these areas where possible. Where avoidance is not possible, additional control measures would be planned for these identified areas;
- consideration of the possibility of staging works to minimise the extent of disturbance at any one time;
- construction and commissioning of all, or where sufficient for treatment purposes, part of, the sediment and water quality basins before any other major earthworks;
- all runoff leaving the construction site would be directed to a detention or water quality facility before downstream release;
- banks of temporary stream diversion channels would be stabilised with suitable materials to minimise scouring and erosion;
- temporary stabilisation or revegetation/rehabilitation works to reduce the extent of disturbed surfaces;
- stabilisation of disturbed areas with an appropriate cover where practicable until works can recommence or permanent vegetation can be established;
- application of temporary surface treatments or blanketing on exposed earth surfaces;
- installation of sediment barriers;
- graded access tracks and speed restrictions for vehicles on site;
- mandatory use of designated stations to wash all vehicles and machinery before exiting the site, including the appropriate capture and treatment of wash-down waters;
- rainfall and wind forecasts to inform on-site managers of daily risks;
- adaptable site activity scheduling to avoid periods of increased erosion risk due to wind, rain and runoff;
- preparation of vegetative buffer strips;
- installation of established drainage lines incorporating rock check dams at regular intervals;
- establishment of baseline environmental conditions and regular water quality monitoring of impacts for the duration of the construction works, in accordance with the requirements of the Construction Environment Management Plan;
- monitoring of discharge from sediment or detention ponds to mitigate the potential for impacts to surface water quality in the receiving environment;

- dosing of sediment ponds with flocculants where there are dispersive soils or excessive nutrients being discharged from the system;
- careful advanced planning and ongoing management of works and mitigation procedures to reduce erosion and pollutant loads;
- keeping clearance of vegetation to a minimum, particularly in the vicinity of streams;
- location of material, overburden and topsoil stockpiles on level ground and away from drainage lines and streams;
- drainage outlets would be provided with energy dissipators where appropriate to minimise water velocity and erosion;
- installation of gross pollutant traps to intercept and retain coarse sediment, rubbish and debris in storm water;
- all silt traps, gross pollutant traps, erosion control fencing, diversion drains, catch drains and other construction management measures would be implemented in accordance with industry standards and design guidelines for construction sites;
- dust control should be managed through the use of water sprays and stabilising or covering of stockpiles; and
- where space allows, construction works should consider the potential for locating sediment retention basins along the perimeters of the site upstream of the proposed bio-retention basins. These basins would reduce the volume of sediment and turbidity levels in runoff potentially discharging from the site.

6.2.2 Chemical Contamination

The SWMP and CEMP should include methods and procedures for reducing the risk of contamination.

Reducing the risk of chemical spill during the construction phase requires the planning and implementation of the following measures:

- preparation of an emergency response plan for spills and leakages of fuels and chemicals;
- installation of flame traps to limit the release of oils and fuels in stormwater;
- mandatory use of fenced and impermeable areas for washing machinery and equipment with collection and treatment systems downslope;
- mandatory use of fenced and impermeable refuelling stations (preferably off-site);
- storage of all chemicals and harmful waste products in secure designated areas (preferably off-site);
- regular maintenance of machinery and vehicles, checking for oil, fuel or hydraulic leaks;
- easily accessible chemical spill clean-up kits on site in case of emergency spills;
- enforcement of incident reporting procedures to record serious spills, the response measures used and their effectiveness; and
- testing of potential contaminated soils prior to excavation.

In addition, reducing pollutant loads sourced from demolition works requires the planning and implementation of the following on-site control measures:

- scheduling of works to avoid strong winds and rainfall;
- mandatory coverage of trucks carrying debris;
- temporary barriers or dust screens, as appropriate, to suppress the effect of dust movement to uncontrolled sites;
- dust suppression such as wetting measures; and
- fencing of temporary stockpiles on hardstands.

7. Summary and conclusions

An assessment of the potential impacts of the proposed airport on surface water quality has been undertaken for both the proposed Stage 1 and longer term development stages of the project.

Available baseline water quality data for the site and surrounding areas were reviewed. The results indicate that nutrient loads in the existing waterways are generally high and do not achieve ANZECC water quality objectives for total phosphorus and total nitrogen. However, total suspended solids loads are generally low and achieve ANZECC objectives.

A MUSIC water quality model was developed and calibrated to the available baseline data. Additional models were then developed to represent the proposed Stage 1 and the longer term development phases of the project and identify the potential impacts of the proposed development.

Bio-retention basins proposed as part of the Draft Airport Plan were incorporated into the modelling. Eight bio-retention basins would be located along the perimeter of the airport site. Basins 1, 2, 3, 4, and 5 were placed along the southern boundary to provide water quality treatment of the stormwater flows prior to discharge to Badgerys Creek. Similarly, Basins 6 and 7 were provided along the northern boundary to manage the flows discharging into Oaky Creek and Cosgroves Creek, while Basin 8 was provided to manage flows discharging into Duncans Creek. All the basins are proposed for construction during Stage 1 of the project, except for Basin 5, which would be constructed during the longer term development phase.

The calibrated MUSIC water quality models were simulated over an extended rainfall time series to assess the pollutant loads and potential impacts of the proposal. In evaluating the effectiveness of the proposed measures, the treatment targets for total suspended solids, total phosphorus and total nitrogen were assessed on the basis of: i) comparison with existing or pre-development pollutant loads (NORBE); ii) WSUD Guidelines; and iii) ANZECC Guidelines.

Under proposed Stage 1 Development conditions, with the proposed bio-retention basins in place, the results indicate that post-development loads would not be reduced to pre-development loads (NORBE), except for suspended solids.

Similarly, the results indicate that the Stage 1 Development, with the bio-retention basins in place, would be unable to satisfy WSUD guideline targets, except for flows discharging from the site into Oaky Creek and Cosgroves Creek. For Badgerys Creek, where the percentage retention targets are not met, supplementary design measures would be provided during detailed design, particularly in the residual catchment areas associated with Basin 2, Basin 4 and Basin 5.

The results indicate that for the Stage 1 Development, ANZECC water quality objectives would not be achieved, except for suspended solids. This is notwithstanding the general improvements in water quality concentrations relative to the existing environment, particularly in Badgerys Creek and South Creek.

Under the longer term development, the results indicate that post-development loads would not be reduced to pre-development loads (NORBE), except for suspended solids.

The results for the longer term development indicate that the WSUD percentage retention targets for total suspended solids, total phosphorus, and total nitrogen are generally satisfied for flows discharging from the site into Oaky Creek, Cosgroves Creek, and Badgerys Creek. At basin outlet locations for Basins 1, 5 and 6, where the targets are not satisfied, supplementary design measures would be provided during detailed design.

Under the longer term development conditions, the concentrations for suspended solids, total phosphorus and total nitrogen are found to generally improve, relative to existing conditions in Oaky Creek, Cosgroves Creek, Badgerys Creek, and South Creek. The exceptions are those at Duncans Creek for suspended solids, phosphorus and nitrogen, and at the Basin 2 and the Basin 3 outlets, with regards to the levels of total phosphorus, where the concentrations are estimated to increase. The results also indicate that ANZECC water quality objectives would not be achieved, except for suspended solids. This is notwithstanding the general improvements in water quality, in terms of concentrations, relative to the existing environment.

During detailed design, additional measures would be required for implementation with the aim of optimising the level of water quality treatment provided prior to downstream discharge. This would include the use of enhanced bio-retention swales along all the drainage lines for additional water quality polishing, the implementation of diversion drains to convey additional flows from the residual areas to the proposed basin locations, and enlarging some of the bio-retention basins where necessary.

Additional mitigation and management measures, as well as water quality monitoring, would also be required during the construction and operational phases of the project.

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Appendices

Appendix A – Water Quality Sampling Data

Matrix:	WATER	Sample Type:		REG	REG	REG	REG	REG	REG	REG	REG	REG	REG	REG
Workgroup:	ES1506236	ALS Sample numbe		ES1506236001	ES1506236002	ES1506236003	ES1506236004	ES1506236005	ES1506236006	ES1506236007	ES1506236008	ES1506236009	ES1506236010	ES1506236011
Project name/number:	WSA AE SURVEY	Sample date:		16/03/2015	16/03/2015	16/03/2015	16/03/2015	16/03/2015	16/03/2015	16/03/2015	16/03/2015	16/03/2015	16/03/2015	16/03/2015
		Client sample ID (1st		SCUS	BCDS	OCDS	SCREC	BCUS	TCUS	DCDS	BCMC	CCUS	CCDS	SCDS
		Client sample ID (2n												
		Site:												
EA010P: Conductivity by PC Titrator														
Electrical Conductivity @ 25°C		µS/cm	1	**1680**	**3050**	**4320**	**1540**	**2710**	**1640**	**847**	**3100**	**5020**	**1050**	**1900**
EA025: Suspended Solids														
Suspended Solids (SS)		mg/L	5	<5	<5	**19**	**10**	**23**	<5	**14**	<5	<5	**44**	**19**
EA065: Total Hardness as CaCO3														
Total Hardness as CaCO3		mg/L	1	**281**	**535**	**604**	**253**	**550**	**179**	**162**	**521**	**806**	**160**	**292**
EK055G: Ammonia as N by Discrete Analyser														
Ammonia as N	7664-41-7	mg/L	0.01	**0.30**	**0.22**	**0.22**	**0.14**	**0.17**	**0.04**	**0.23**	**0.28**	**0.14**	**0.04**	**0.06**
EK057G: Nitrite as N by Discrete Analyser														
Nitrite as N		mg/L	0.01	**0.02**	<0.01	<0.01	<0.01	**0.08**	<0.01	**0.01**	**0.08**	<0.01	<0.01	<0.01
EK058G: Nitrate as N by Discrete Analyser														
Nitrate as N	14797-55-8	mg/L	0.01	**0.08**	**0.10**	**0.06**	**0.12**	**4.56**	**0.01**	**0.19**	**15.5**	**0.15**	**0.03**	**0.10**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser														
Nitrite + Nitrate as N		mg/L	0.01	**0.10**	**0.10**	**0.06**	**0.12**	**4.64**	**0.01**	**0.20**	**15.6**	**0.15**	**0.03**	**0.10**
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser														
Total Kjeldahl Nitrogen as N		mg/L	0.1	**1.1**	**2.2**	**1.1**	**0.9**	**1.6**	**1.0**	**0.7**	**2.9**	**0.6**	**1.3**	**1.0**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser														
Total Nitrogen as N		mg/L	0.1	**1.2**	**2.3**	**1.2**	**1.0**	**6.2**	**1.0**	**0.9**	**18.5**	**0.8**	**1.3**	**1.1**
EK067G: Total Phosphorus as P by Discrete Analyser														
Total Phosphorus as P		mg/L	0.01	**0.27**	**1.00**	**0.05**	**0.05**	**0.42**	**0.09**	**0.06**	**0.31**	**0.03**	**0.30**	**0.08**
EP005: Total Organic Carbon (TOC)														
Total Organic Carbon		mg/L	0.2	**10.1**	**12.7**	**19.3**	**14.4**	**10.2**	**20.3**	**6.3**	**31.7**	**8.9**	**10.5**	**16.6**
EP020: Oil and Grease (O&G)														
Oil & Grease		mg/L	5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

Appendix B – MUSIC Water Quality Results for Stage 1 Development

Plots of pollutant concentrations at various locations

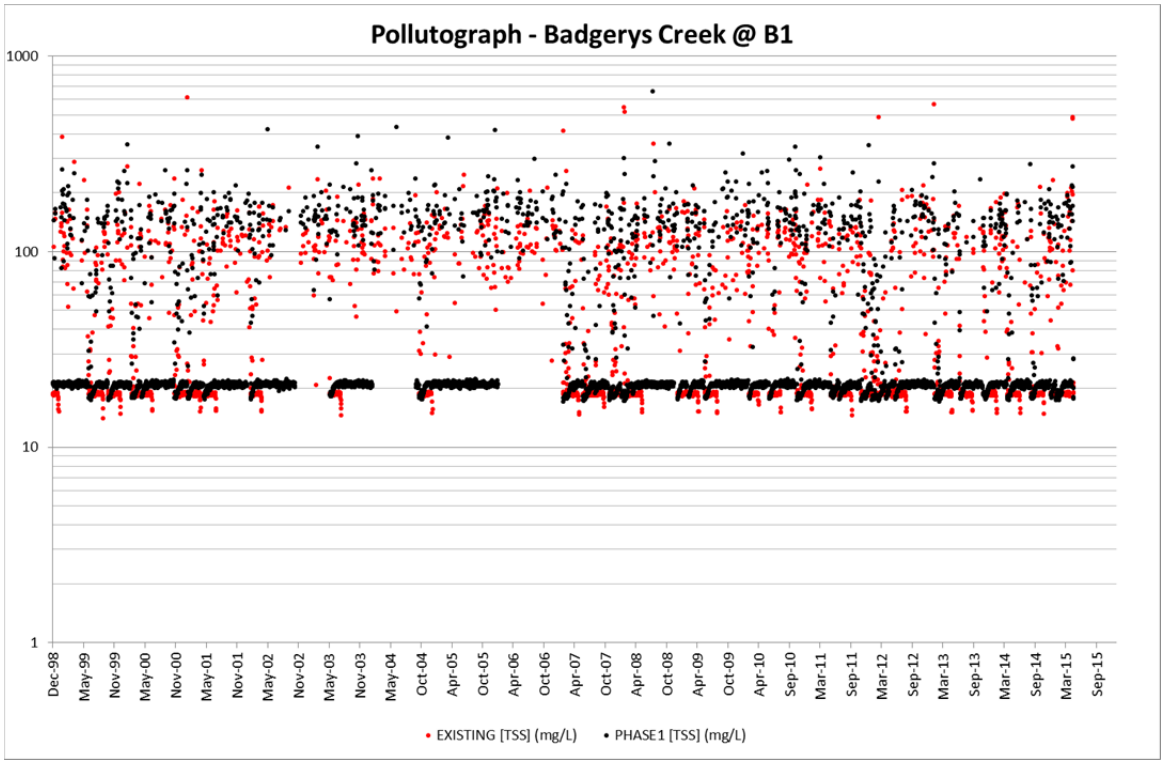


Figure B 1 Stage 1Total Suspended Solids at Badgerys Creek B1

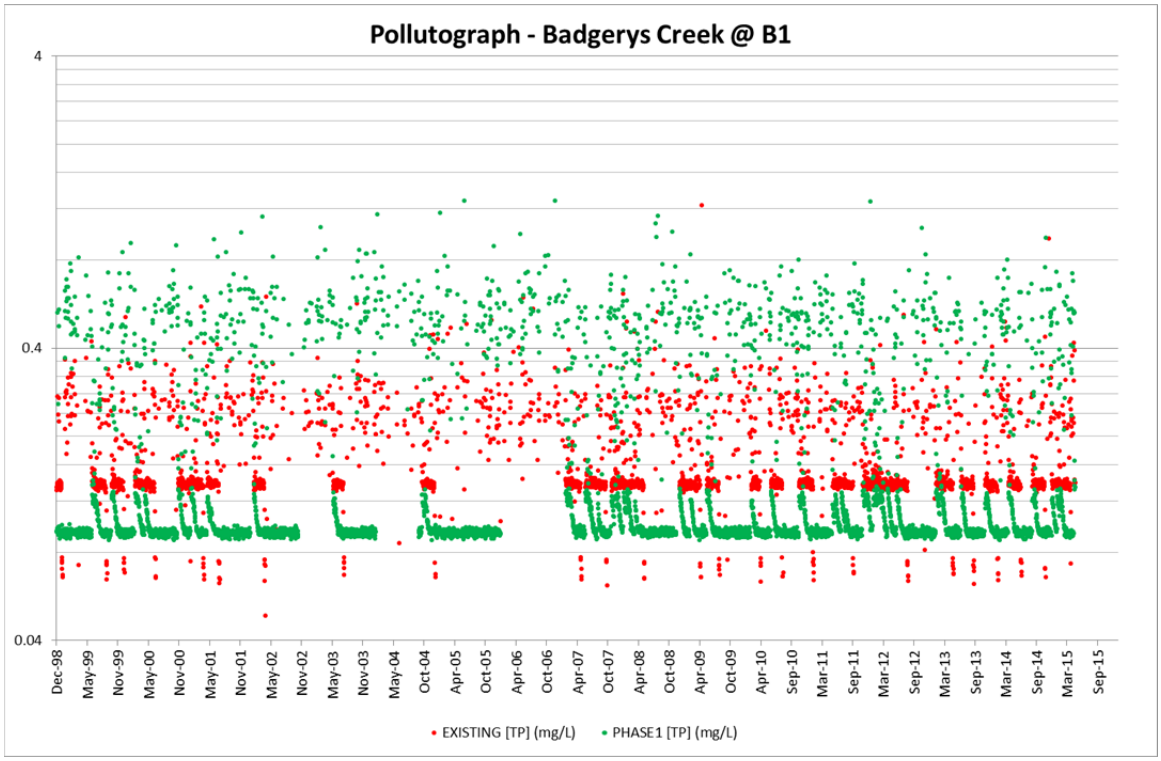


Figure B 2 Stage 1Total Phosphorus at Badgerys Creek B1

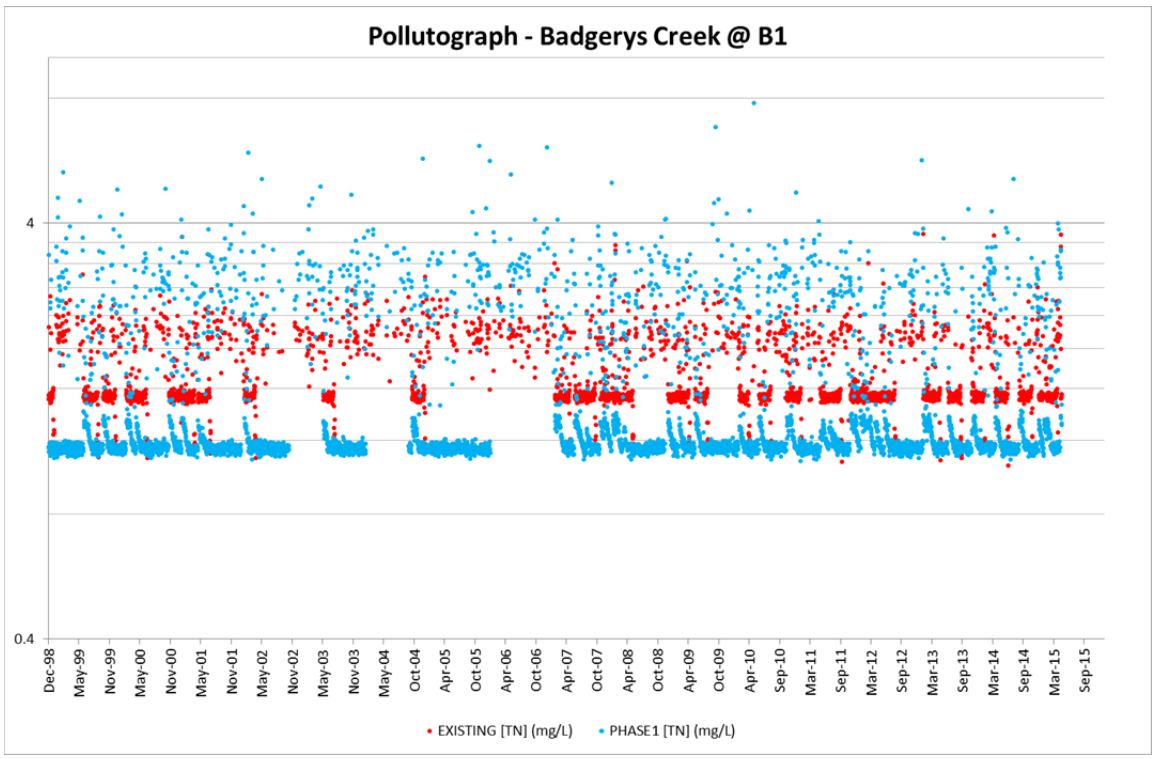


Figure B 3 Stage 1 Total Nitrogen at Badgerys Creek B1

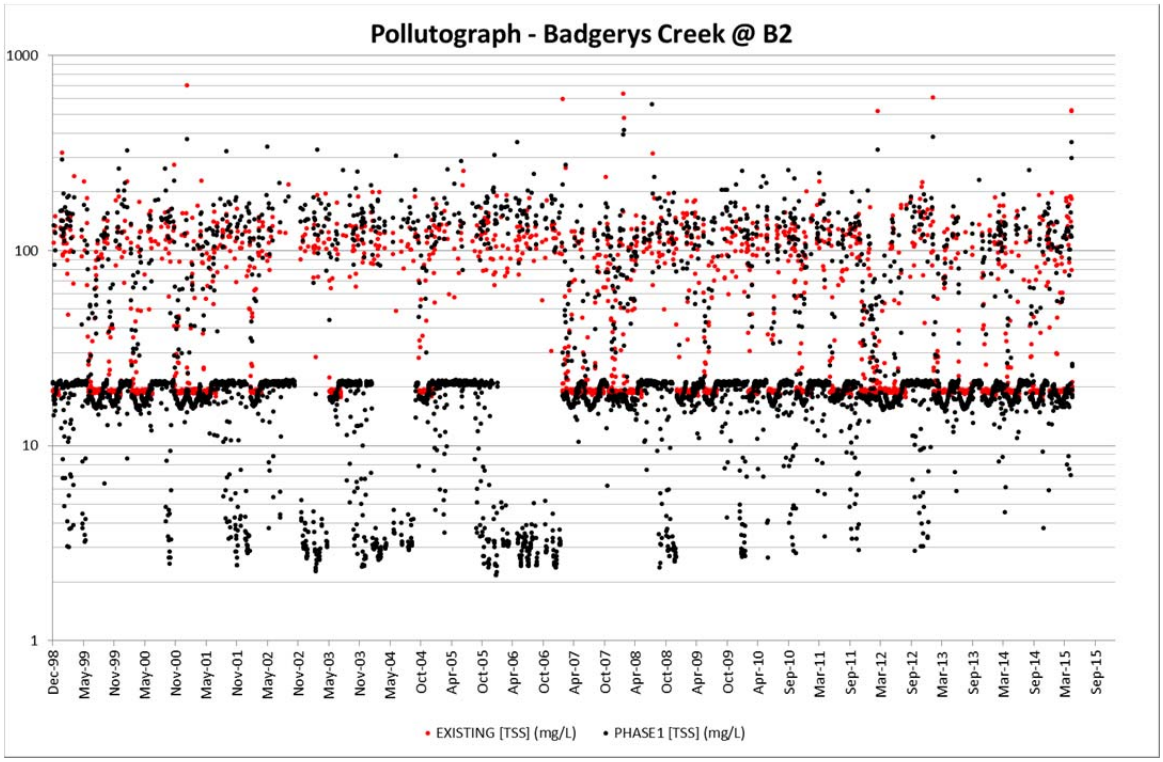


Figure B 4 Stage 1Total Suspended Solids at Badgerys Creek B2

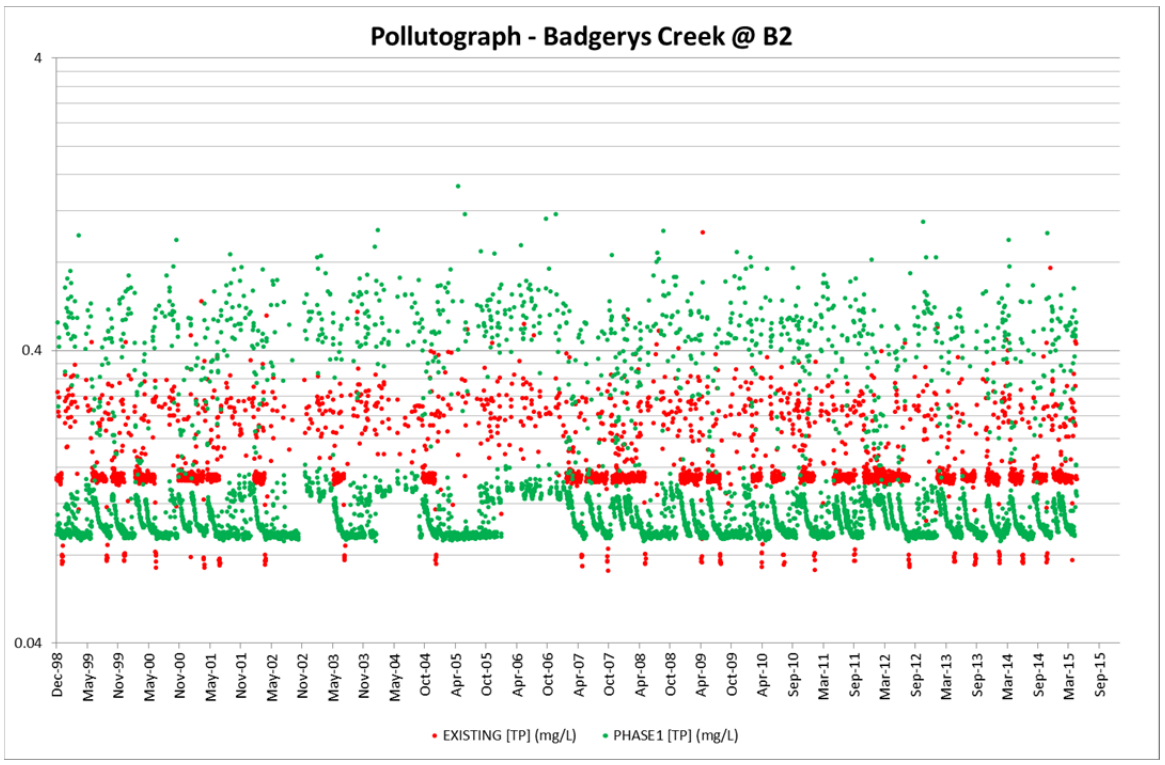


Figure B 5 Stage 1Total Phosphorus at Badgerys Creek B2

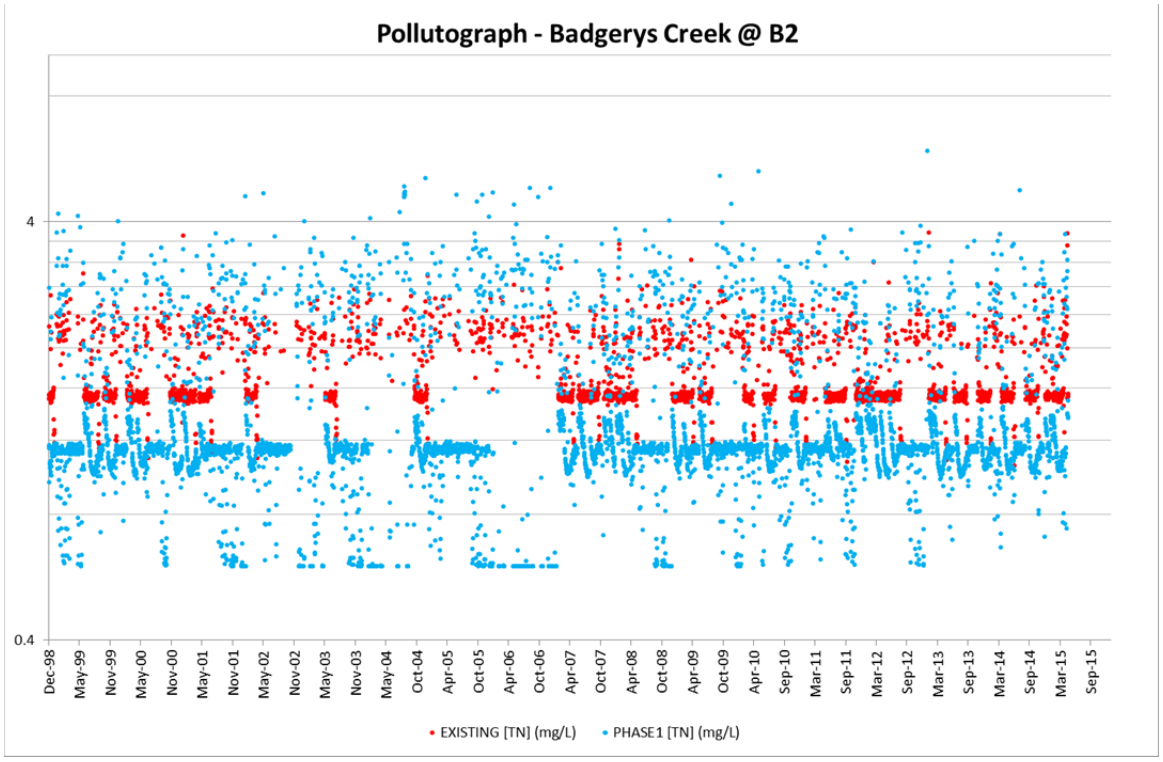


Figure B 6 Stage 1Total Nitrogen at Badgerys Creek B2

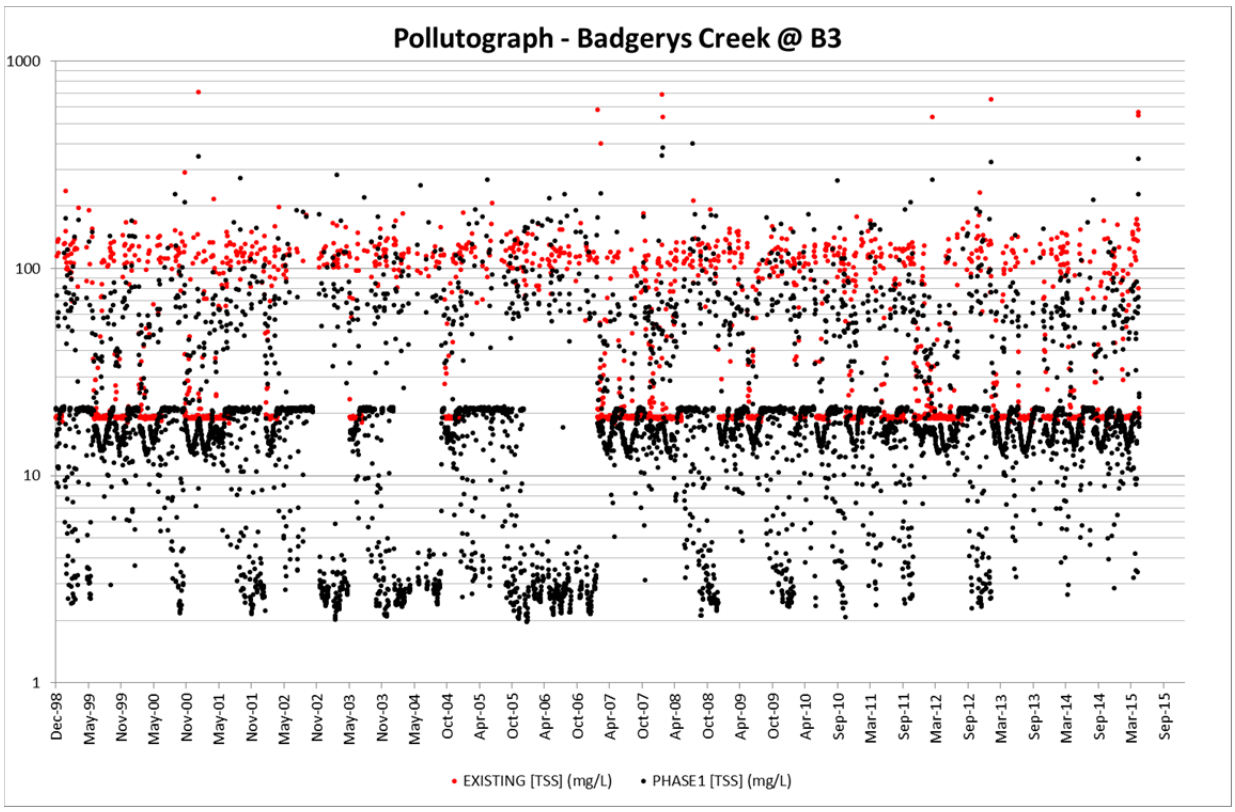


Figure B 7 Stage 1Total Suspended Solids at Badgerys Creek B3

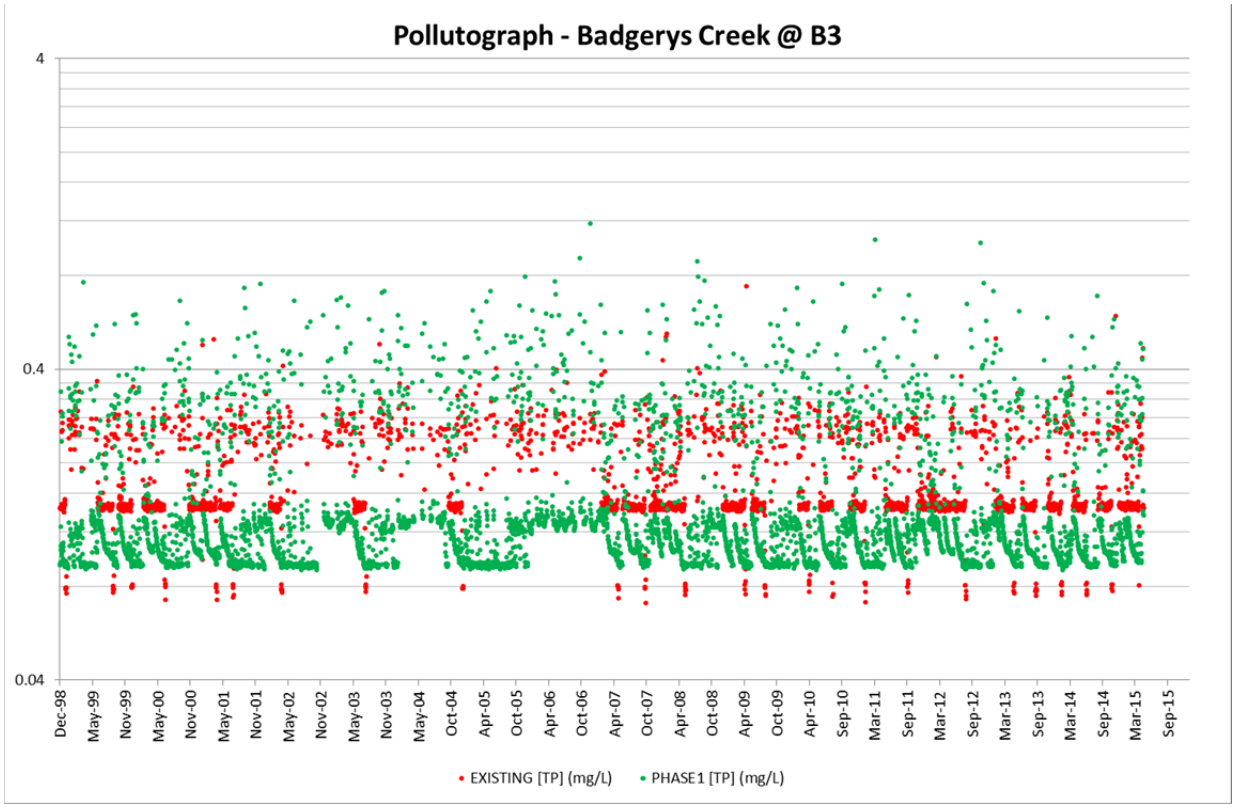


Figure B 8 Stage 1Total Phosphorus at Badgerys Creek B3

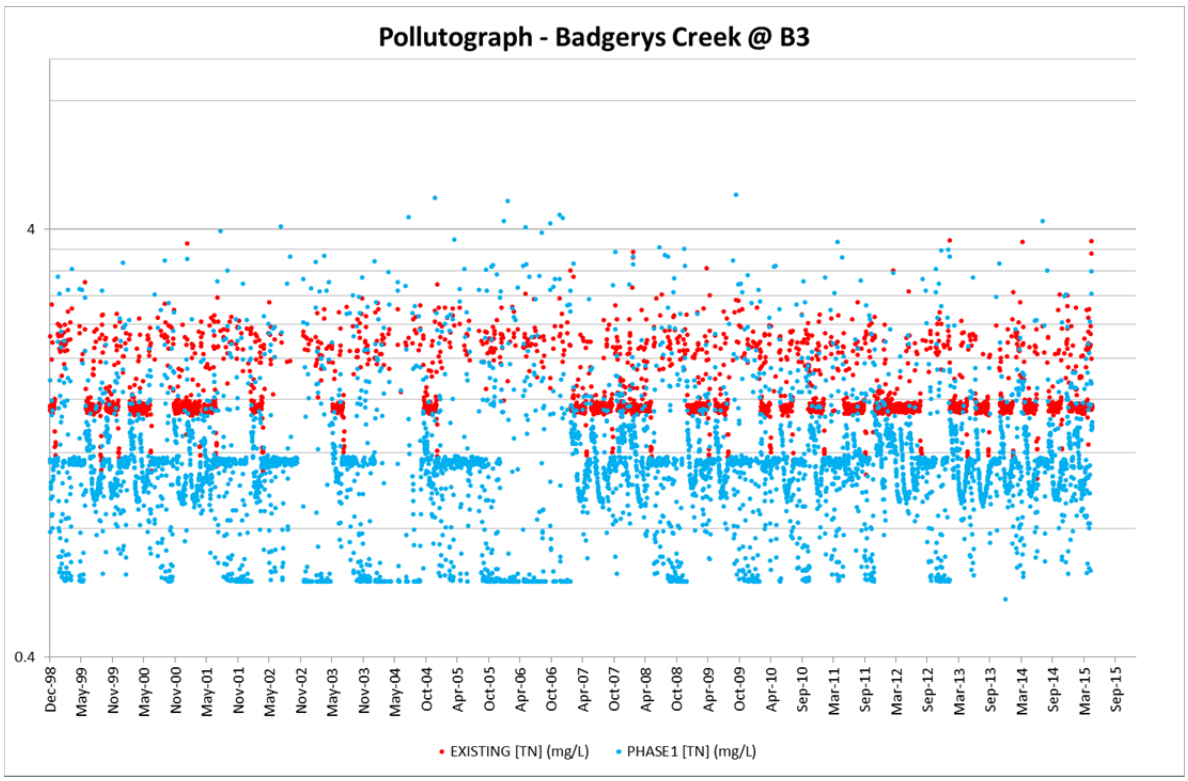


Figure B 9 Stage 1Total Nitrogen at Badgerys Creek B3

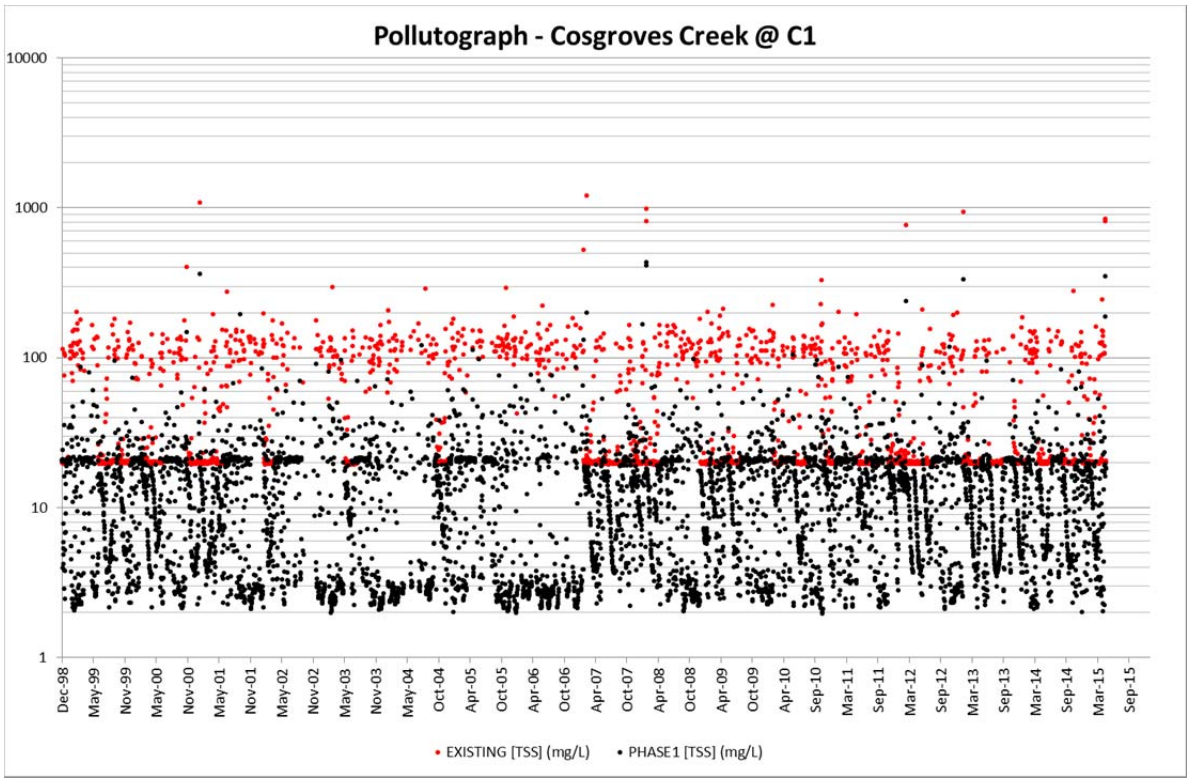


Figure B 10 Stage 1 Total Suspended Solids at Cosgroves Creek C1

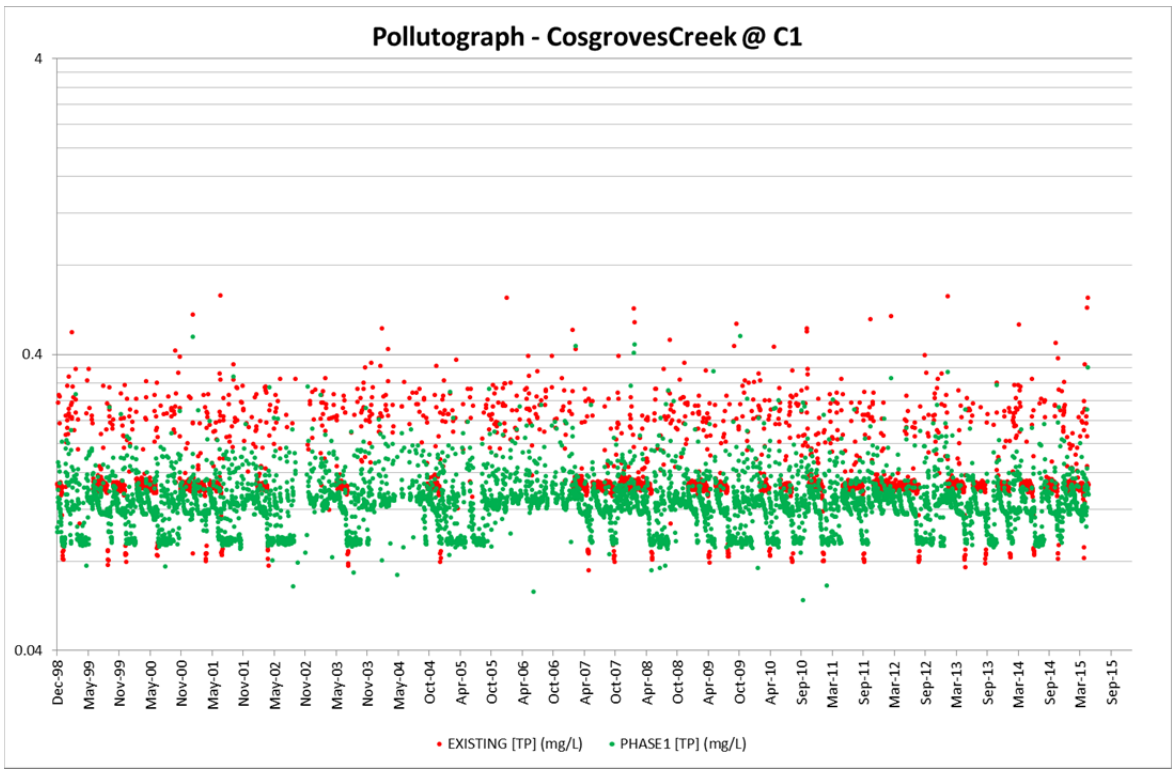


Figure B 11 Stage 1Total Phosphorus at Cosgroves Creek C1

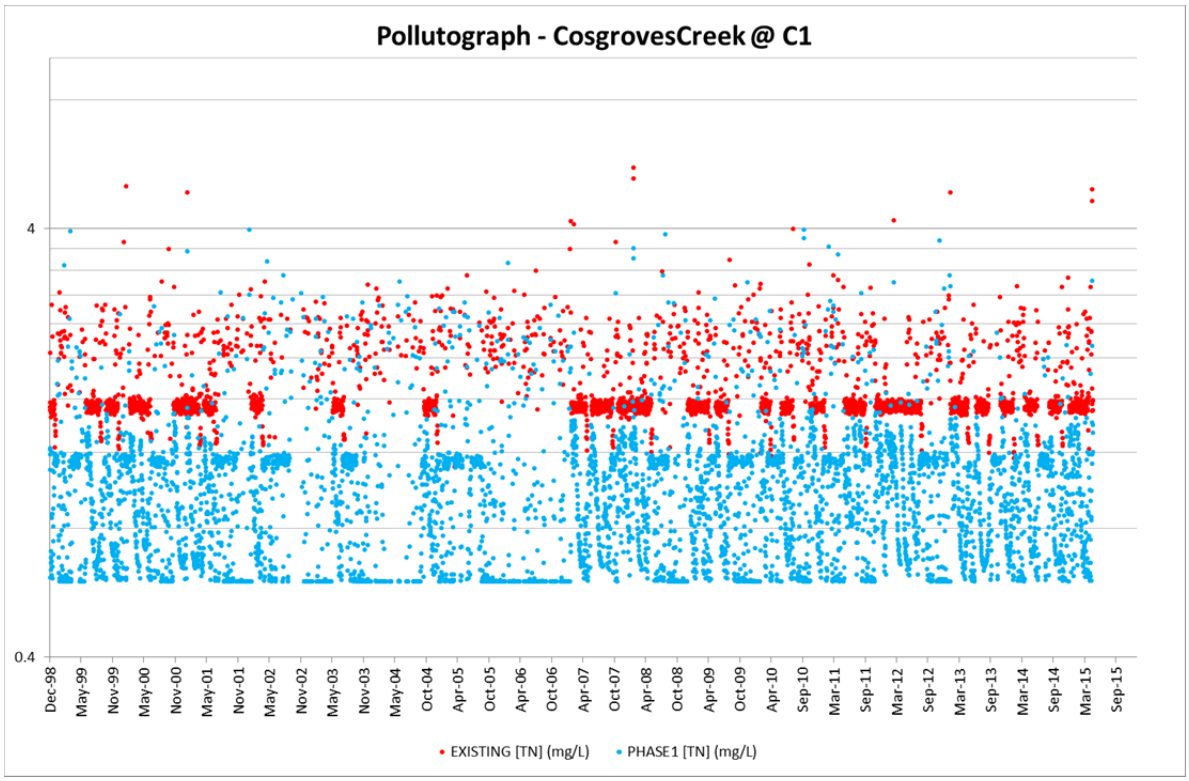


Figure B 12 Stage 1Total Nitrogen at Cosgroves Creek C1

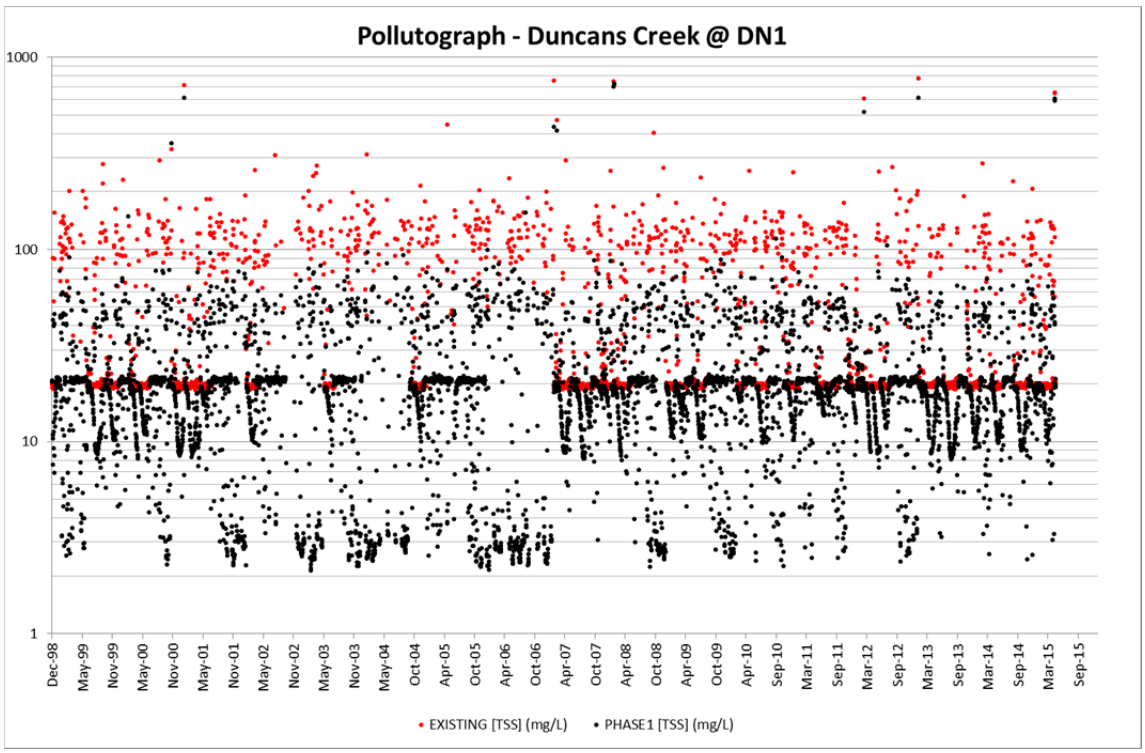


Figure B 13 Stage 1Total Suspended Solids at Duncans Creek DN1

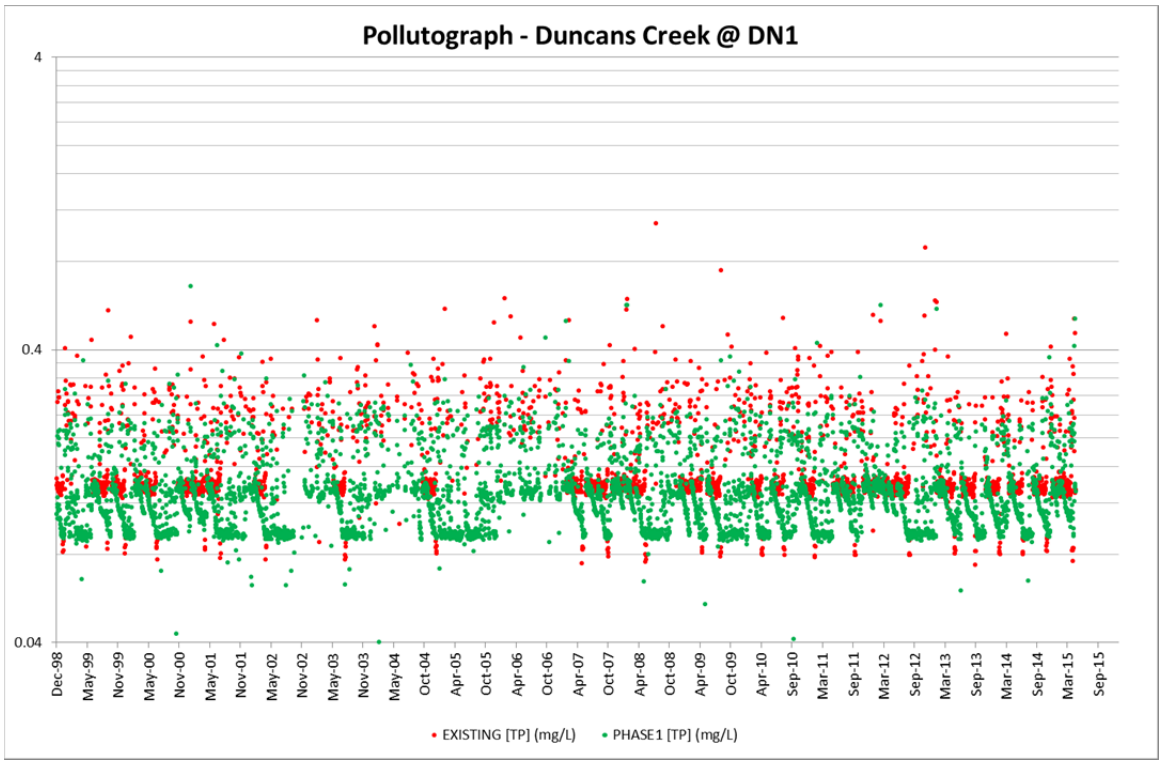


Figure B 14 Stage 1Total Phosphorus at Duncans Creek DN1

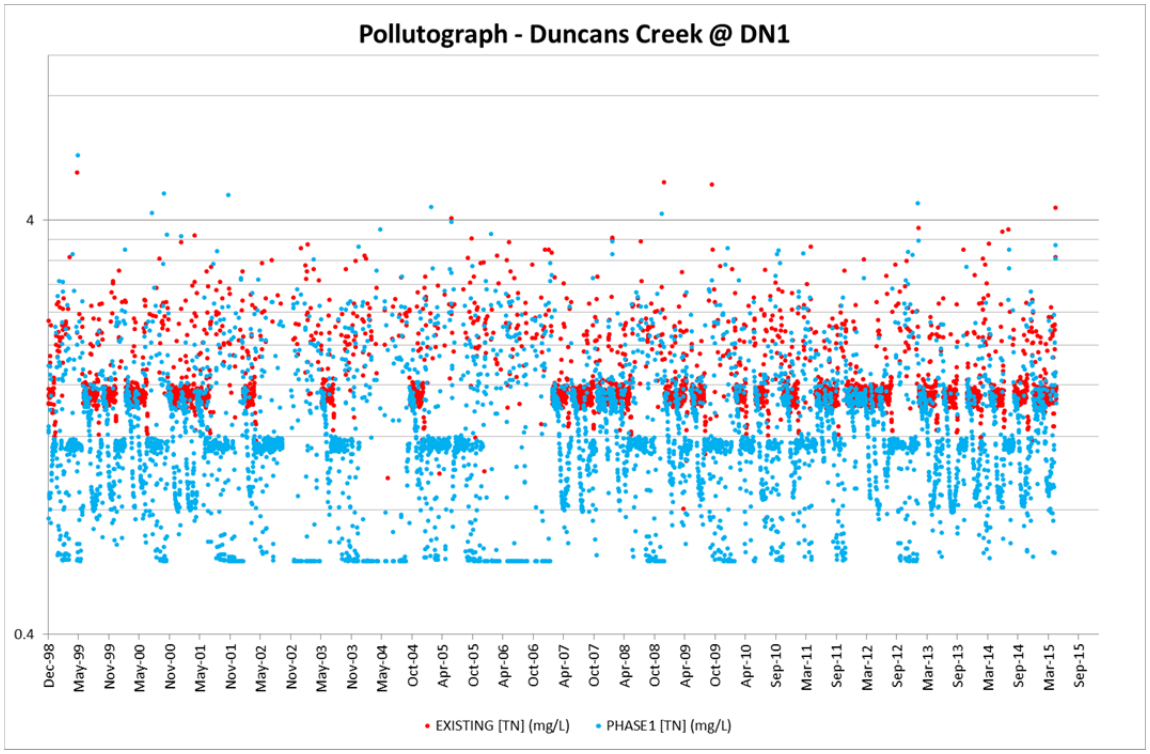


Figure B 15 Stage 1Total Nitrogen at Duncans Creek DN1

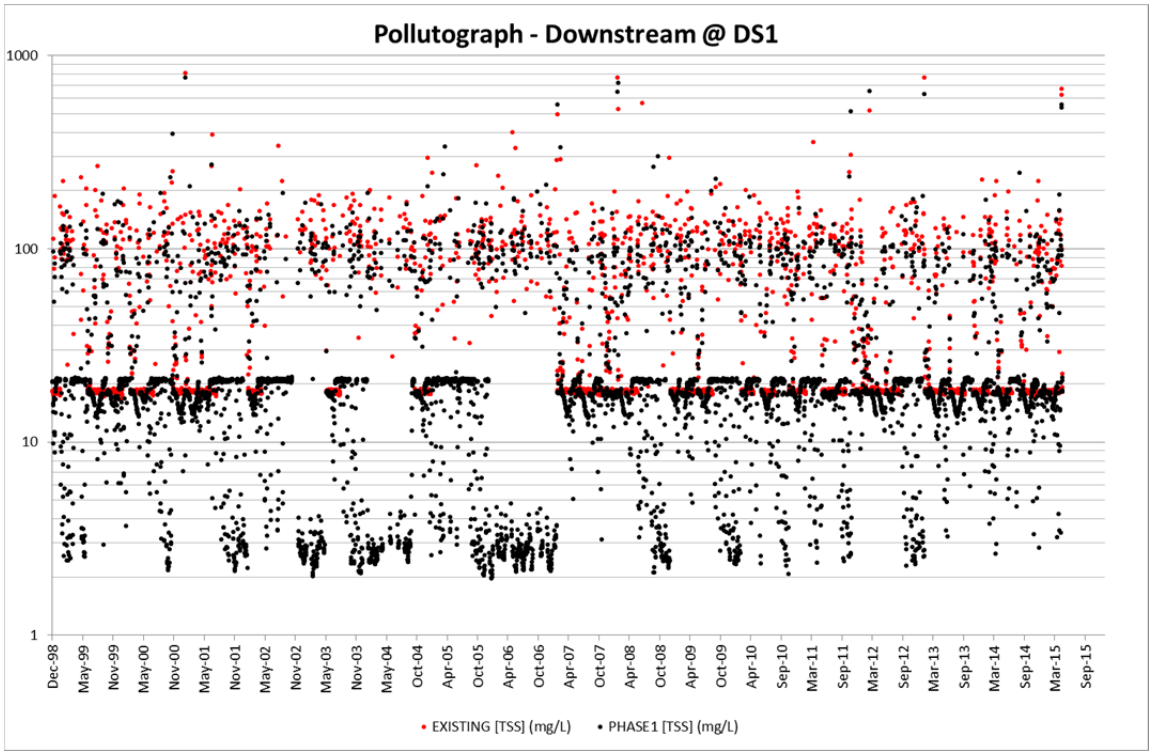


Figure B 16 Stage 1Total Suspended Solids Downstream at DS1

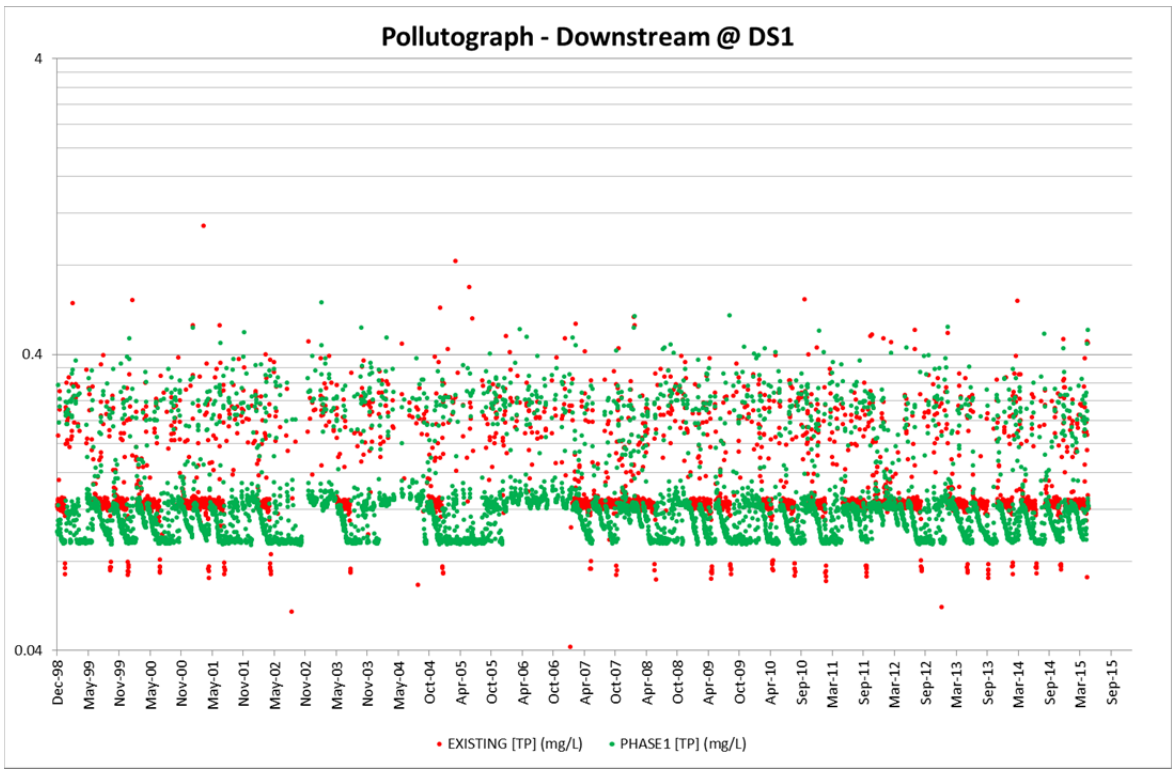
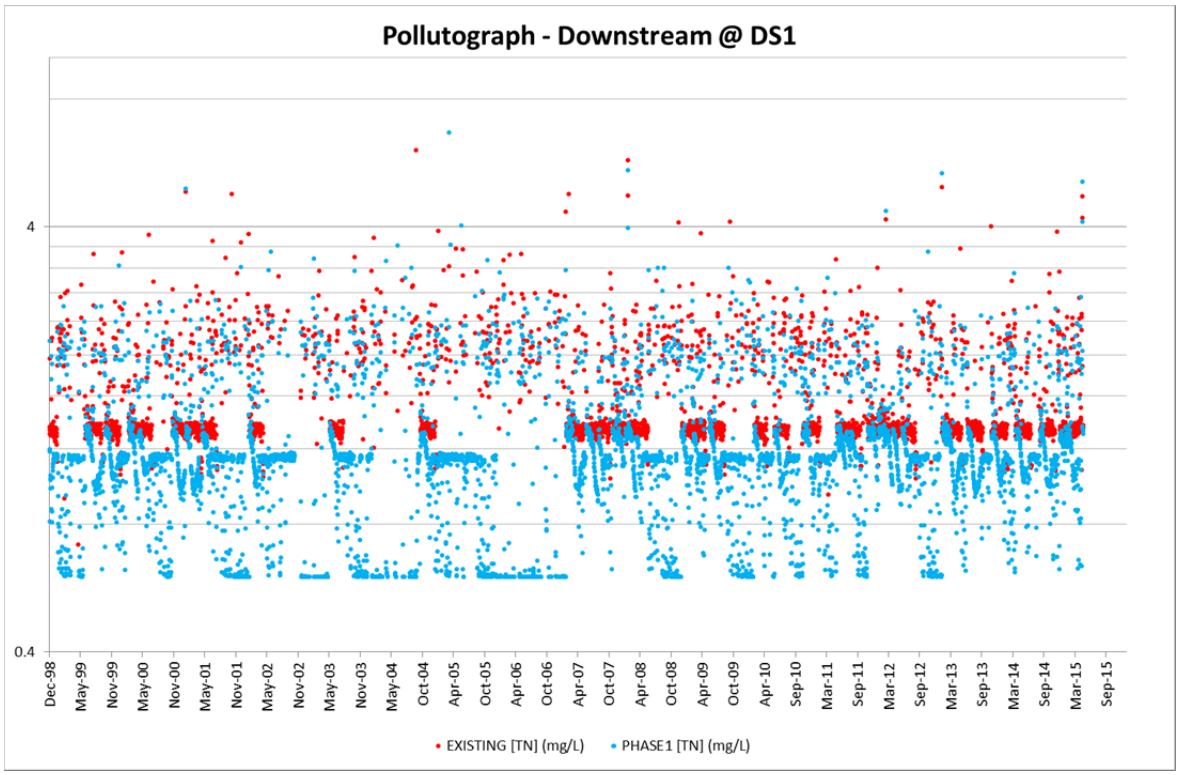


Figure B 17 Stage 1Total Phosphorus Downstream at DS1



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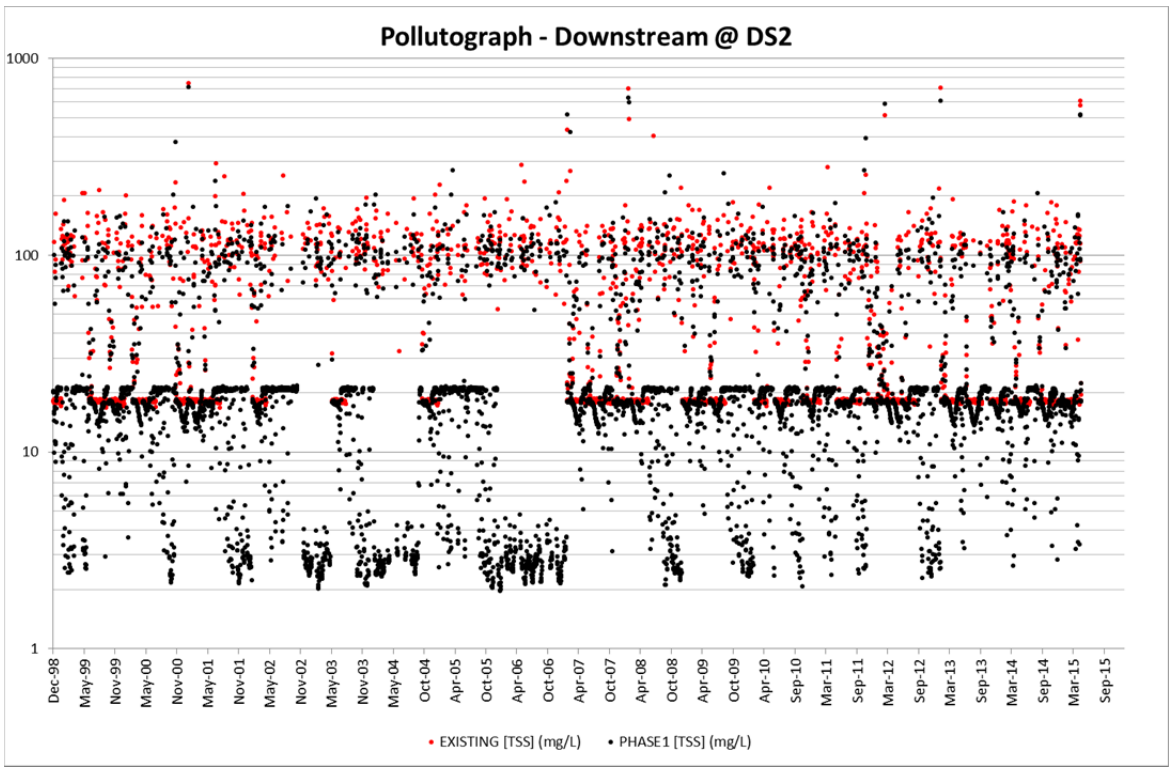


Figure B 19 Stage 1Total Suspended Solids Downstream at DS2

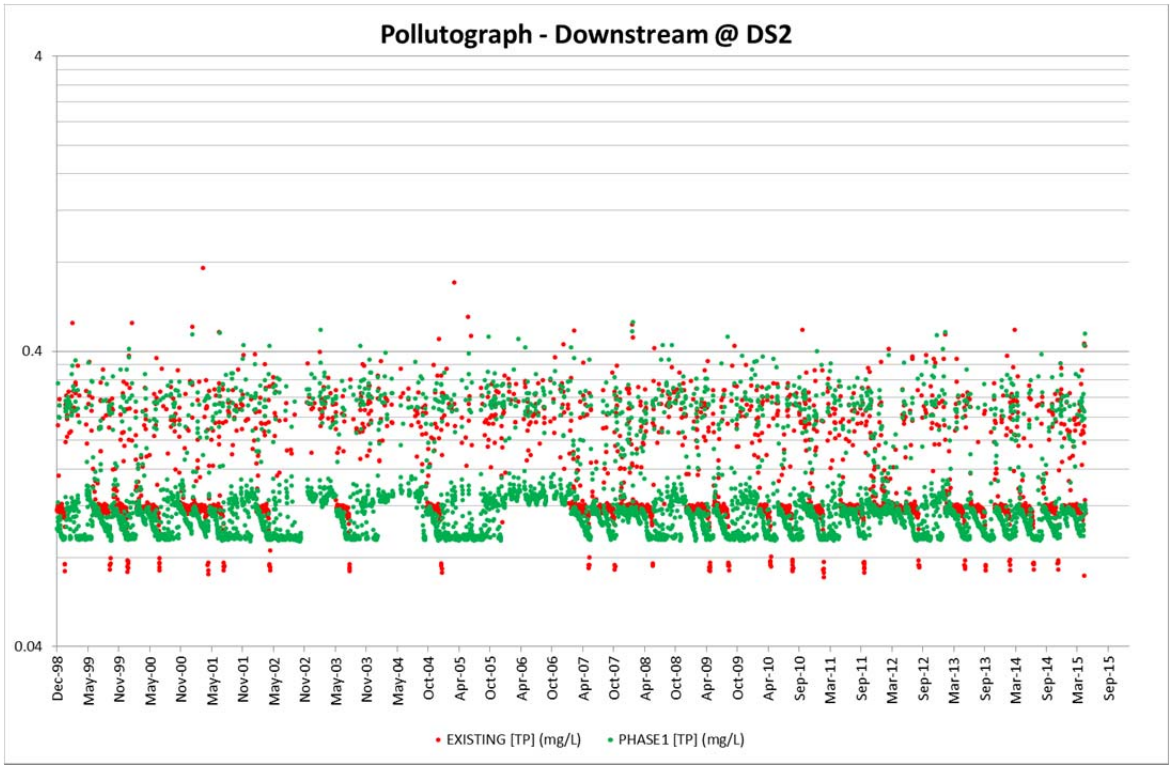


Figure B 20 Stage 1Total Phosphorus Downstream at DS2

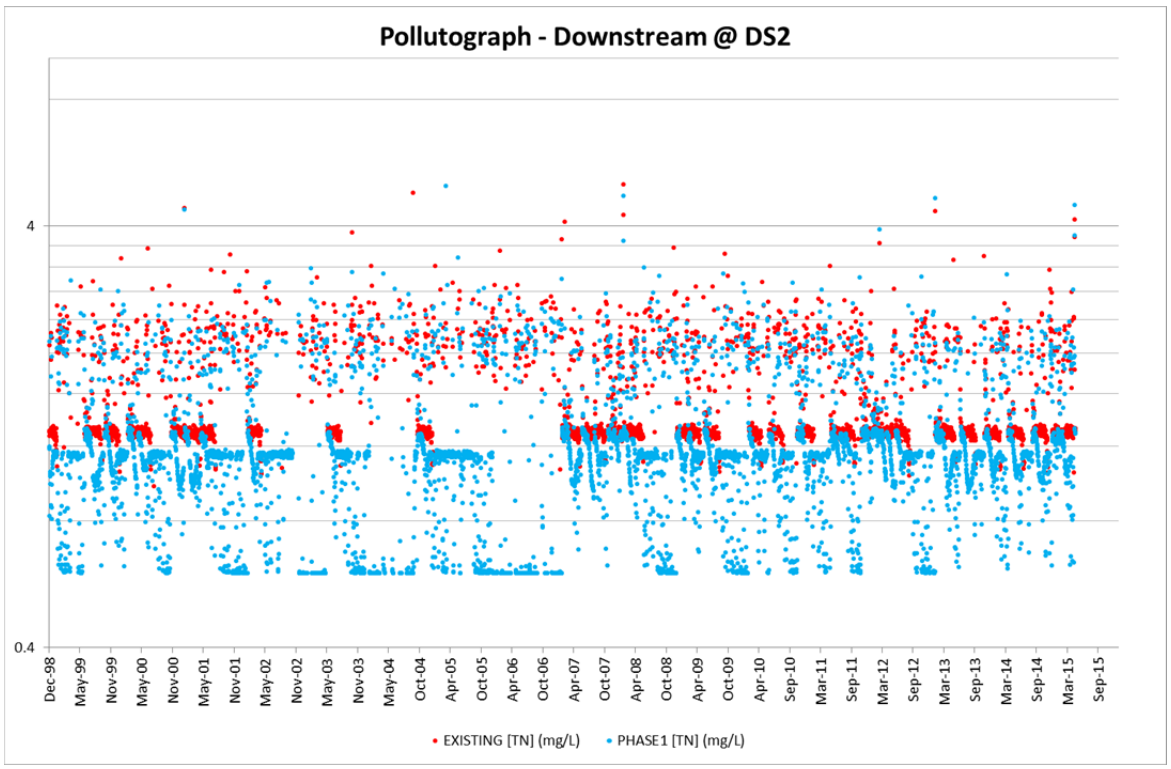


Figure B 21 Stage 1Total Nitrogen Downstream at DS2

Appendix C - MUSIC Water Quality Results for Longer Term Development

Plots of pollutant concentrations at various locations

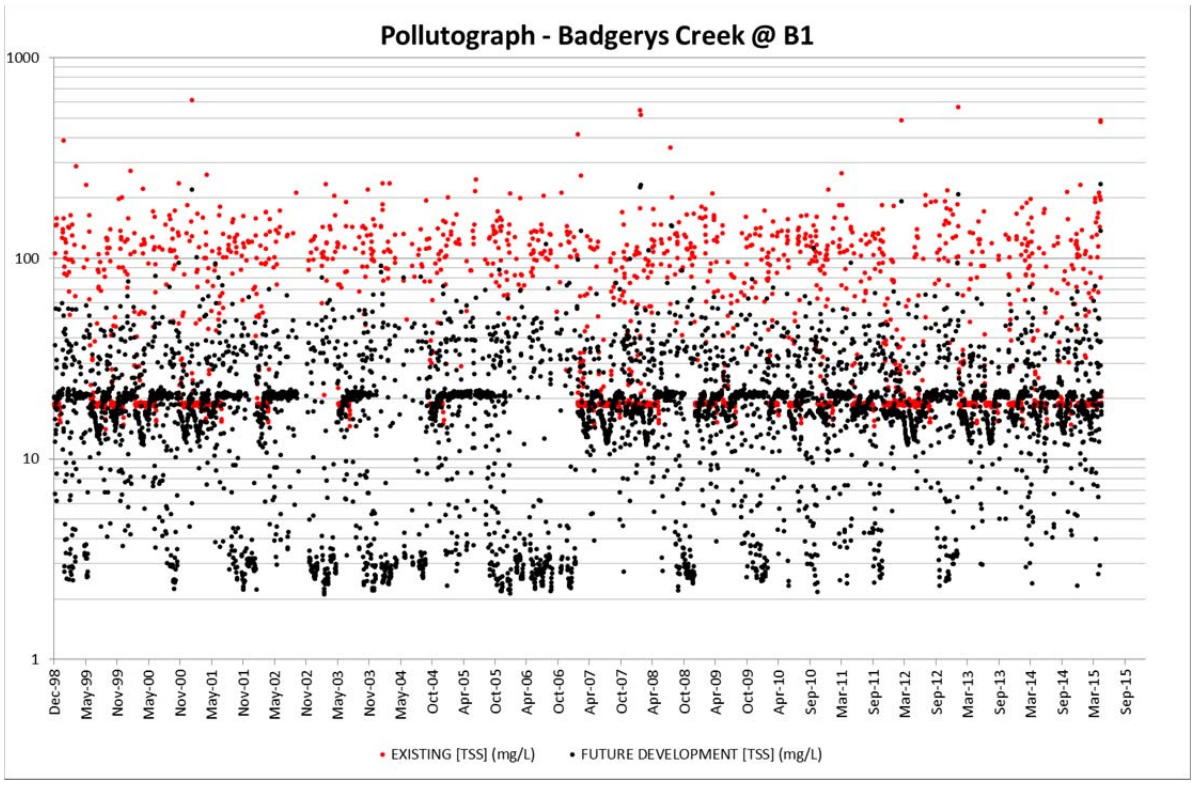


Figure C 1 Longer Term Development Total Suspended Solids at Badgerys Creek B1

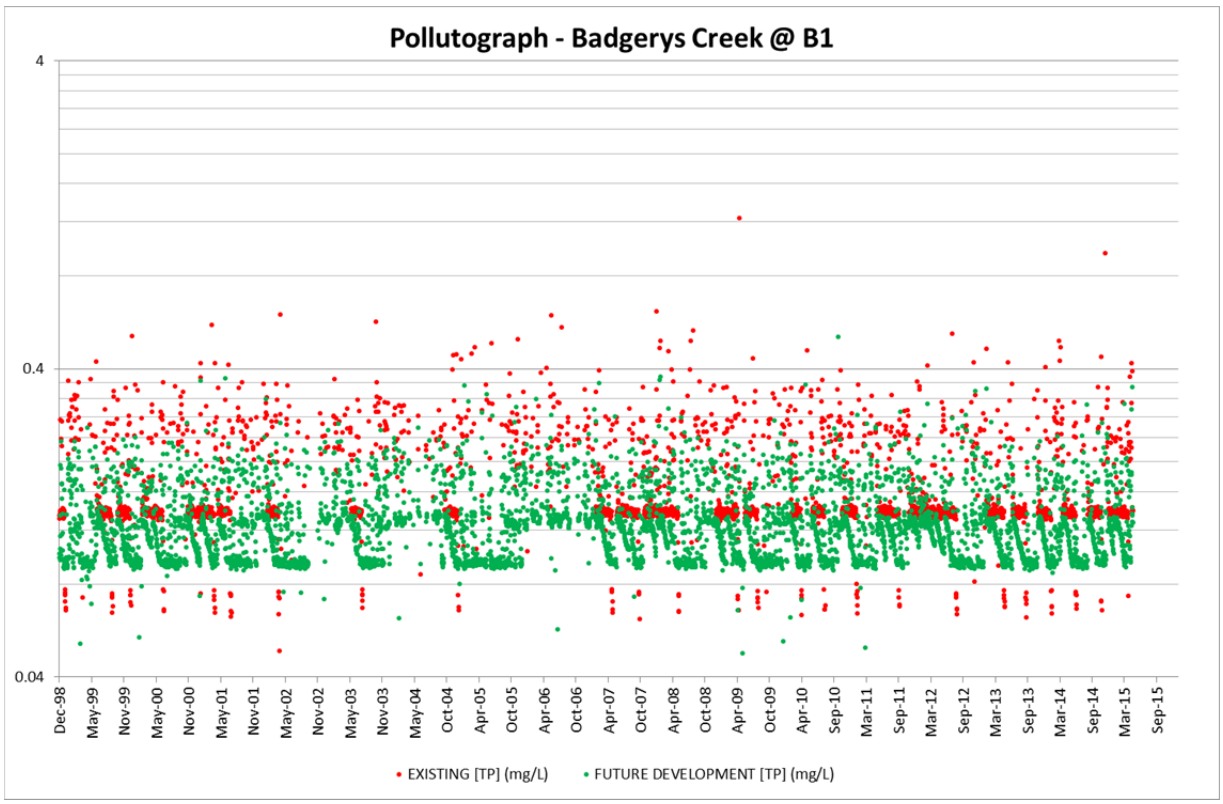


Figure C 2 Longer Term Development Total Phosphorus at Badgerys Creek B1

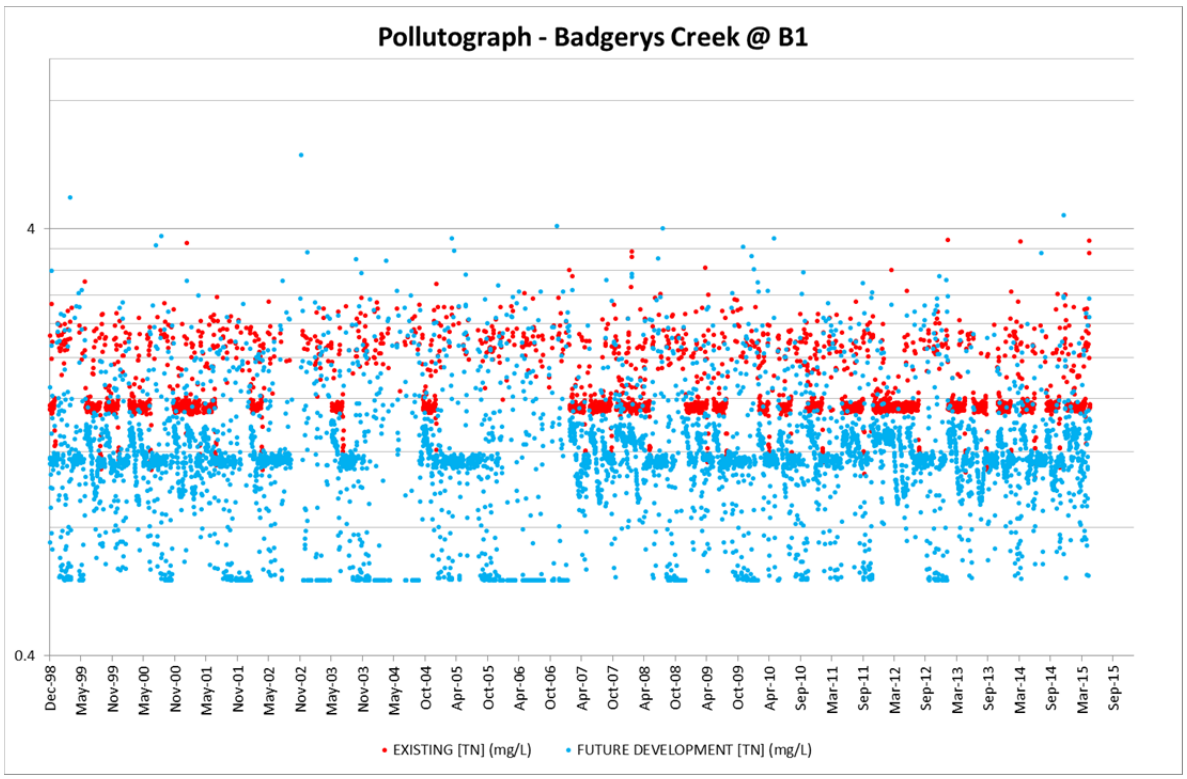


Figure C 3 Longer Term Development Total Nitrogen at Badgerys Creek B1

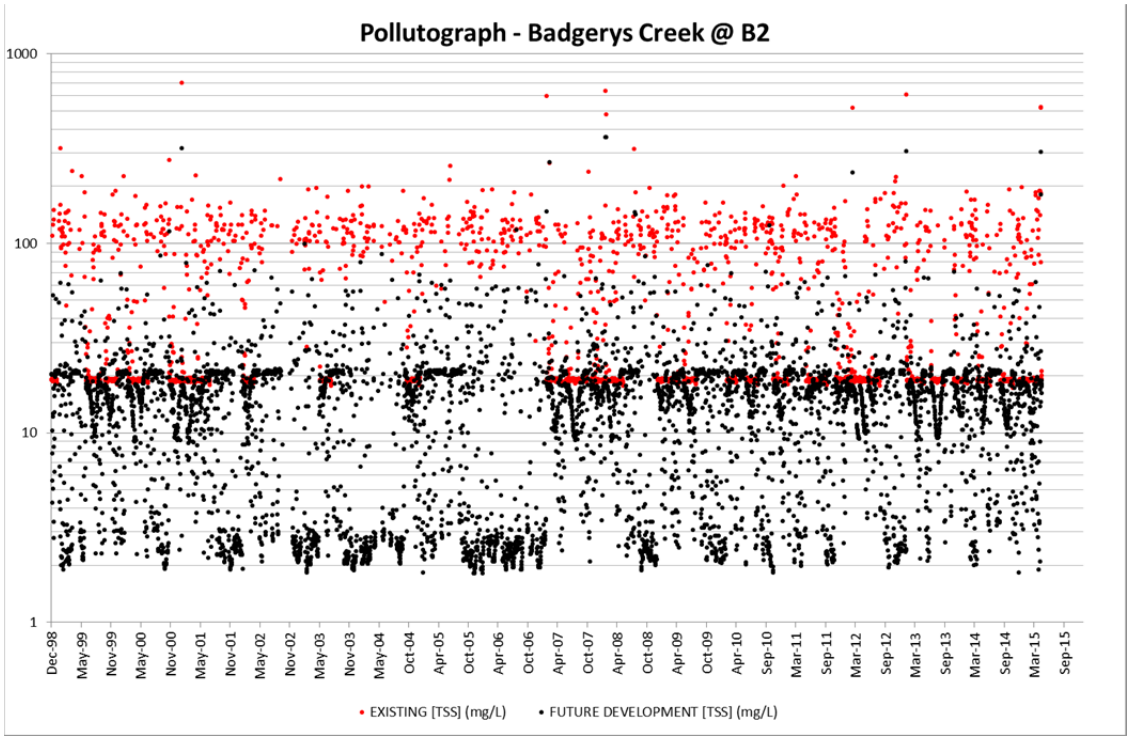


Figure C 4 Longer Term Development Total Suspended Solids at Badgerys Creek B2

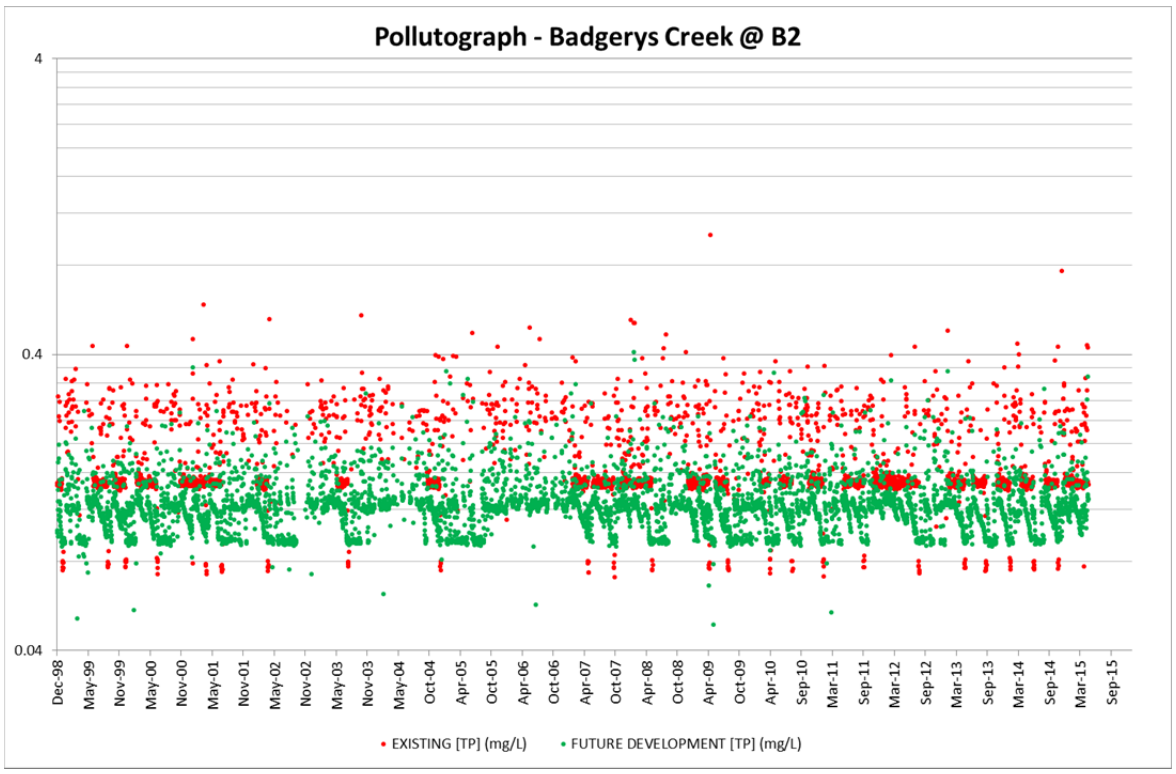


Figure C 5 Longer Term Development Total Phosphorus at Badgerys Creek B2

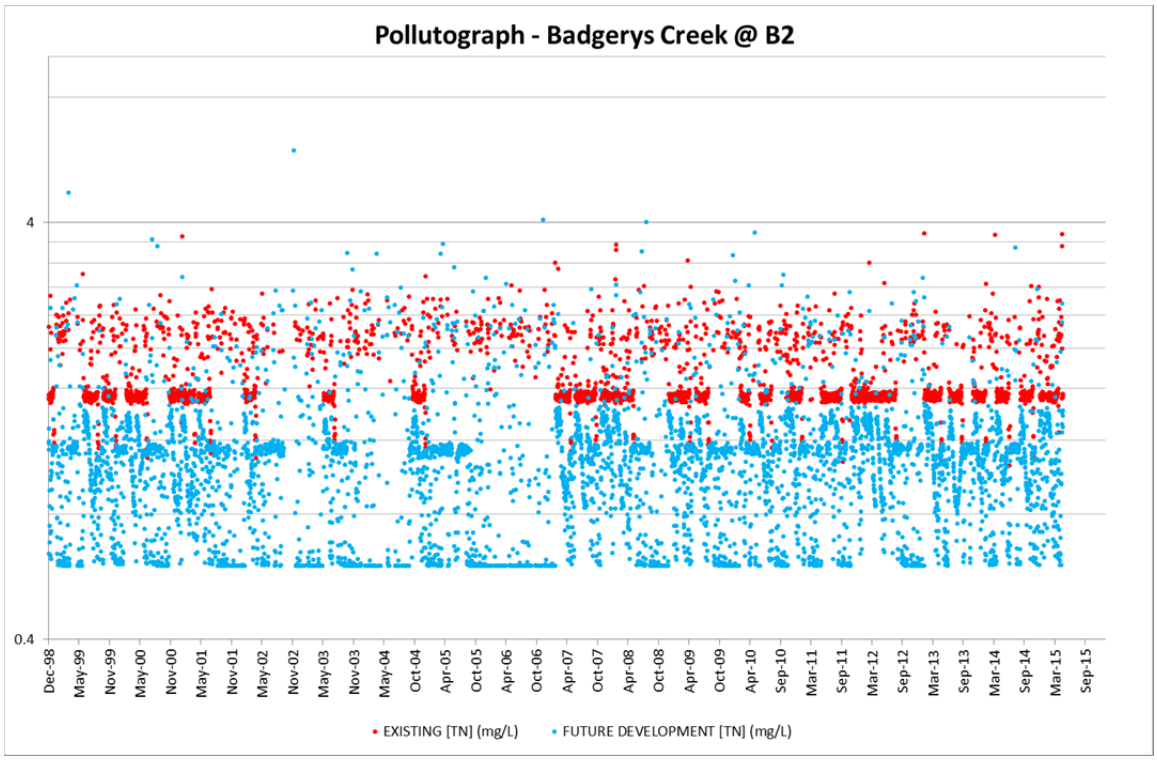


Figure C 6 Longer Term Development Total Nitrogen at Badgerys Creek B2

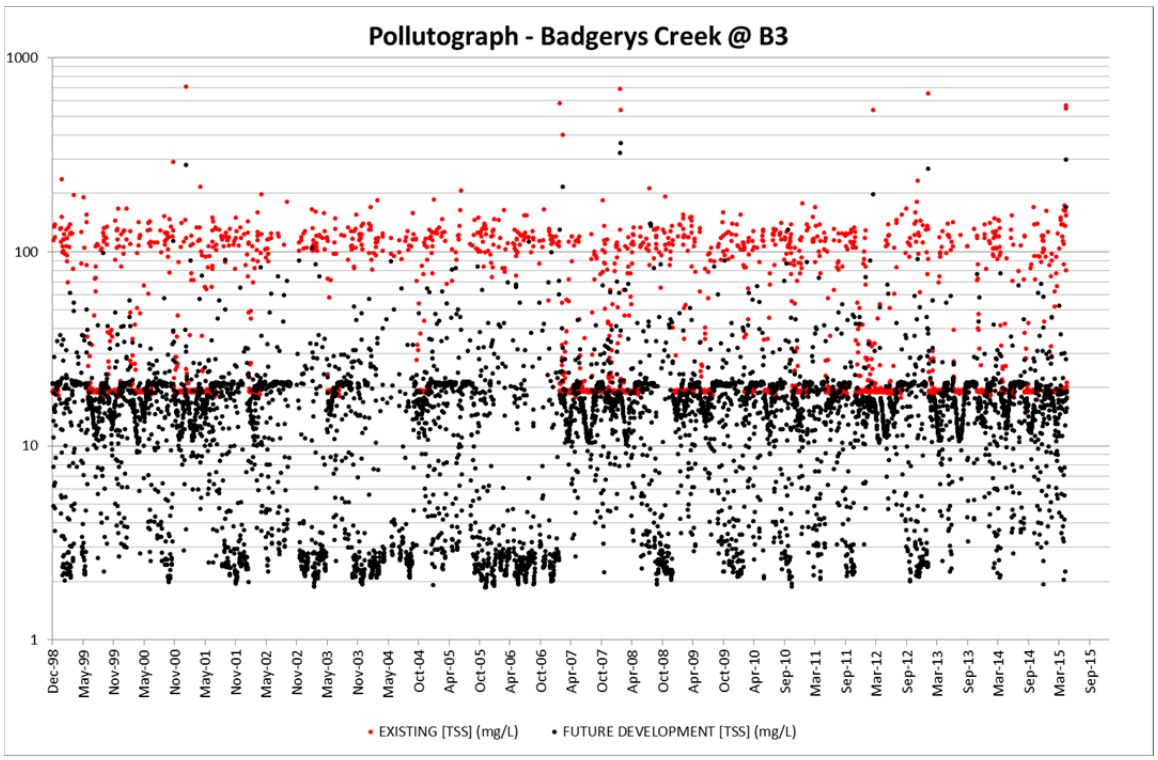


Figure C 7 Longer Term Development Total Suspended Solids at Badgerys Creek B3

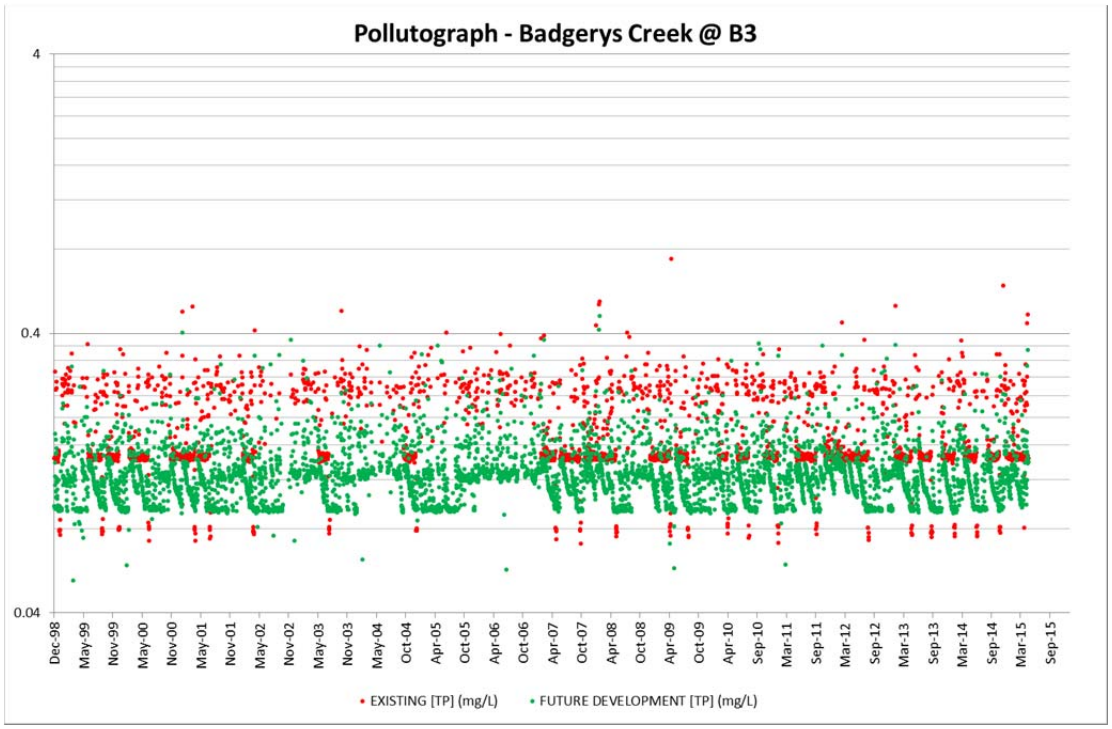


Figure C 8 Longer Term Development Total Phosphorus at Badgerys Creek B3

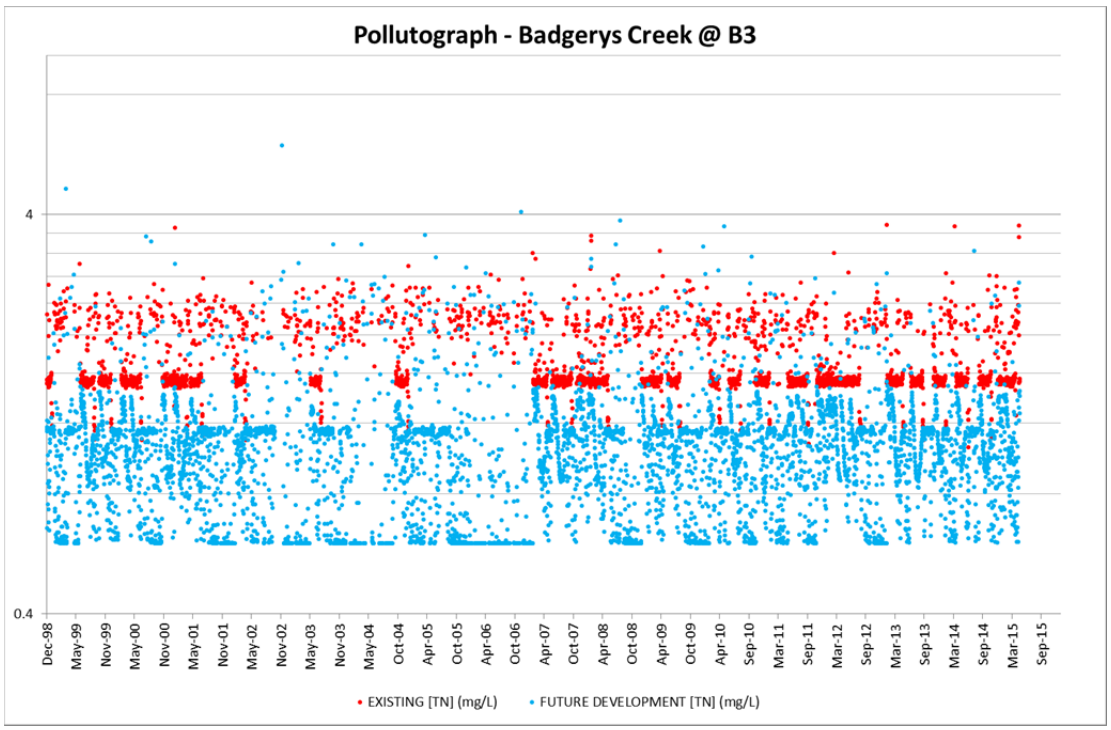


Figure C 9 Longer Term Development Total Nitrogen at Badgerys Creek B3

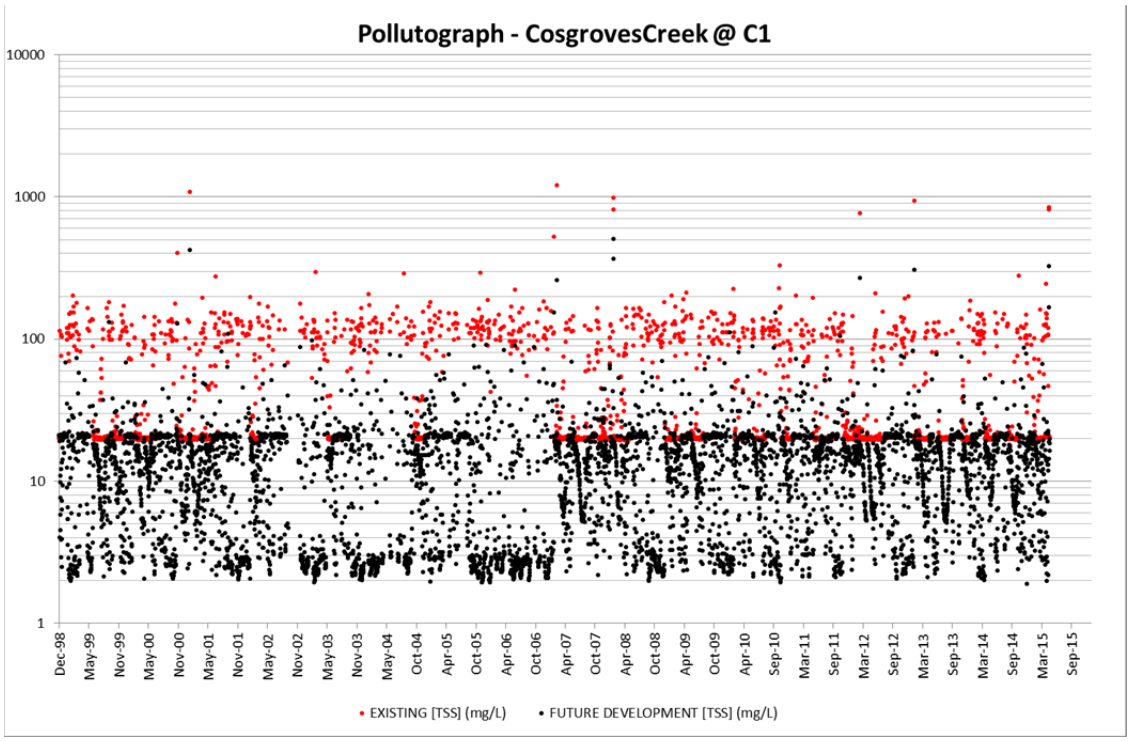


Figure C 10 Longer Term Development Total Suspended Solids at Cosgroves Creek C1

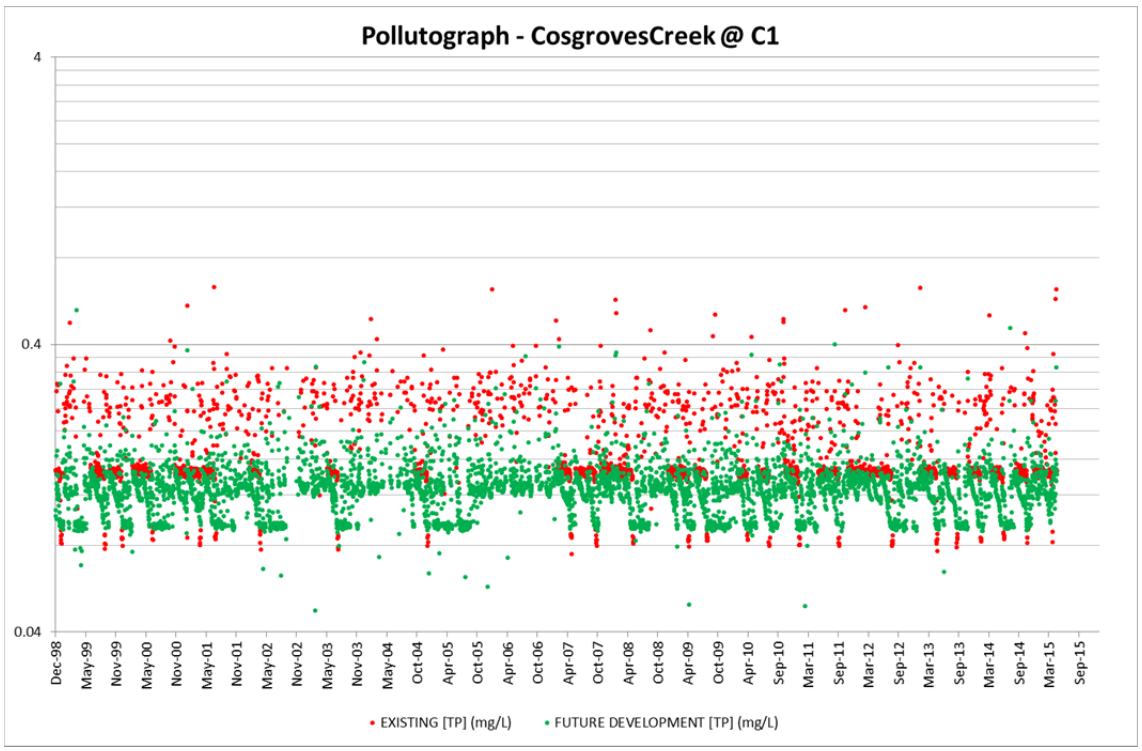


Figure C 11 Longer Term Development - Total Phosphorus at Cosgroves Creek C1

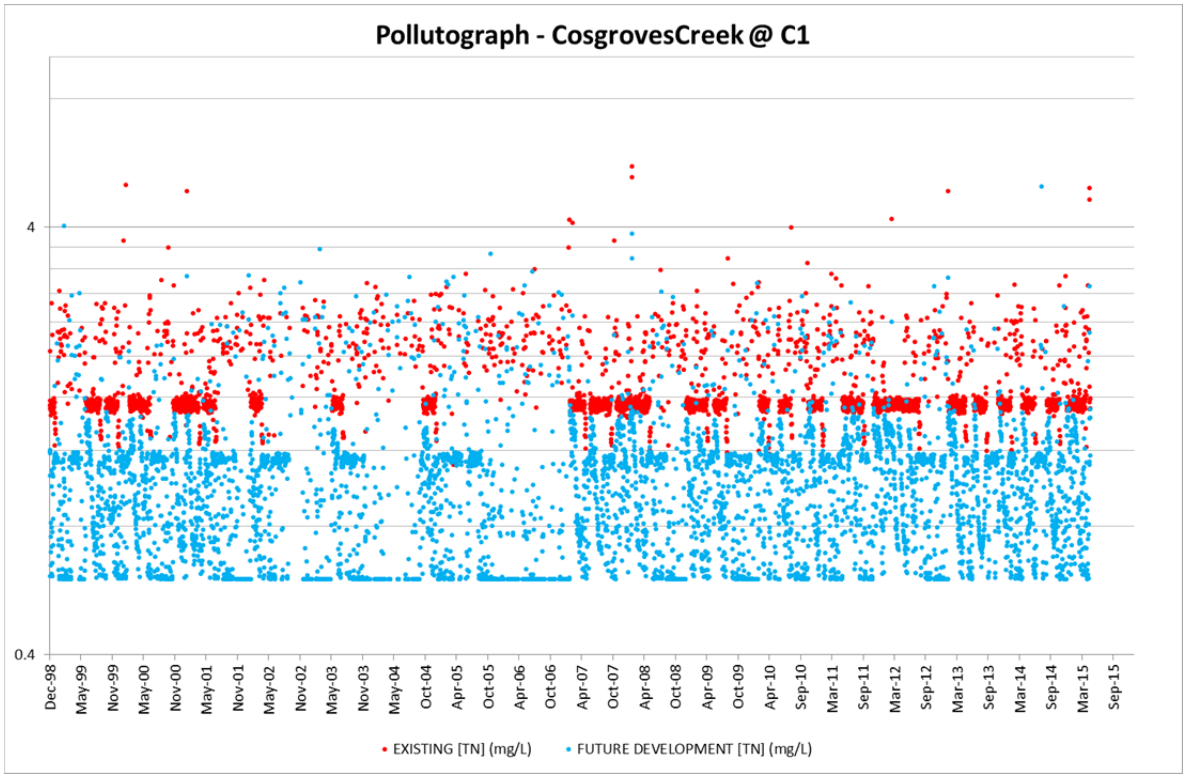


Figure C 12: Longer Term Development Total Nitrogen at Cosgroves Creek C1

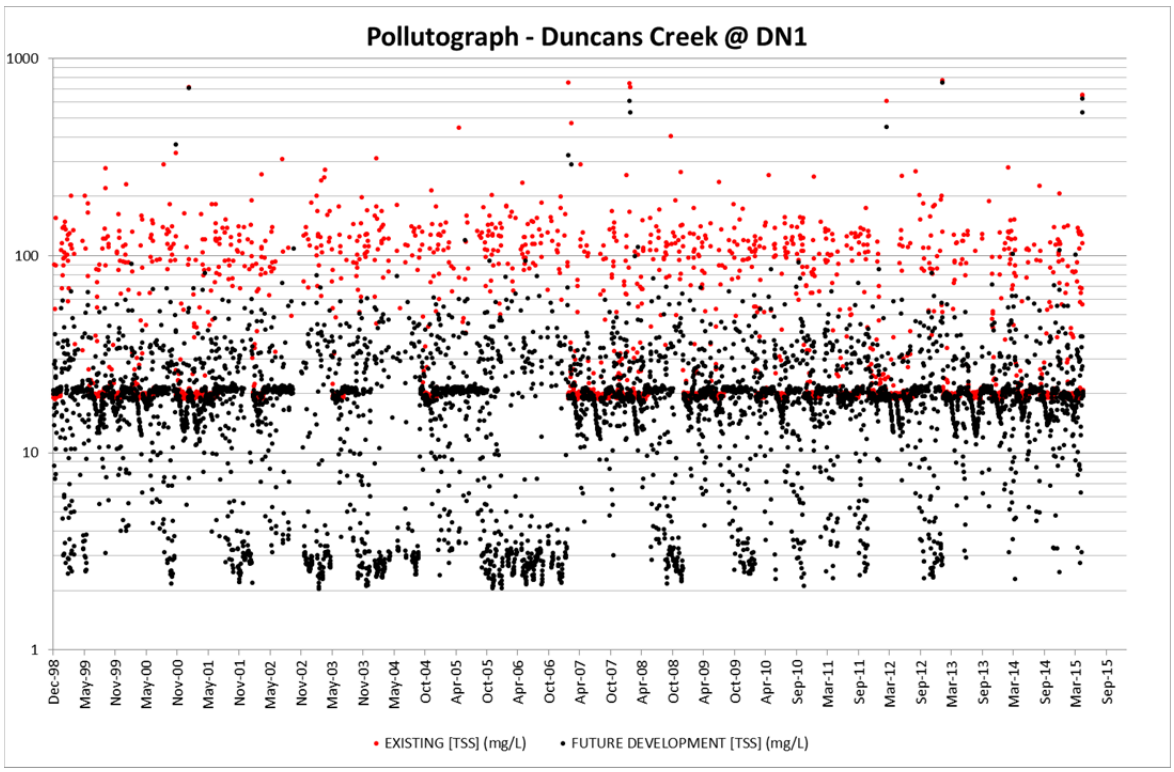


Figure C 13 Longer Term Development Total Suspended Solids at Duncans Creek DN1

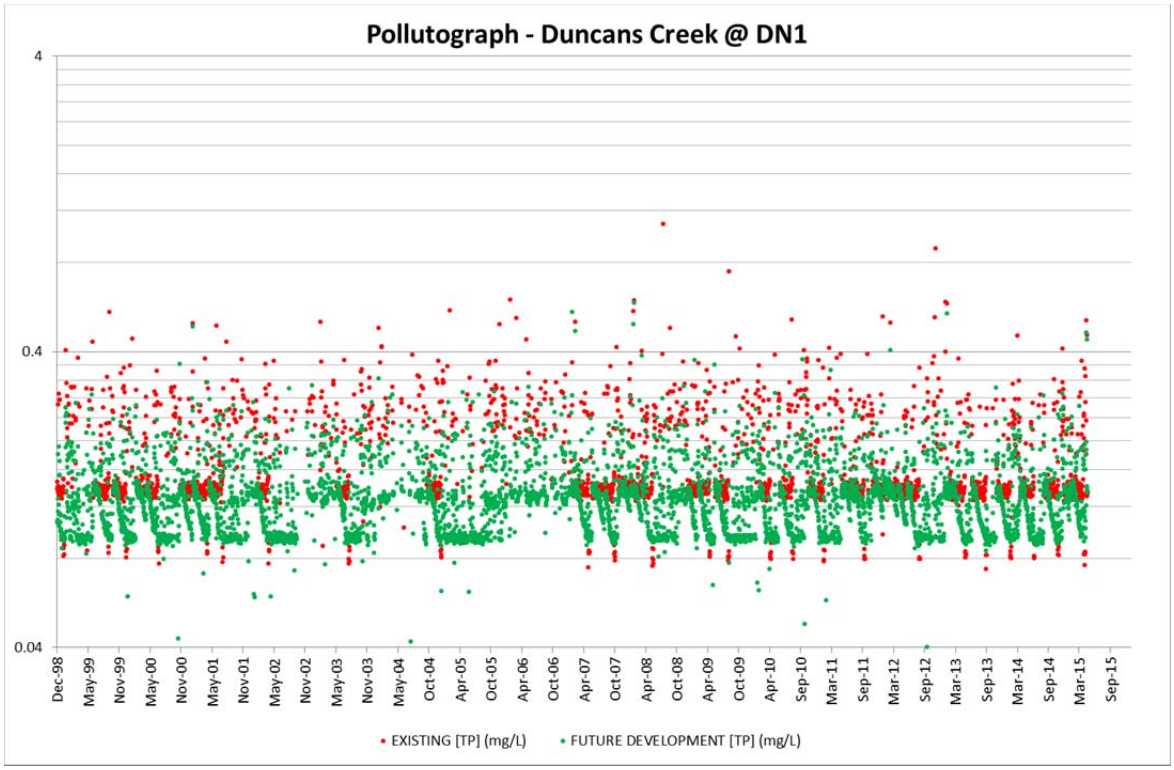


Figure C 14 Longer Term Development Total Phosphorus at Duncans Creek DN1

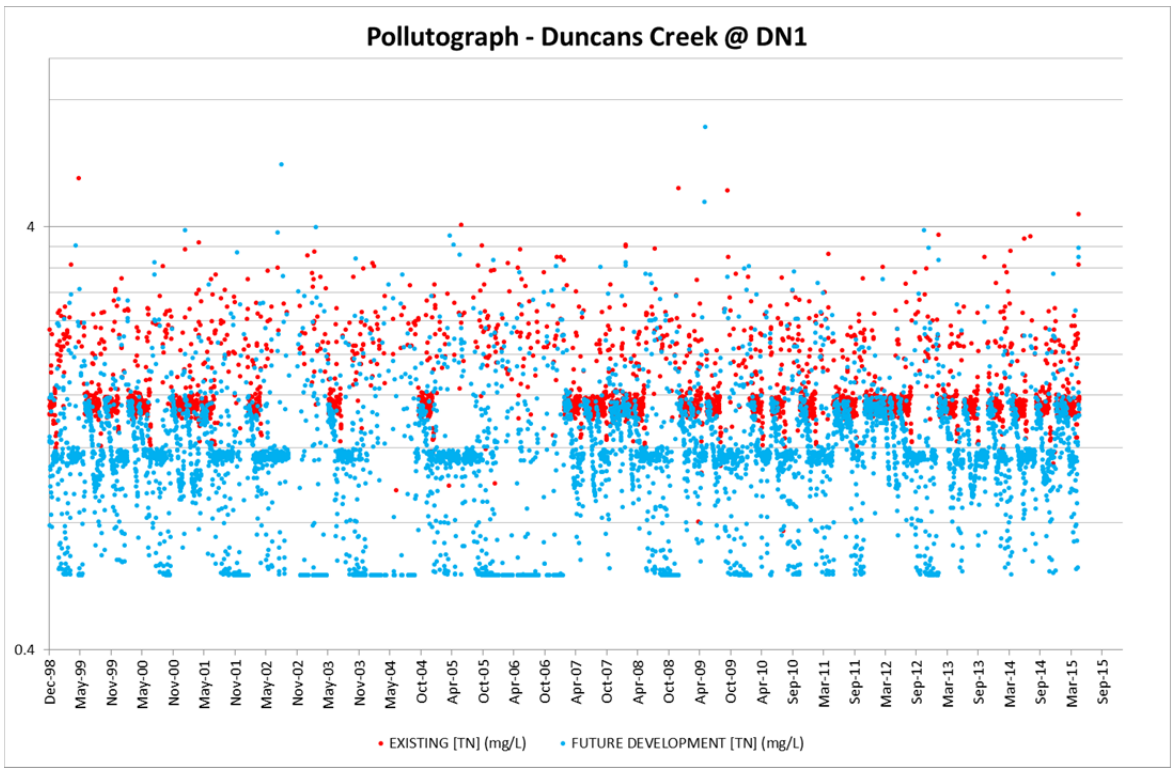


Figure C 15 Longer Term Development Total Nitrogen at Duncans Creek DN1

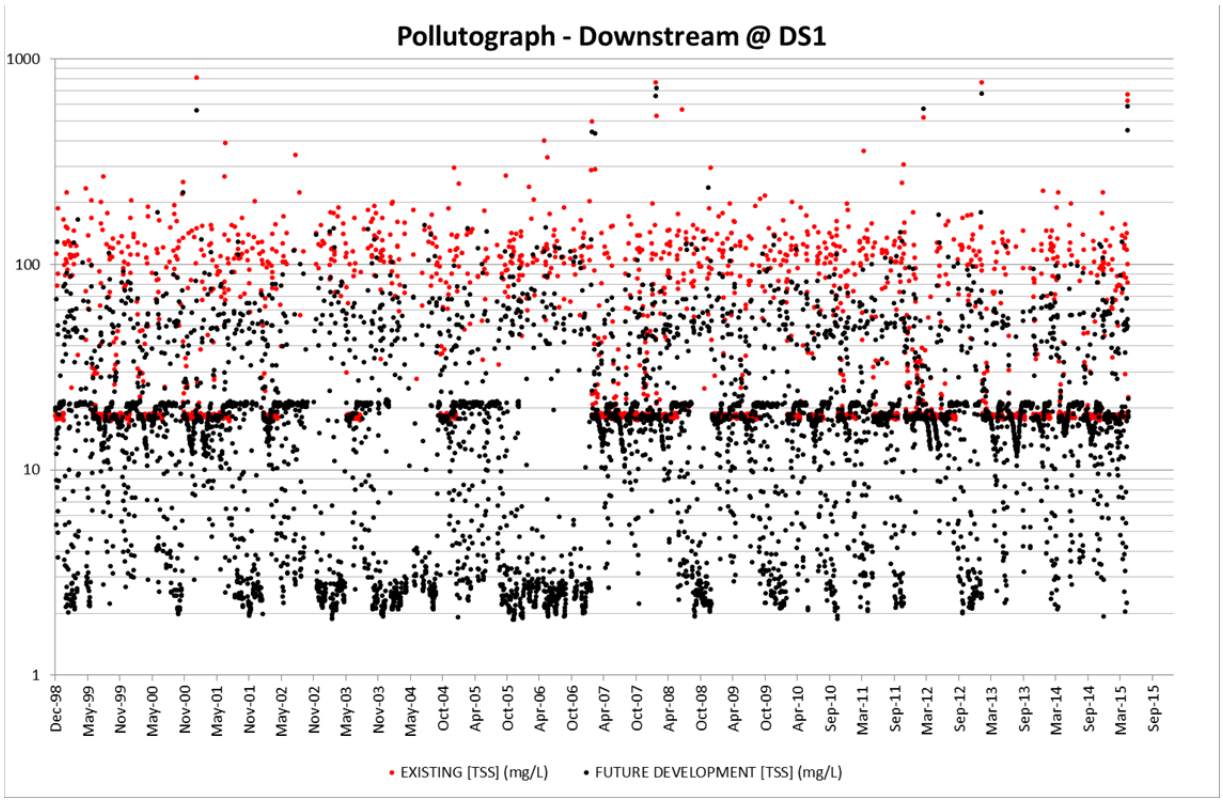


Figure C 16 Longer Term Development Total Suspended Solids Downstream at DS1

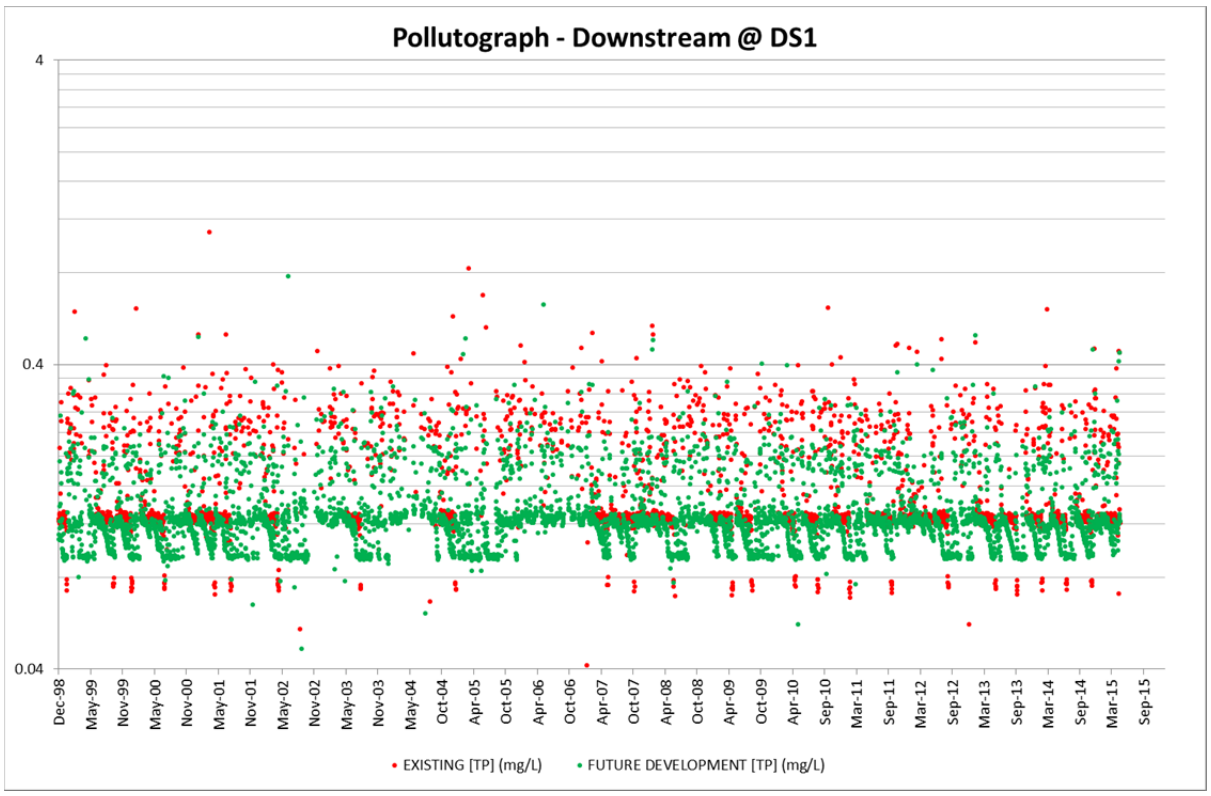
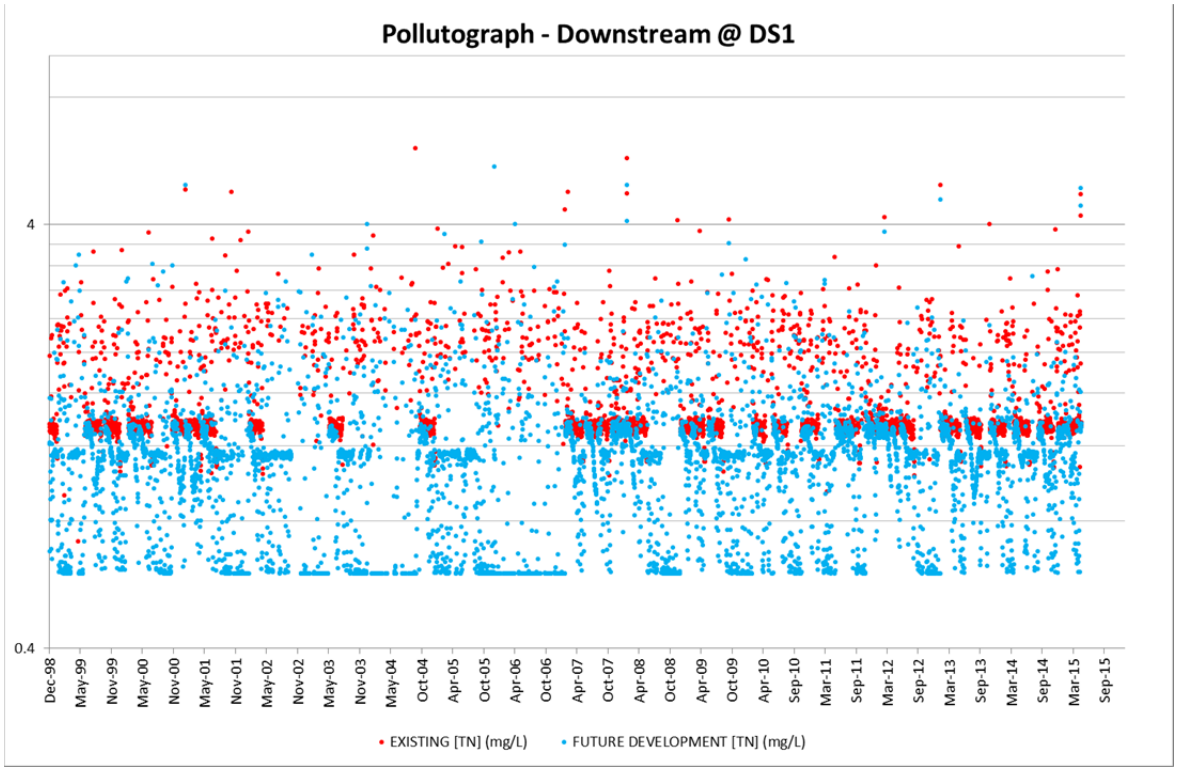


Figure C 17 Longer Term Development Total Phosphorus Downstream at DS1



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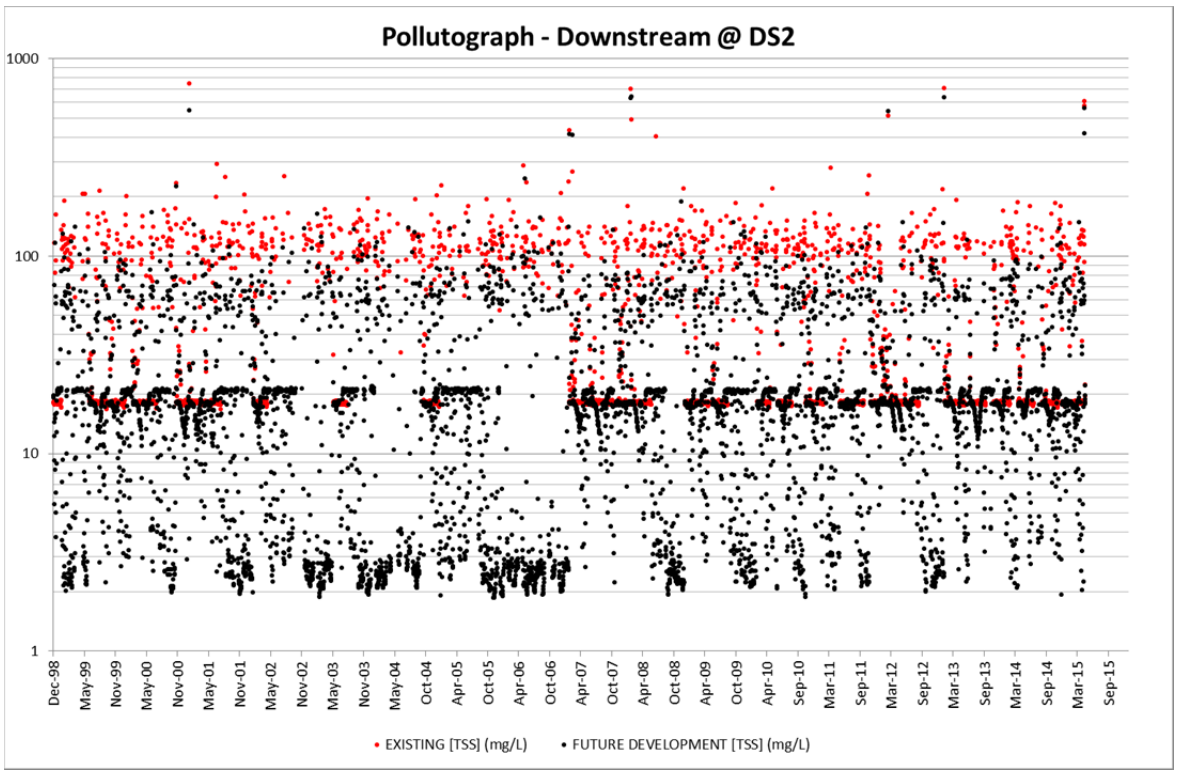
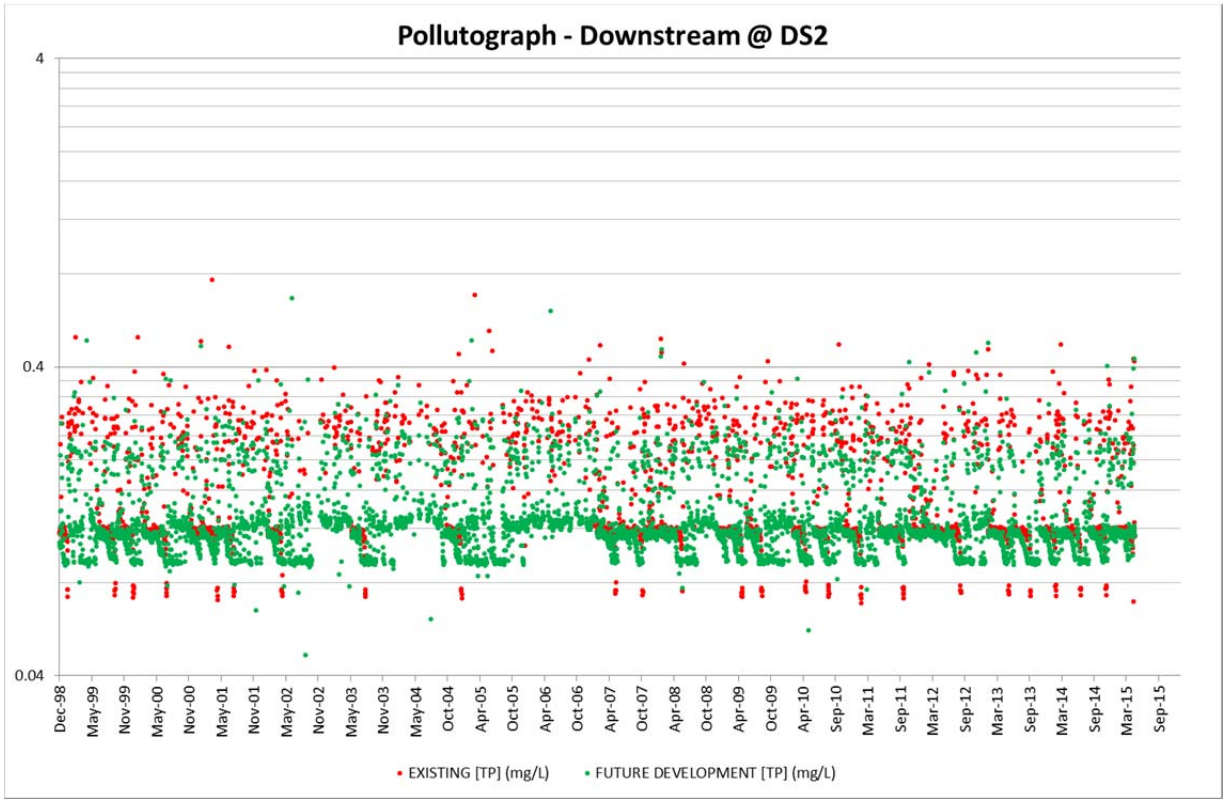


Figure C 19 Longer Term Development Total Suspended Solids Downstream at DS2



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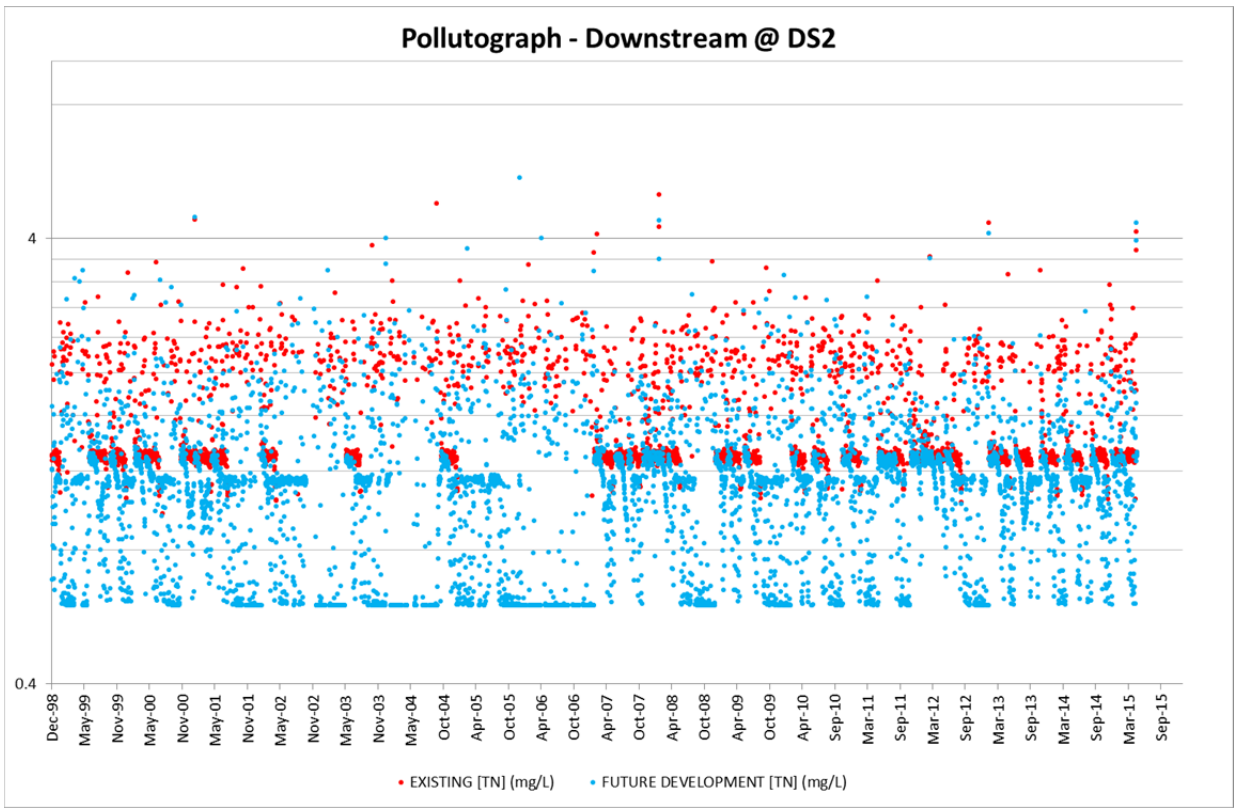

Figure C 21 Longer Term Development Total Nitrogen Downstream at DS2

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
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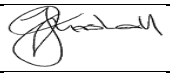
A	Ricky Kwan	G Marshall		N Bailey		27.07.15
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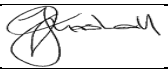
C	Ricky Kwan	Ricky Kwan		G Marshall		26.08.15

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VOLUME 4

Appendix L3
Groundwater





Department of Infrastructure and Regional Development

Western Sydney Airport EIS

Groundwater Assessment

October 2015

Limitations

GHD has prepared this report pursuant to the conditions in the Department of Infrastructure and Regional Development Deed of Standing Quotation (SON2030181), the Commonwealth RFQTS Number 2014/7540/001, the subsequent response accepted and referenced in the relevant Official Order (collectively the "Contract"):

In particular, this report has been prepared by GHD for the Commonwealth (and to the extent expressly stated in the Contract (and for the purposes stated therein) the parties referred to in the Contract ("Other Parties") and may only be used and relied on by the Commonwealth and the Other Parties in accordance with the Contract for the purpose agreed between GHD and the Commonwealth as set out in the Contract.

Other than as stated in the Contract, GHD disclaims responsibility to any person other than the Commonwealth (or the Other Parties and for the purposes expressly stated in the Contract or in this report) arising out of or in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services and the purpose undertaken by GHD under the Contract in connection with preparing this report were limited to those specifically detailed in the Contract and this report and are subject to the scope limitations set out in the Contract and this report.

Other than as expressly stated in this report to the contrary, the opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update

this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by the Commonwealth and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work as stated in the Contract. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

Executive summary

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed Western Sydney Airport (the proposed airport).

The Australian Government Minister for the Environment determined that the construction and operation of the proposed airport would require assessment in accordance with the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).* Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015.

The EIS Guidelines make no specific mention of groundwater issues. Despite this, a review of the information contained in the previous approval (PPK 1997) and of documentation describing new or changed environmental conditions, relative to the proposed airport concept design has been undertaken.

The review of hydrogeological and groundwater quality information indicates that the airport site is located on Bringelly Shale and near to alluvial aquifers. The groundwater in the shales has very limited environmental value due to poor water quality. As such, there is a low overall risk of adverse impacts occurring to the groundwater environment from construction and operation of the proposed airport development.

The review indicates that there is some vegetation located along riparian areas that may have some reliance on shallow groundwater. This vegetation is located on alluvium flanking Badgerys Creek, Duncans Creek and Cosgroves Creek that is not expected to be adversely impacted by the proposed airport development. Although impacts are expected to be minor, a groundwater elevation monitoring regime near to sensitive vegetation in riparian areas would be implemented to monitor for emergent impacts.

Surface water flows in Badgerys Creek, Cosgroves Creek and Duncans Creek have only a minor inflow from groundwater in the Bringelly Shale. Because of this limited inflow, groundwater quality impacts from the airport development have the potential to migrate into the surface water and impact the instream water quality. To manage this, it is proposed that surface water drainage systems would incorporate appropriate measures during construction and operation to limit spills and leakage to underlying groundwater. This would include appropriate handling and storage of fuel and chemicals. Further surface water drainage systems such as first flush systems, treatment/bio-retention basins and swales would be lined to minimise the potential for impacts to migrate to groundwater resources. To ensure these systems are working properly, a groundwater monitoring program would be implemented around key sources of impact (i.e. fuel farms, refuelling areas, wash down facilities, firefighting facilities, maintenance facilities and other chemical storage areas). The emergence of impacts would be linked to response and remediation activities as required.

If subsurface structures are developed such as basements and rail corridors, there would be potential for groundwater seepage. Based on inherent groundwater chemical data and the expected chemicals to be handled on-site, the collected groundwater may require monitoring and treatment before discharge. Monitoring and treatment may be required for total dissolved solids, suspended solids, metals, pH, nitrogen and phosphorus, petroleum hydrocarbons, pesticides, and aqueous film forming foam substances. Given the seepage volumes, expected treatment via the surface water system could be appropriate. Further investigations of seepage volumes and treatment measures would be undertaken at the detailed design stage.

No other potentially significant impacts have been identified to potential groundwater resources from the proposed airport development.

Glossary and abbreviations

Term	Definition
ADWG	Australian Drinking Water Guidelines
Airport	Western Sydney Airport
Airport site	The airport site is the total of all properties that may become part of Western Sydney Airport. The airport site includes existing Commonwealth land and land to be acquired by the Commonwealth, such as The Northern Road.
Airport features	Specific features of the proposed airport, such as runways, taxiways, terminal buildings or hangars.
Alluvium	Unconsolidated deposit of gravel, sand or mud formed by water flowing in identifiable channels. Commonly well sorted and stratified.
ANZECC	Australian and New Zealand Environment Conservation Council
Aquifer	A groundwater bearing formation sufficiently permeable to transmit and yield groundwater.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrences of a flood as big as or larger than the selected event.
Australian Height Datum (AHD)	A common reference level used in Australia which is approximately equivalent to the height above sea level.
Badgerys Creek	Badgerys Creek is a suburb of Sydney approximately 50 kilometres west of the Sydney central business district, and the general locality of the proposed airport. Badgerys Creek is also the name of a watercourse which is referred to in this report.
BOM	Bureau of Meteorology
Bore	Constructed connection between the surface and a groundwater source that enables groundwater to be transferred to the surface either naturally or through artificial means.
Catchment	The area drained by a stream or body of water or the area of land from which water is collected.
Consent	Approval to undertake a development received from the consent authority.
Construction	In this report the term construction is inclusive of both earthworks and construction of site facilities.
Datum	A level surface used as a reference in measuring elevations.
DEM	Digital elevation model
DTV	Default Trigger Value
Discharge	Quantity of water per unit of time flowing in a stream, for example cubic meters per second or megalitres per day.

Term	Definition
Drawdown	A reduction in piezometric head within an aquifer.
EC	Electrical Conductivity
EIS	Environmental Impact Statement
Erosion	A natural process where wind or water detaches a soil particle and provides energy to move the particle.
Formation	A fundamental unit used in the classification of rock or soil sequences, generally comprising a body with distinctive physical and chemical features.
Fracture	Cracks within the strata that develop naturally or as a result of underground works.
Groundwater	Subsurface water stored in pores of soil and geological formations.
GDE	Groundwater Dependent Ecosystem
ha	Hectares
Hazard	The potential or capacity of a known or potential risk to cause adverse effects.
Hydraulic conductivity	The rate at which water at the prevailing kinematic viscosity will move under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow, usually expressed in metres per day (this assumes a medium in which the pores are completely filled with water).
Hydrogeology	The area of geology that deals with the distribution and movement of groundwater in soils and rocks.
Infiltration	The downward movement of water into soil and rock, which is largely governed by the structural condition of the soil, the nature of the soil surface (including presence of vegetation) and the antecedent moisture content of the soil.
km	Kilometre
Landform	A specific feature of the landscape or the general shape of the land.
LTAAEL	Long Term Average Annual Extraction Limit
Longer term development	A future stage in the development of the proposed airport, where the airport is assumed to comprise parallel runways and handling approximately 82 million passengers annually. The EIS assumes this occurs in 2063 for assessment purposes.
LPMA	NSW Land and Property Management Authority
m	Metres
m/day	Metres per day
m3/day	Metres cubed per day
Max	Maximum

Term	Definition
Min	Minimum
ML	Megalitres
Monitoring well/bore	A hole sunk into the ground and completed for the abstraction or injection of water or for water observation purposes. Generally synonymous with bore.
NWQMS	National Water Quality Management Strategy
Outcrop	Where the bedrock is exposed at the ground surface.
Permeability	The capacity of a porous medium to transmit water.
POEO	Protection of Environment Operation
Recharge	Addition of water to the zone of saturation; also the amount of water added. An area in which there are downward components of hydraulic head in the aquifer. Infiltration moves downward into the deeper parts of an aquifer in a recharge area.
Risk	The chance of something happening that will have an impact measured in terms of likelihood and consequence.
Risk assessment	Systematic process of evaluating potential risks of harmful effects on the environment from exposure to hazards associated with a particular product or activity.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
Salinity	The total soluble mineral content of water or soil (dissolved solids); concentrations of total salts are expressed as milligrams per litre (equivalent to parts per million).
Sediment	Material of varying sizes that has been or is being moved from its site of origin by the action of wind, water or gravity.
Stage 1 (or initial) development	The initial stage in the development of the airport, including a single runway and facilities to handle approximately 10 million passengers annually. The EIS assumes 10 million passengers is reached in 2030 for assessment purposes.
Study area	The subject site and any additional areas which are likely to be affected by the proposal, either directly or indirectly. The study area extends as far as is necessary to take all potential impacts into account.
Surface water	Water that is derived from precipitation or pumped from underground and may be stored in dams, rivers, creeks and drainage lines.
Surface water features	These include watercourses and wetlands and their attributes (water quality and geomorphology). The term is generally used in this report to describe natural resources, but may also extend to artificial surface water features including lakes, dams and man-made wetlands.

Term	Definition
TDS	Total Dissolved Solids
Topography	Representation of the features and configuration of land surfaces.
Water quality	Chemical, physical and biological characteristics of water. Also the degree (or lack) of contamination.
Water table	The surface of saturation in an unconfined aquifer, or the level at which pressure of the water is equal to atmospheric pressure.
Western Sydney Airport	The proposed airport at Badgerys Creek and assessed in the Western Sydney Airport environmental impact statement.
WSP	Water Sharing Plan

Table of contents

Limitations i

1. Introduction 1
   - 1.1 Introduction 1
   - 1.2 Project location 2
   - 1.3 Scope 2
   - 1.4 Structure of this report 4

2. Regulatory Context 5
   - 2.1 Introduction 5
   - 2.2 Environment Protection and Biodiversity Conservation Act 1999 5
   - 2.3 Airports Act 1996 and Airports (Environment Protection) Regulations 1997 5
   - 2.4 NSW Water Management Act 2000 5
   - 2.5 Other Policies and Guidelines 8

3. Existing Environment 13
   - 3.1 Topographical Setting 13
   - 3.2 Surface Water Features 13
   - 3.3 Geology 15
   - 3.4 Hydrogeological Conditions 17
   - 3.5 Groundwater Elevations 18
   - 3.6 Settlement of Soft Sediments 21
   - 3.7 Groundwater Recharge 21
   - 3.8 Water Quality 21
   - 3.9 Registered Groundwater Bores 23
   - 3.10 Groundwater Dependent Ecosystems 25
   - 3.11 Conceptual Model 25

4. Assessment of Impacts 29
   - 4.1 Introduction 29
   - 4.2 Groundwater Recharge 29
   - 4.3 Groundwater Drawdown 34
   - 4.4 Groundwater Quality 35
   - 4.5 Cumulative Impacts 38

5. Mitigation and Management Measures 39
   - 5.1 Construction 39
   - 5.2 Operation 39
   - 5.3 Monitoring 40

6. Summary and Conclusions 43
   - 6.1 Groundwater Flow and Drawdown 43
   - 6.2 Groundwater Quality 44
   - 6.3 Conclusions 45

7. References 47

Table index

Table 1 – Expected Storage Parameters 18
Table A–1 – Site Groundwater Monitoring Well Data 50
Table B–1 – Registered Groundwater Bores 54
Table C–1 – Historical Surface Water Data 57
Table C–2 – Historical Ground Water Data 58

Figure index

Figure 1 – Site Location 3
Figure 2 – Surface Water Features 14
Figure 3 – Site Geology 16
Figure 4 – Key Groundwater Monitoring Locations and Contours for the Bringelly Shale Aquifer 20
Figure 5 – Registered Groundwater Bores 24
Figure 6 – Conceptual Hydrogeological Model 27
Figure 7 – Conceptualisation of Construction Interactions with Groundwater 31
Figure 8 – Conceptualisation of Operational Interactions with Groundwater 32

Appendices

Appendix A – Site Groundwater Monitoring Well Data
Appendix B – Registered Groundwater Bores
Appendix C – Historical Water Quality Data

1. Introduction

1.1 Introduction

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian

Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Project location

The site for the proposed Western Sydney Airport (the proposed airport) covers an area of approximately 1,700 hectares located at Badgerys Creek in Western Sydney as shown in Figure 1. The airport site is located within the Liverpool local government area, around 50 kilometres west of Sydney's Central Business District and 15 to 20 kilometres from major population centres such as Liverpool, Fairfield, Campbelltown and Penrith.

The Northern Road transects the western end of the airport site and Elizabeth Drive borders the site to the north. Badgerys Creek flows in a north-easterly direction and forms the south eastern boundary of the airport site. The airport site is located on undulating topography that has been extensively cleared with the exception of stands of remnant vegetation located predominantly along Badgerys Creek and the south western portion of the site.

1.3 Scope

This groundwater assessment presents a qualitative analysis of potential impacts on groundwater resources based on a review of previous environmental impact statements undertaken for a proposed major airport at Badgerys Creek. The previous investigations reviewed include:

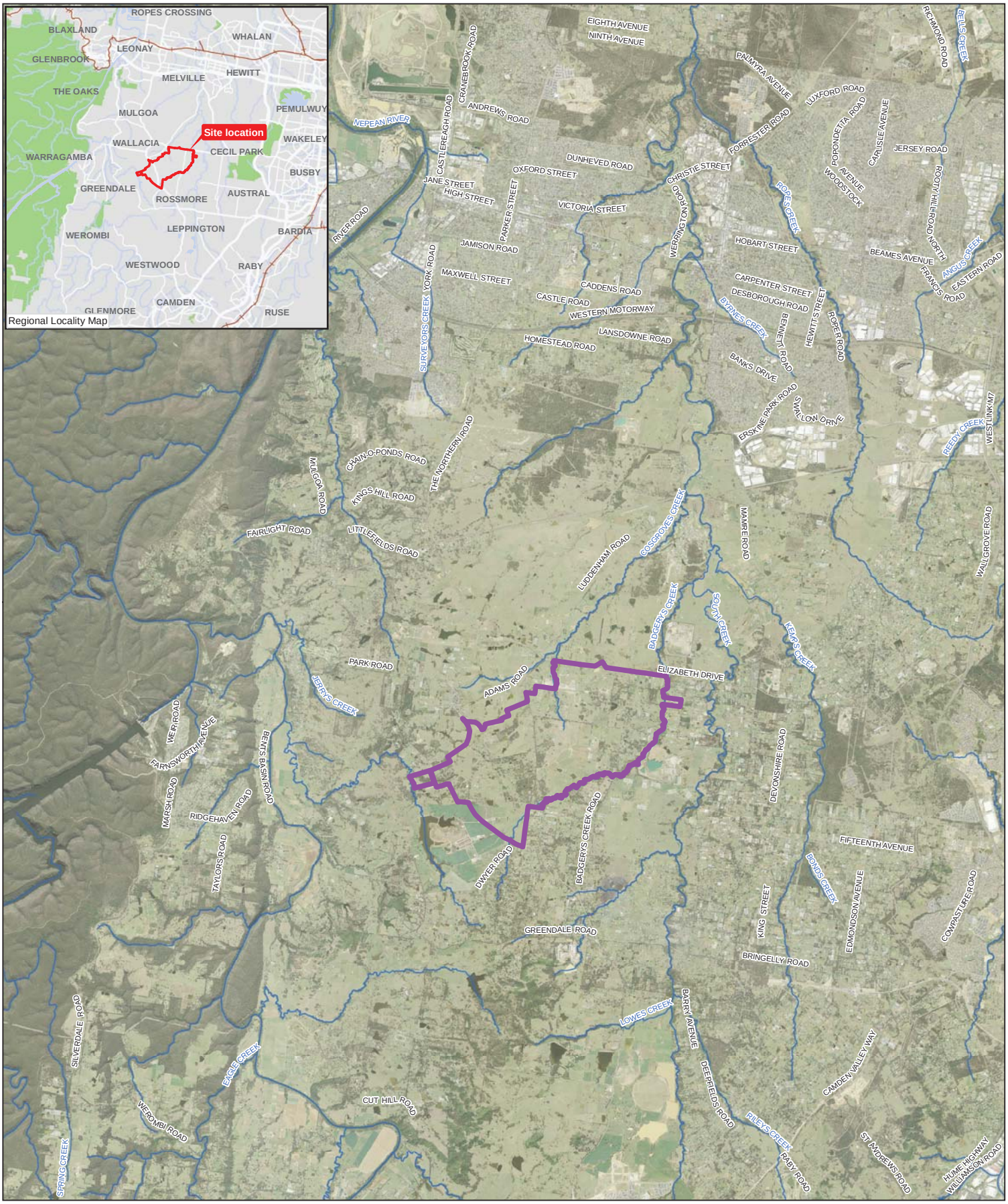
- concept design investigations reported in 1991
- a draft environmental impact statement (EIS) prepared in 1997 and an independent audit of the draft EIS
- a supplement to the draft EIS, prepared in 1999, which was also subject to independent review.

The key technical investigations undertaken for these assessments that relate to groundwater include:

- Coffey & Partners International, January 1991 – Second Sydney Airport at Badgerys Creek Concept Design Report Volume 3 Geotechnical Investigation
- PPK Environment and Infrastructure, 1997 – Geology, Soils and Water – Proposal for Second Sydney Airport at Badgerys Creek or Holsworthy Military Area
- PPK Environment and Infrastructure, 1999 – Appendix E1 – Groundwater Studies
- PPK Environment and Infrastructure, 1999 – Appendix E3 – Existing Environment and Water Quality.

The investigations included characterisation works to highlight geological conditions and hydrogeological conditions (including hydraulic properties) across the site, groundwater elevations, and groundwater and surface water quality. Groundwater modelling was completed using numerical modelling software (MODFLOW) to assess the likely impacts of the project on groundwater elevations.

The final scope of works completed for the previous investigations was based on an independent review of the 1997 Draft EIS (SMEC, 1998) and took into account submissions on the 1997 Draft EIS. This resulted in a comprehensive assessment of the key issues at the Badgerys Creek site.



LEGEND

Site Boundary

Major Watercourses

Paper Size A3

0 500 1,000 2,000 3,000 4,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Department of Infrastructure and Regional Development
Groundwater Impact Assessment

Job Number 21-24265-09
Revision A
Date 06 Jul 2015

Site Location

Figure 1

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Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

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Data source: Aerial Imagery: Dept of Lands, 2013. Topo Data: NSW LPI DTDB & DCDB 2012 Created by:mweber

The existing environmental conditions in relation to groundwater have not changed significantly since the completion of previous investigations (see Section 3 for further detail on the existing environment). While the proposed operational capacity of the proposed airport has increased from previous assessments, the configuration of the runway(s) and associated aviation infrastructure remains similar to both the concept design assessed by Coffey and Partners in 1991 and the Option A airport design assessed by PPK Environment and Infrastructure in 1997-1999.

The previous investigations are therefore considered suitable to provide a characterisation of the existing groundwater conditions at the airport site and to form the basis for the assessment of impacts for the current proposal. The desktop investigation has focused on the following key tasks:

- review of the legislative and policy settings for the groundwater assessment;
- characterisation of the current conceptual hydrogeological and groundwater conditions in the region;
- characterisation of existing water quality relative to key trigger/threshold criteria that are protective of potential receiving systems;
- development of measures that would be adopted to identify potential emerging impacts and the requirement for implementing mitigation measures; and
- assessment of the treatment required for discharge of groundwater seepage.

1.4 Structure of this report

To document the works completed, the following report structure has been adopted:

- **Section 1 – Introduction** – which details the project background, objectives and scope, as outlined above;
- **Section 2 – Regulatory Context** – which details key legislative drivers and how these are addressed by the groundwater assessment;
- **Section 3 – Existing Environment** – which details the current understanding of the existing environment;
- **Section 4 – Assessment of Impacts** – which interprets the potential impacts of construction and operational activities on the existing environment as well as potential cumulative impacts;
- **Section 5 – Mitigation and Management Measures** – which describes the further work proposed to be undertaken during the subsequent stages of design and the monitoring framework to identify the potential emergence of any issues; and
- **Section 6 – Summary and Conclusions**.

2. Regulatory Context

2.1 Introduction

The airport site is located on land entirely owned by the Commonwealth.

The Australian and NSW legislative and policy settings and guidelines in regards to groundwater management – even where not directly applicable to the proposed airport – have been considered as part of the review process.

2.2 Environment Protection and Biodiversity Conservation Act 1999

The Australian Government Minister for the Environment determined that the construction and operation of the proposed airport would require assessment in accordance with the EPBC Act. Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015.

The guidelines contain no specific requirements for the consideration of groundwater issues, but do require broad consideration of the potential environmental impacts on all aspects of the environment.

This report has been prepared in accordance with the guidelines.

2.3 Airports Act 1996 and Airports (Environment Protection) Regulations 1997

Following an environmental impact assessment finalised under the EPBC Act, the Airport Plan will be determined under the Airports Act. Stage 1 of the proposed airport will be developed in accordance with the airport plan provisions in the Airports Act.

In the period prior to the grant of an airport lease, any construction activities on the airport site will be conducted in accordance with the Airport Plan and having regard to the requirements of the Airports (Environment Protection) Regulations 1997.

Once an airport lease is granted, environmental management at the Western Sydney Airport site will be undertaken in accordance with Part 6 of the Airports Act and the Airports (Environment Protection) Regulations 1997. The Airports Act specifies offences relating to environmental harm, environmental management standards, and monitoring and incident response requirements, including in relation to water pollution.

2.4 NSW Water Management Act 2000

2.4.1 Introduction

The NSW *Water Management Act 2000* (WM Act) is administered by the NSW Department of Primary Industries (DPI) Water (formerly NSW Office of Water) and is intended to ensure that water resources are conserved and properly managed for sustainable use benefitting both present and future generations. The WM Act is also intended to provide a formal means for the protection and enhancement of the environmental qualities of waterways and their in-stream uses as well as to provide for protection of catchment conditions. The intent and objectives of the WM Act have been considered as part of this assessment.

2.4.2 Water Sharing Plans

Water Sharing Plans (WSPs) have been developed under the WM Act for all water sources within NSW with the aims of:

- clarifying the rights of the environment, basic landholder rights users, town water suppliers and other licensed users;
- defining the long-term average annual extraction limit (LTAAEL) for water sources;
- setting rules to manage impacts of extraction; and
- facilitating the trading of water between users.

WSP for the Greater Metropolitan Region Groundwater Sources

The WSP for the Greater Metropolitan Region Groundwater Sources covers 13 groundwater sources on the east coast of NSW. The airport is located within the Sydney Basin Central Porous Rock groundwater source area. The porous rock aquifer is referenced in the WSP as sedimentary sandstone and siltstone formations with intervening coal seams.

The background document for the water sharing plan (NOW, 2011) lists the Sydney Basin Central porous rock aquifer as having:

- low to moderate contact with surface water with generally long travel times (years to decades); and
- allocated volumes of 2,592 ML/yr versus a long-term average annual extraction limit of 45,915 ML/yr, which suggests that there is a significant amount of groundwater in the aquifer that has not been released for use. The estimated LTAAEL volumes are based on average recharge rates of six per cent of annual rainfall.

This information suggests that, if required, there would be sufficient available groundwater within the aquifer resource to allow groundwater extraction or collection of groundwater seepage.

The WSP also sets out a number of key water sharing rules for the Sydney Basin Central Porous Rock groundwater resource. These rules may relate to the take of water from the aquifer system beneath the airport site. The water sharing rules are outlined below.

- With regards to eligibility for obtaining water access licences, commercial use is permitted in this area under a controlled allocation. Seepage to subsurface facilities falls under this criterion as an aquifer interference activity and also possibly as a water take.
- The minimum distances allowed between a new water supply works and neighbouring water supply works ranges from 50 metres from a neighbouring property to one kilometre from a major water utility bore. It is assumed that this rule is designed to minimise drawdown impacts between water supply wells. While the site will require water supply wells, any excavations may have seepage that could have drawdown effects. Given the existing environment (see Section 3), it is not expected that there are any surrounding water supply works that would be subject to drawdown impacts.
- The minimum distances allowed between a new water supply works and a contaminated site range from 250 metres to greater than 500 metres depending on the potential for impact. While the subsurface infrastructure may result in a migration of impacted groundwater from the source of impact, the subsurface infrastructure would serve as a capture system for the groundwater. This groundwater would be treated accordingly before discharge to the receiving environment.

- There is a requirement to protect sandstone aquifers by sealing off shale aquifers that are highly saline. The depth of subsurface infrastructure is not expected to create any connection between shales and underlying sandstone aquifers. As such, there is unlikely to be an increased risk for migration into the underlying sandstone aquifer system.
- The distances allowed between new water supply works and high priority groundwater dependent ecosystems range from between 100 metres for basic land rights wells to 200 metres for all other uses. Further to this, no new water supply works are allowed within 40 metres of a river or stream that is 3rd order or above or within 40 metres of a 1st or 2nd order stream unless located within underlying parent material or within 100 metres of an escarpment. Project areas that result in drawdown impacts are unlikely to come within 40 m of surrounding creeks, except the upper reaches of Oaky Creek which will be disturbed as part of the proposed airport development.
- Regarding permission to trade water allocated under an access licence, trading is permitted within this groundwater resource.

Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources

The WSP for the Greater Metropolitan Region Unregulated River Water Sources commenced in 2011 and covers 87 management zones that are grouped into six water sources. The airport site is situated in the Hawkesbury and Lower Nepean Rivers catchment or source.

The Hawkesbury and Lower Nepean Rivers catchment is separated into management areas that include the Upper South Creek management area/unit, which includes Badgerys Creek and its catchment area within the airport site.

The water sharing plan background document (NOW 2011b) suggests that the South Creek region has high economic significance and depends on extraction for irrigation, town and industrial water supply.

South Creek is described as a "*meandering deep and narrow channel with chain of ponds headwaters*". The 20th percentile flow is 34 ML/day which is "*primarily treated effluent discharge*". This flow is expected to be recorded below the gauging station at the Great Western Highway, St Marys (gauge station 212297).

The water access rules for South Creek are as follows:

- Class A approvals must cease to pump when flows are at or less than 0.2 ML/day at the downstream flow gauge 212048 located at the Great Western Highway, St Marys;
- Class B approvals must cease to pump when flows are at or less than 6.2 ML/day; and
- pumping may commence when flows have exceeded 0.2 ML/day for a period of 24 hours.

2.4.3 Protection of the Environment Operations Act (PoEO Act)

The objectives of the NSW *Protection of the Environment and Operations Act 1997* (PoEO Act) are to protect, restore and enhance the quality of the environment, in recognition of the need to maintain ecologically sustainable development. This assessment has taken into account the intent and objectives of that Act.

2.5 Other Policies and Guidelines

2.5.1 National Water Quality Management Strategy (NWQMS)

The NWQMS policy and principles document (ARMCANZ/ANZECC 1994) provides an overview of the principles for water quality management in Australia. The primary objective of the guideline/policy is:

"to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development."

The policy and principles document states that:

"the generally accepted mechanism for establishing in-stream or aquifer water quality requirements is a two-step process which involves:

- *establishing a set of environmental values, and*
- *establishing scientifically based water quality criteria corresponding to each environmental value."*

Environmental values are often interchanged with the term 'beneficial use' and are identified in the guidance to include:

- ecosystem protection;
- recreation and aesthetics;
- drinking water;
- agricultural water (irrigation and stock water); and
- industrial water.

Ecosystem protection, in this context, refers to aquatic ecosystems which depend at least in part on groundwater to maintain ecosystem health (groundwater-dependent ecosystems). Depending on the site setting, this may include surface water bodies such as wetlands, streams and rivers reliant on groundwater base flow, some estuarine and near-shore marine systems, as well as aquifer and cave ecosystems.

Criteria have been developed to characterise water quality relative to these environmental criteria and are outlined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality and the Australian Drinking Water Guidelines (ADWG) and are discussed further below. The criteria specified in these documents have been used as the basis for characterising the current environmental values for this assessment and the treatment requirements for discharge to receiving water environments.

2.5.2 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The National Water Quality Management Strategy (NWQMS) provides a national framework for improving water quality in Australia's waterways. The main policy objective of the NWQMS is to achieve sustainable use of the nation's water resources by protecting and enhancing their quality, while maintaining economic and social development. The NWQMS process involves community and government interaction, and implementation of a management plan for each catchment, aquifer, estuary, coastal water or other water body. This includes the use of national guidelines for local implementation.

For this project, the national guidelines on water quality benchmarks within the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000)

are applicable and provide default trigger values (DTVs) of various analytes for comparison with sampled values. Guideline water criteria are presented in the guidelines for:

- aquatic ecosystems;
- primary industries (which include agricultural and industrial water criteria);
- recreational water quality and aesthetics; and
- drinking water.

The guideline values are not standards and should not be regarded as such (ANZECC, 2000). It should also be noted that the water quality values are not suitable for direct application to stormwater quality. Rather, the guidelines have been derived to apply to the ambient waters that receive stormwater discharges and to protect the environmental values that they support.

Of particular importance is the philosophical approach for using the ANZECC guidelines, which:

"*protect environmental values by meeting management goals that focus on concerns or potential problems"* (ANZECC, 2000).

That is, development of a monitoring programme, including the performance objectives, standards and measurement criteria, should focus on specific issues not on pre-determined guideline values.

The surface water features receiving water from the airport site and surrounding area are located primarily within agricultural catchments and as such are considered to be "slightly modified fresh water systems" (ANZECC, 2000). Based on this a protection level of 95 per cent for freshwater ecosystems, as recommended in ANZECC (2000) is considered to be suitable for the assessment.

ANZECC (2000) also provides screening trigger values for southeast Australia NSW lowland rivers (less than 150 metres in altitude). The lowland rivers criterion has also been used in this assessment.

ANZECC (2000) also provides a range of data for health-based recreational water use, sustainable irrigation and stock water purposes. These values have been adopted in the assessment to characterise the overall environmental value of the groundwater beneath the site.

2.5.3 Australian Drinking Water Guidelines

The *Australian Drinking Water Guidelines* (ADWG) (NHMRC, 2013) provide a framework for the management of drinking water supplies to achieve a safe and appropriate point of supply. The guidelines provide a base standard for aesthetic and health water quality levels. These values have been adopted for the assessment to characterise the suitability of the groundwater for potable use.

2.5.4 NSW Aquifer Interference Policy

The purpose of the Aquifer Interference Policy is to explain the role and requirements of the responsible NSW Minister in administering the water licensing and assessment processes for aquifer interference activities under the WM Act. The Aquifer Interference Policy clarifies the requirements for obtaining water licences for aquifer interference activities under NSW water legislation. The Aquifer Assessment Framework outlines the basic framework which the NSW Office of Water uses to assess project proposals against the NSW Aquifer Interference Policy.

An aquifer interference approval is typically required for any works that involve:

a. the penetration of an aquifer;

b. the interference with water in an aquifer;

c. the obstruction of the flow of water in an aquifer;

d. the taking of water from an aquifer in the course of carrying out mining, or any other activity prescribed by the regulations; and

e. the disposal of water from an aquifer as referred to in paragraph (d).

The policy applies to all aquifer interference activities, but has been developed to address a range of high risk activities. This includes large infrastructure developments that require dewatering for the construction and maintenance of facilities such as building basements and tunnel cuttings and any activities with the potential to intercept groundwater.

An aquifer interference approval will generally not be granted unless the “Minister is satisfied that adequate arrangements are in force to ensure that no more than minimal harm will be done to any water source, or its dependent ecosystems, as a consequence of being interfered with” by the activities the approval relates to.

The minimal impact criteria, specified in the Aquifer Interference Policy, for the groundwater source at the airport site are summarised below.

- With regard to the water table, impact is considered to be minimal where the water table change is less than ten per cent of the cumulative variation in the water table 40 metres from any high priority groundwater dependent ecosystem (GDE) or high priority culturally significant site listed in the water sharing plan. If an impact is greater than this it must be demonstrated to the Minister’s satisfaction that the variation will not prevent the long term viability of a GDE of cultural significance. There are no high priority sites listed in the water sharing plan near to the site; however, site specific potential GDEs have been identified that are considered to be sensitive and are considered in this assessment.
- With regard to the water table, impact is considered to be minimal where there is less than a cumulative two metre decline at any water supply work. If the impact is greater make good provisions apply.
- With regard to water pressure, impact is considered to be minimal where the cumulative decline in head is less than two metres at any water supply work. If the impact is greater, then further studies are required to satisfy the Minister that long term viability of the affected water supply works will not be affected. Otherwise make good provisions will apply.
- With regard to water quality, impact is considered to be minimal where the change in groundwater quality is within the current beneficial use category of the groundwater source beyond 40 metres from the activity. If this cannot be achieved studies will need to demonstrate that the change will not prevent the long term viability of the dependent ecosystem, or affected water supply works.

If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable. The Aquifer Interference Policy also provides a list of "defined minimal impact aquifer interference activities" that are considered as having a minimal impact on water-dependent assets. This includes caverns, tunnels, cuttings, trenches and pipelines (intersecting the water table) if a water access licence is not required.

The proposed airport development includes the potential for a cut and cover tunnel to be developed to establish a void for a future underground rail connection. Basement levels for the major terminal buildings may also result in the interception of an aquifer.

2.5.5 NSW State Groundwater Policy Framework Document (DLWC, 1997)

The objective of the NSW State Groundwater Policy Framework Document (NSW Government 1997) is to manage the State's groundwater resources so that they can sustain environmental, social and economic uses for the people of NSW. The NSW groundwater policy has three component parts:

- NSW Groundwater Quantity Protection Policy outlined in DLWC (1997);
- NSW Groundwater Quality Protection Policy (DLWC, 1998); and
- NSW Groundwater Dependent Ecosystems Policy (DLWC, 2002).

NSW Groundwater Quantity Management Policy

The principles of this policy include:

- maintain total groundwater use within the sustainable yield of the aquifer from which it is withdrawn;
- groundwater extraction shall be managed to prevent unacceptable local impacts; and
- all groundwater extraction for water supply is to be licensed. Transfers of licensed entitlements may be allowed depending on the physical constraints of the groundwater system.

These principles are implemented under the WM Act and the Aquifer Interference Policy, which have been discussed above.

NSW Groundwater Quality Protection Policy

The objective of this policy is the ecologically sustainable management of the State's groundwater resources so as to:

- slow and halt, or reverse any degradation in groundwater resources;
- direct potentially polluting activities to the most appropriate local geological setting so as to minimise the risk to groundwater;
- establish a methodology for reviewing new developments with respect to their potential impact on water resources that will provide protection to the resource commensurate with both the threat that the development poses and the value of the resource; and
- establish triggers for the use of more advanced groundwater protection tools such as groundwater vulnerability maps or groundwater protection zones.

NSW Groundwater Dependent Ecosystems Policy

This policy is designed to protect ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations.

This assessment considers the potential for impacts to groundwater dependent ecosystems associated with the proposed airport development.

2.5.6 Risk Assessment Guidelines for Groundwater Dependent Ecosystems

The *Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (NOW, 2012) comprises four volumes and provides a conceptual framework for identifying and assessing ecosystems along with worked examples of assessments. The guidelines discuss the identification of high probability GDEs and also discuss the ecological value of GDEs. The results from the groundwater assessment have been used to inform the assessment of the presence potential impacts on GDEs (GHD, August 2015).

3. Existing Environment

3.1 Topographical Setting

The airport site is located in the south-west portion of the Cumberland Plain (PPK, 1997) in Western Sydney and includes rolling hills dissected by a number of drainage lines. The ridge system trends northwest to southeast in the vicinity of The Northern Road and reaches elevations of just over 120 m AHD. There are some other isolated ridge lines in and around the Luddenham Dyke and The Northern Road with approximate elevations of slightly more than 100 m AHD.

The topography generally slopes away from these ridgelines to the south and east into Oaky, Cosgroves and Badgerys Creeks which form part of the South Creek catchment and to the northwest into Duncans Creek which forms part of the Nepean River Catchment. The lowest points of the site are where Badgerys Creek exits the north eastern extent of the site (approximately 44 m AHD).

3.2 Surface Water Features

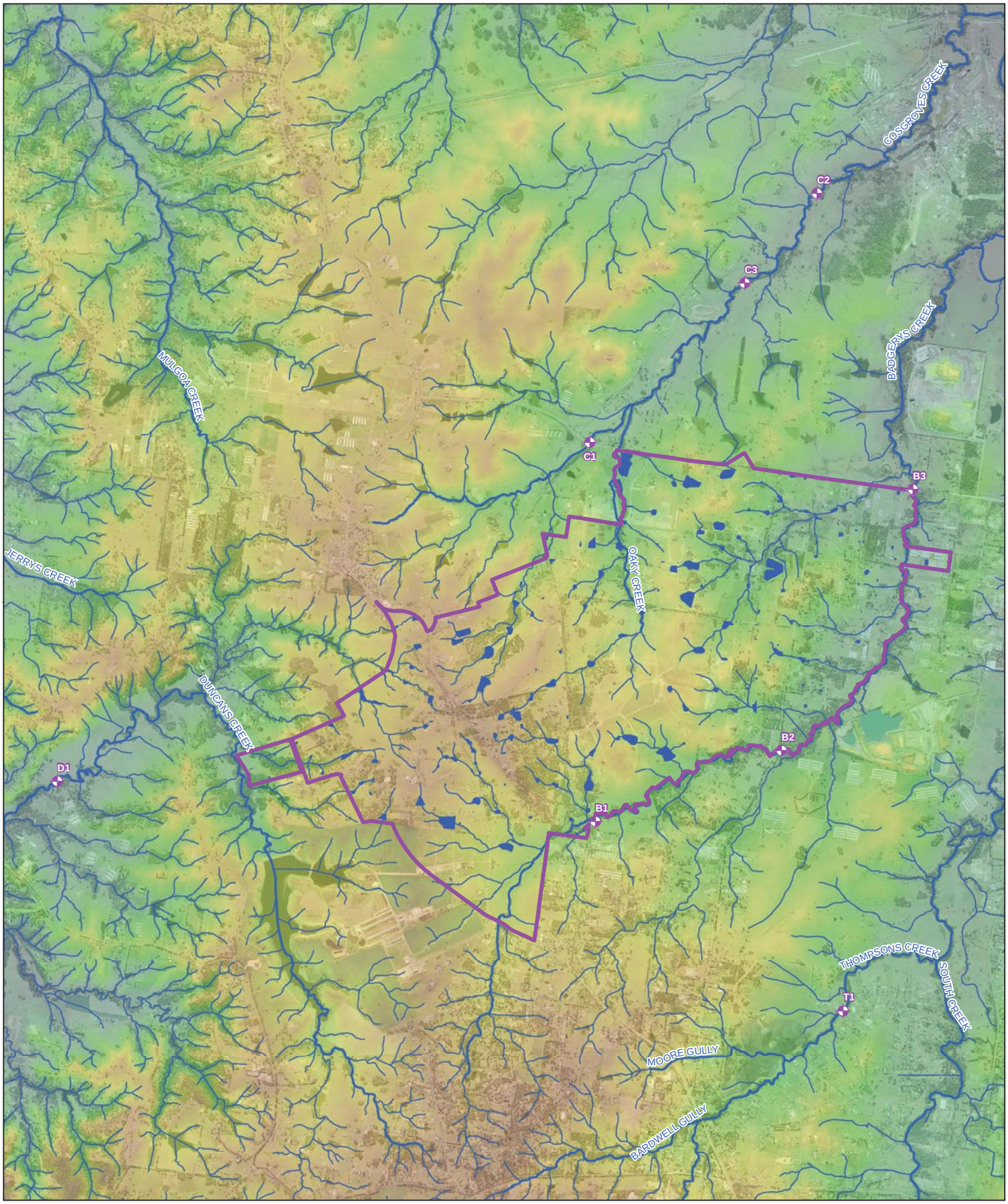
As noted above there are two main catchments that drain the site - the South Creek Catchment and the Nepean River Catchment. These catchments include a number of tributaries that also drain the airport site. Duncans Creek drains into the Nepean River catchment while Oaky Creek, Cosgroves Creek and Badgerys Creek drain into South Creek. There are also numerous farm storage dams, with a notably large dam located at the head waters of Duncans Creek to the west of the airport site boundary.

Figure 2 shows the location of the farm dams and the creek systems draining the airport site.

Previous site investigations undertaken by PPK (PPK 1997), which included a number of site visits during wet and dry conditions, suggest that the creeks draining the site may not flow continuously but that during periods of dry weather, intermittent pools may remain.

Real-time flow data at station 212048 located on South Creek at the Great Western Highway, St Marys for the period 1986 to 2015 has the following flow statistics:

- a median flow of approximately 6 ML/day;
- a 20th percentile flow of approximately 0.6 ML/day; and
- a no flow percentile occurrence rate of approximately 3 per cent.



LEGEND

- Site Boundary
- Major Watercourses
- Dams (within site boundary)
- Tributaries
- Approximate Surface Water Sample Locations (PPK, 1997)

Digital Elevation Model (m ADH)

High : 126.847

Low : 27.779

Paper Size A3

0 125250 500 750 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Infrastructure and Regional Development
Groundwater Impact Assessment

Job Number 21-24265-09
Revision A
Date 06 Jul 2015

Surface Water Features

Figure 2

G:\21\24265\GIS\Maps\Deliverables\21-24265-Z073_Groundwater_SurfaceWaterFeatures.mxd

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3.3 Geology

According to the 1:250,000 Geological Series Sheet for Sydney, the site is underlain by Triassic rocks (Bringelly Shale) and unconsolidated Quaternary alluvial sediments.

PPK (1997) indicates that Quaternary alluvium appears as accumulated surficial deposits along the main creeks in the area. These creeks include Cosgroves Creek to the north and Badgerys Creek to the south and east of the airport site. The alluvium typically comprises fine grained sand, silt and clay, with isolated areas of gravelly clay and clayey gravel present. An extensive drilling and test pitting program undertaken by Coffey & Partners International (1991) indicated that these sediments can be up to 5 m thick.

Cross-sections in the 1:250,000 Geological Series Sheet for Sydney indicate that the Bringelly Shales overlie the Triassic aged Hawkesbury Sandstone. The Bringelly Shales are shown in the cross-sections to approximate thicknesses of 100 m in the vicinity of the site. Drilling undertaken by Coffey & Partners International (1991) and PPK (1999) has confirmed that Bringelly Shale extends to depths of greater than 42 m across the site. Further characterisation of the geology across the site is currently being undertaken as part of detailed geotechnical investigations being undertaken by the Department of Infrastructure and Regional Development.

The Bringelly Shale is the uppermost unit of the Wianamatta Group and underlies the surface soils across the majority of the site. PPK (1997) notes that the Bringelly Shale is interpreted as a coastal alluvial plain which grades up from a lagoonal coastal marsh sequence at the base to an increasingly terrestrial, alluvial plain sediment sequence towards the top of the formation. Drilling at the site undertaken by Coffey & Partners International (1991) and PPK (1999) suggests that the predominant lithology in the Bringelly Shale includes:

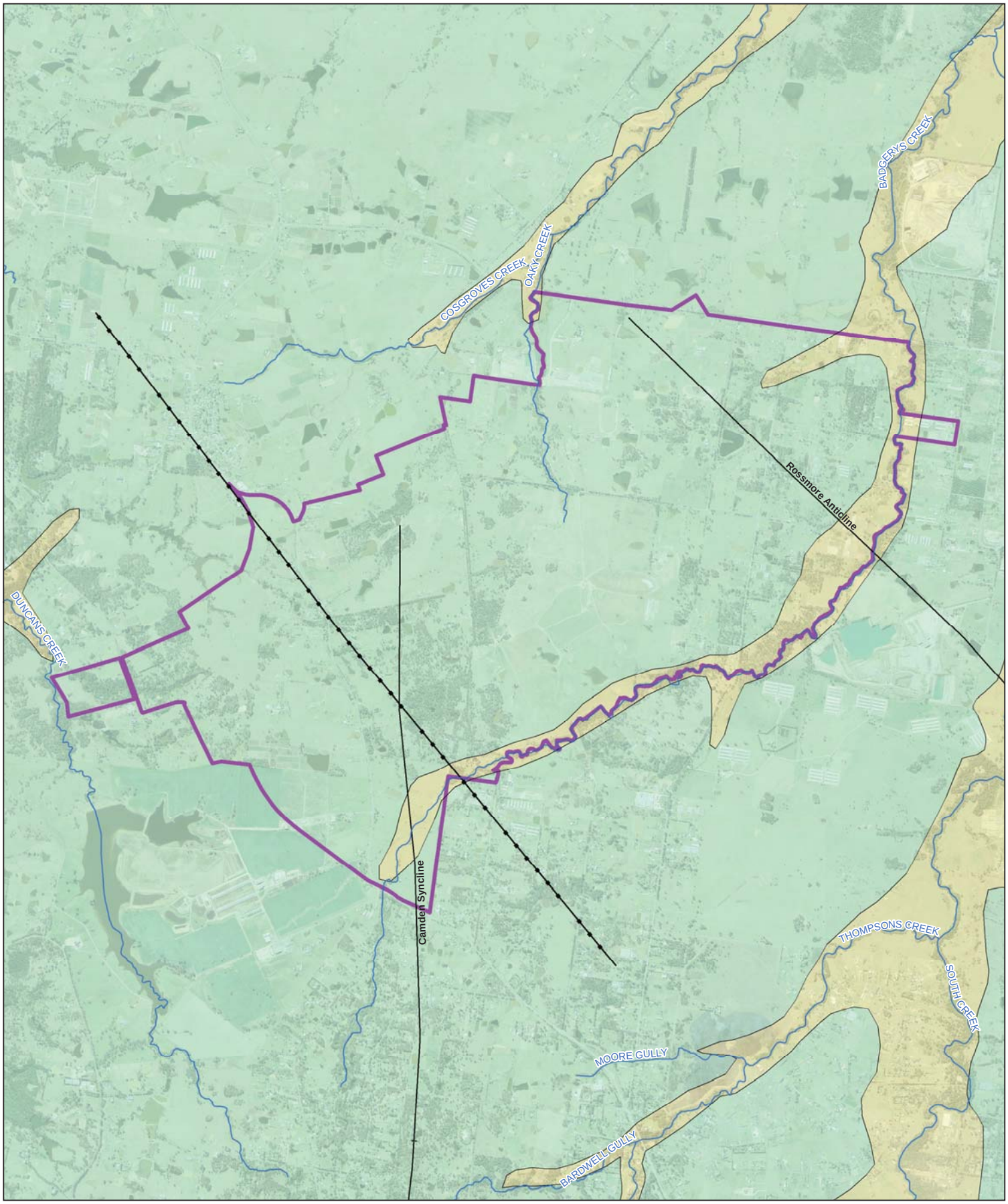
- claystone and siltstone;
- laminate;
- sandstone;
- coal and highly carbonaceous claystone; and
- tuff.

Coffey & Partners reported that the uppermost part of the Bringelly Shale is weathered to depths of between 19 m below ground surface in the vicinity of the Luddenham Dyke and approximately 5.6 m below ground surface in north western areas of the site. The weathered sediments are predominantly clays.

PPK (1997) notes that the Luddenham Dyke outcrops along the top of a ridge at the site in the vicinity of The Northern Road. The dyke consists of olivine basalt carrying analcite. It intrudes the Wianamatta Shale and trends north-west to south-east.

A review of the bore logs of NSW registered groundwater bores GW104979, GW104215 and GW105959 (see Figure 5) surrounding the site suggests that the Hawkesbury Sandstone underlies the Bringelly Shales at depths greater than 100 m below ground surface.

Figure 3 presents the site geology.



LEGEND

- Site Boundary
- Major Watercourses
- Geological Boundary
- Camden Syncline
- Rossmore Anticline
- Dyke
- Quaternary Alluvium
- Bringelly Shale
- Cranebrook Formation

Paper Size A3

0 125 250 500 750 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Department of Infrastructure and Regional Development
Groundwater Impact Assessment

Job Number 21-24265-09
Revision A
Date 06 Jul 2015

Geology

Figure 3

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3.4 Hydrogeological Conditions

PPK (1999) identified the presence of two main aquifer systems, namely:

- an unconfined aquifer system located within the quaternary alluvium localised around the main creeks draining the site; and
- a confined regional aquifer intersected at depths of approximately 20 m below ground surface that intersects the Bringelly Shale.

Groundwater elevations in the weathered shales were interpreted by PPK (1999) to be intermittent and not to support a significant aquifer system.

A regional aquifer is interpreted to be present within the Hawkesbury Sandstone which underlies the site at depths of greater than 100 m below ground surface. NSW registered groundwater information (see Section 3.9) suggests that this aquifer is used for water supply purposes.

Geological, water strike information and groundwater elevation data suggested that these aquifers had limited hydraulic connection at the time of the PPK study.

3.4.1 Aquifer Parameters

PPK (1999) undertook hydraulic testing of 14 wells. The results suggest that the alluvial and shale aquifers were of low hydraulic conductivity. A summary of the mean values reported for each aquifer system is provided below:

- alluvial aquifer – 0.14 m/day;
- perched weathered clay/shale zone – 0.0027 m/day; and
- shale aquifer – 0.034 m/day.

The hydraulic conductivity data collected by PPK (1999) are presented in Appendix A.

PPK (1999) suggests that vertical hydraulic conductivities within the Bringelly Shale could be expected to be two to three orders of magnitude lower than horizontal hydraulic conductivities for the shales. The standing water elevations relative to well depth in the surrounding registered use bores (presented in Appendix B), suggests there is a strong downward head gradient, which supports the presence of very low vertical hydraulic conductivities.

Storage Parameters

Storage parameters are representative of the ability of an aquifer to store and release water. These parameters have a significant impact on how aquifers respond to rainfall events or to construction of infrastructure below the groundwater table. For example, where groundwater is intersected by construction works, the amount of water that will initially flow into an excavation will be from storage in the surrounding media. Once the storage in the surrounding media completely drains, the flow into an excavation will be controlled by the hydraulic conductivity properties of the aquifer.

Large responses to relatively small rainfall events usually coincide with smaller overall storage properties and are often indicative of fractured conditions.

There are two properties that dictate the amount of storage within an aquifer system and the amount of storage release from an aquifer system. These properties are:

- specific yield (S_y), which generally relates to unconfined aquifer conditions and which will be the primary parameters impacting flow into an excavation. Specific yield is generally equivalent to the effective porosity of an aquifer; and

- storativity (S), which represents the primary factor controlling storage release in confined aquifer systems. Storativity generally represents an ability of the aquifer to release water by expanding and contracting.

At present, specific data outlining these properties are scarce; as such literature values have been adapted to represent site conditions. Values for unconsolidated material have been adapted from Weight and Sonderegger (2001) and are presented in Table 1. For fractured bedrock, the open area associated with fractures represents the primary storage characteristic.

Table 1 – Expected Storage Parameters

Hydrogeological unit	Specific Yield (dimensionless)			Storativity (dimensionless)		
	Min	Pref.	Max	Min	Pref.	Max
Residual clay	0.01	0.06	0.18	0.00001	0.001	0.001
Bringelly Shale	0.001	0.01	0.1	0.00001	0.001	0.001

Source: Weight and Sonderegger (2001)

3.5 Groundwater Elevations

Groundwater elevations were observed in wells drilled across the site by Coffey International (1991) and PPK (1999). The groundwater elevation data for these observations are presented in Appendix A. Key observations regarding the groundwater levels are summarised below.

- The depth to the water table in the alluvial aquifer ranged between 0.7 and 4.7 metres below the measuring point.
- The depth to groundwater observed in the weathered shales ranged between 2.4 m and 4 m below the measuring point.
- The depth to groundwater in the Bringelly Shale aquifer ranged between 3.0 m below ground surface and 11.7 m below the measuring point.

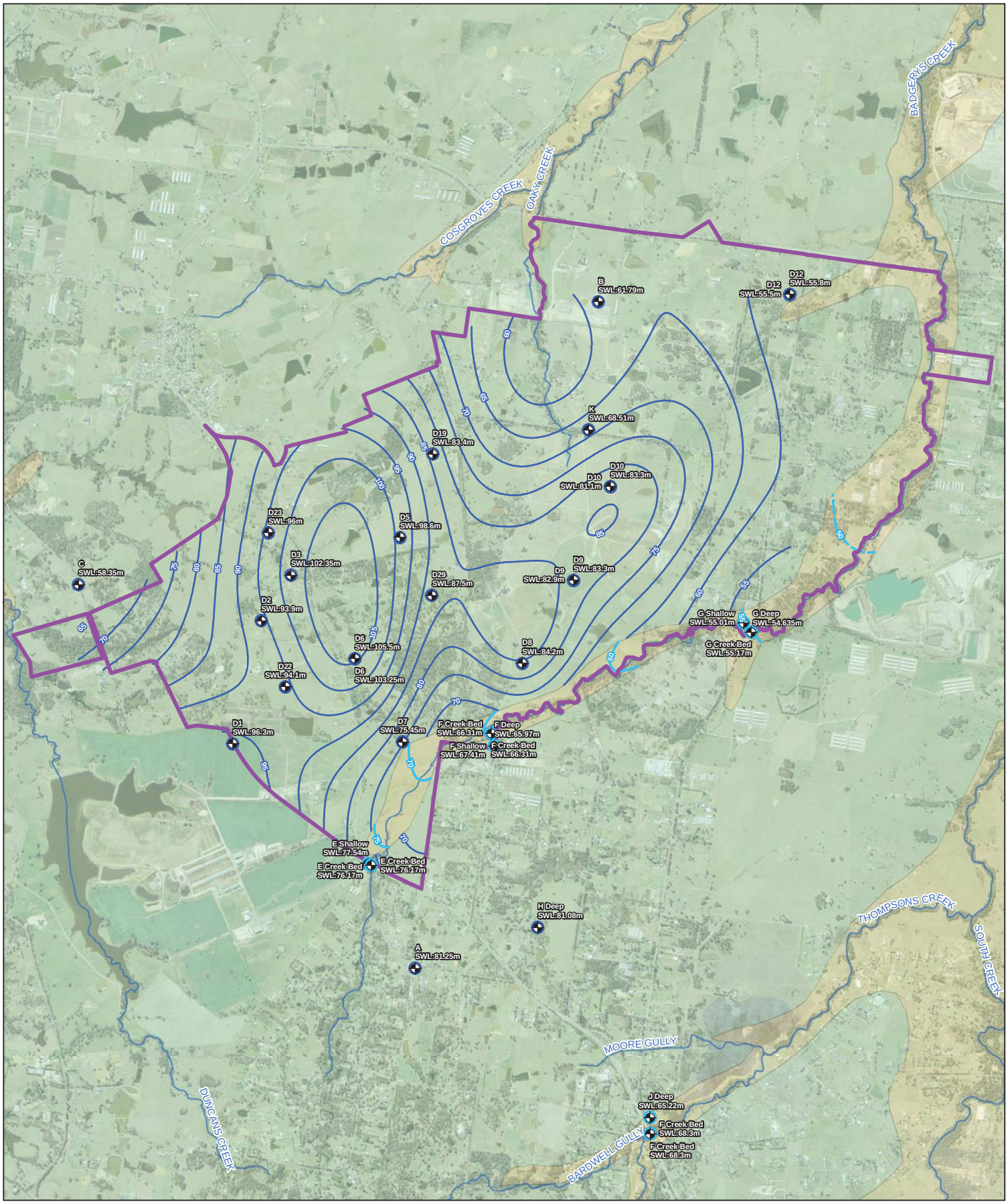
PPK (1999) noted that the water bearing zone for the Bringelly Shale aquifer was intersected at depths greater than 20 m below ground surface. The groundwater elevations in the shale aquifer were generally deeper than in the alluvial aquifer by between 0.4 m and 2.2 m where dual piezometers were installed along Badgerys Creek. This suggests that there is a limited hydraulic connection between the two aquifer systems and supports the presence of low vertical hydraulic conductivities in the Bringelly Shale aquifer.

The standing water elevations relative to well depth in the surrounding NSW registered groundwater bores (and presented in Appendix B), suggest that there is a strong downward head gradient between the Bringelly Shale aquifer and the underlying Hawkesbury sandstone aquifer. This suggests that there is very limited hydraulic connection between these two aquifer systems.

Figure 4 presents the interpolated groundwater contours using the data presented in Appendix B. The trends in the groundwater contour data presented in the figures are summarised below.

- The Luddenham Dyke tends to create a flow divide of elevated groundwater in the Bringelly Shale aquifer with flow east towards Badgerys Creek and west towards Duncans Creek. Badgerys Creek appears to be acting as a discharge point for the shale aquifer, although groundwater elevations for the shale aquifer appear to be between 0.3 m and 0.8 m below the creek bed when observed by PPK (1999). Groundwater elevations range from 105 m AHD near the Luddenham Dyke to 55 m AHD near to Badgerys Creek.
- Groundwater elevations in the alluvium suggest that the alluvial aquifer discharges to surface water features and flows in the same direction as the fall of the creeks to which they discharge. Groundwater elevations ranged between 55 m AHD and 75 m AHD in the alluvial aquifer along Badgerys Creek.

Regionally, the groundwater elevations suggest that the shallow groundwater systems at the site are bounded by discharge points to the west at Duncans Creek, to the south and east by Badgerys Creek, to the north and northwest by Cosgroves Creek and at the base by very low vertical permeabilities through the shales. There may be some groundwater flow offsite to the north; however, it is expected that this groundwater would eventually discharge to either Cosgroves Creek or Badgerys Creek before they intersect South Creek approximately 5 km to the northwest.



LEGEND

- Site Boundary
- Historical Groundwater Bores (Bringelly Shale)
- Historical Groundwater Bores (Alluvial)
- Major Watercourses
- Interpreted Groundwater Contours mADH (Alluvial)
- Extrapolated Groundwater Contours mADH (Alluvial)
- Interpreted Groundwater Contours mADH (Bringelly Shale)
- Quaternary Alluvium
- Bringelly Shale

Paper Size A3

0 125 250 500 750 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Department of Infrastructure and Regional Development
Groundwater Impact Assessment

Job Number 21-24265-09
Revision A
Date 14 Jul 2015

Groundwater Observations

Figure 4

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3.6 Settlement of Soft Sediments

As noted earlier, the alluvial aquifer and weathered shale derived clays are present across the site and are saturated in shallow depths in places. Any dewatering of these sediments has the potential to result in settlement of the ground surface.

3.7 Groundwater Recharge

The mean rainfall over the last 19 years for Bureau of Meteorology Weather Station 067108 located at Badgerys Creek and within the site boundary is 696.2 mm/yr. The maximum mean monthly rainfall is 108 mm for February and minimum mean monthly rainfall is 23 mm for July.

The Water Sharing Plan for the Greater Metropolitan Region Groundwater Resources adopts an annual recharge rate of 6 per cent of annual rainfall for assessing available yields within these groundwater aquifer systems, which would be a groundwater recharge rate of 41.8 millimetres/year (mm/yr).

The CSIRO (Jolly et al, 2011) provides a range of methods for estimating likely recharge rates using scarce site data. This includes a method for estimating the recharge based on clay content in the top two metres of the soil profile. The clay content established from particle size distribution analysis of samples taken from test pits and bore holes completed across the site by Coffey & Partners International (1991). Ten samples from ten locations were used for this method, which estimated a recharge rate of between 0.3 mm/yr and 36 mm/yr with an average of 3.4 mm/yr. Given an average annual rainfall rate in this area of 696.2 mm/yr, these recharge rates represent a minimum of 0.04 per cent, an average of 0.5 per cent, and a maximum of 5.2 per cent of average annual rainfall.

Soil infiltration testing completed by PPK (1999) estimated maximum recharge rates of approximately 0.012 metres/day (m/day) for the clayey shale soils and 0.0057 m/day for the alluvium. This suggests that run-off would be generated from the shale-derived clay soils after a rainfall event greater than 12 mm/day and from the alluvial soils at a rainfall rate greater than 5.7 mm/day. The infiltration testing results also support the presence of very low overall groundwater recharge conditions.

There are a number of farm dams currently present at the site that have the potential to act as a point of recharge across the site. Based on the salinity of groundwater across the site (see Section 3.8.3), it does not appear recharge from these systems is having a significant impact on regional groundwater within the clay and shales. For example if significant freshwater recharge was occurring, shallow groundwater in the Bringelly Shale and overlying weathered clays would be expected to have lower salinity than currently observed.

3.8 Water Quality

Surface water and groundwater sampling was undertaken during the previous EIS investigations for the purposes of characterising the baseline water quality conditions and environmental values. This section summarises the findings of those surface water and groundwater quality investigations.

3.8.1 Basis of Water Quality Assessment

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC guidelines) provide a management framework, guideline water quality triggers, and protocols and strategies to assist water resource managers in assessing and maintaining aquatic ecosystems.

To characterise the overall water quality, the data reported for the site were compared against the ANZECC (2000) freshwater criteria, irrigation criteria, stock water criteria and recreational

water use criteria. The surface water features in or near the site are located within rural catchments and as such are considered to be “slightly modified fresh water systems” (ANZECC, 2000). Based on this, a protection level of 95 per cent for freshwater ecosystems, as recommended in ANZECC (2000), was used to assess groundwater and surface water quality.

ANZECC (2000) also provides screening trigger values for southeast Australia NSW low land rivers (less than 150 m in altitude). The lowland rivers criterion has also been used in this assessment to further characterise overall water quality conditions.

The groundwater data were also compared against Australian Drinking Water Guideline values for human health and aesthetic values.

The adopted criteria are listed within the analytical results tables presented in Appendix C.

The data were collected between 1991 and 1999. The surface water sampling events were conducted over a range of climatic (wet and dry) conditions. While this sampling was conducted some time ago, the land use conditions do not appear to have changed significantly and the data are therefore expected to be representative of current water quality conditions. The sampling locations are presented in Figure 2. (surface water) and Figure 1 (groundwater).

3.8.2 Surface Water Quality Data

The data suggest that the surface water has background concentrations for cadmium, iron and zinc consistently above the selected ANZECC (2000) freshwater criteria. Chromium and copper also exceed ANZECC (2000) freshwater criteria on a regular but less frequent basis. This is generally consistent with the findings of additional water sampling undertaken for the biodiversity assessment (GHD, 2015, Section 4.4), although detections were apparent for nickel in recent sampling.

The iron concentrations are also generally above ANZECC (2000) irrigation threshold criteria.

There were no detectable concentrations of petroleum hydrocarbons. This is consistent with the findings of additional water sampling undertaken for the biodiversity assessment (GHD, 2015, Section 4.4).

Nitrate, total nitrogen and phosphorus were regularly above ANZECC (2000) freshwater criteria or general lowland river characteristics. Phosphorus also exceeds long term irrigation criteria. This is expected to be reflective of a catchment that has been disturbed by agricultural and other rural development. This is consistent with the findings of additional water sampling undertaken for the biodiversity assessment (GHD, 2015, Section 4.4).

Electrical conductivity (EC) values ranged between 645 μS/cm and 9,550 μS/cm. When these values are compared to the salinity criteria for lowland rivers of 125 to 2200 μS/cm (ANZECC, 2000), it is apparent that the concentrations generally exceed the range. This is expected to be due to the influence of the surrounding shale geology that has interstitial connate seawater that discharges into surface water features via groundwater. Based on this, locations with higher concentrations such as Thompsons Creek would be expected to have relatively higher interaction with groundwater discharge (see the discussion on groundwater quality below). The findings are consistent with the recent water quality sampling results presented in the biodiversity assessment (GHD, 2015, Section 4.4).

3.8.3 Groundwater Quality Data

The data suggest that the groundwater water quality has background concentrations of lead, zinc and copper consistently above the selected ANZECC (2000) freshwater criteria. Total nitrogen and phosphorus concentrations were all above freshwater criteria for lowland rivers with some exceedances of the irrigation criteria. Isolated samples had concentrations of nitrate

above ANZECC (2000) freshwater criteria. Concentrations of sulphate above human health drinking criteria are present at a number of locations across the site.

Recreational water quality criteria and aesthetic human health criteria were generally exceeded by more than an order of magnitude for chloride and sodium.

EC ranged between 1,350 μS/cm and 40,800 μS/cm with average and median concentrations being 21,474 μS/cm and 25,100 μS/cm, respectively. These values are predominantly much higher than the salinity criteria for lowland rivers of 125 to 2200 μS/cm.

A comparison of the EC results for groundwater with the surface water results (as noted in the previous section) indicates that groundwater salinity concentrations are generally an order of magnitude higher on average than surface water concentrations. This suggests that the overall contribution of groundwater to surface water inputs is small.

The high EC values also support a low groundwater flow environment, which also supports the assumption of low rainfall recharge to groundwater.

When the total dissolved solids (TDS) values are converted to TDS using the criteria listed in ANZECC (2000) (21,474 μS/cm EC converts to 14,387 mg/L TDS and 25,100 μS/cm converts to 16,817 mg/L TDS) and compared against stock usage criteria presented in ANZECC (2000), the groundwater can be categorised as being unsuitable for watering all stock types.

The converted TDS data are generally more than an order of magnitude above the “unacceptable” criteria (<1,200 mg/L) for TDS in the Australian Drinking Water Guidelines (ADWG, 2011).

Based on this data, it is concluded that:

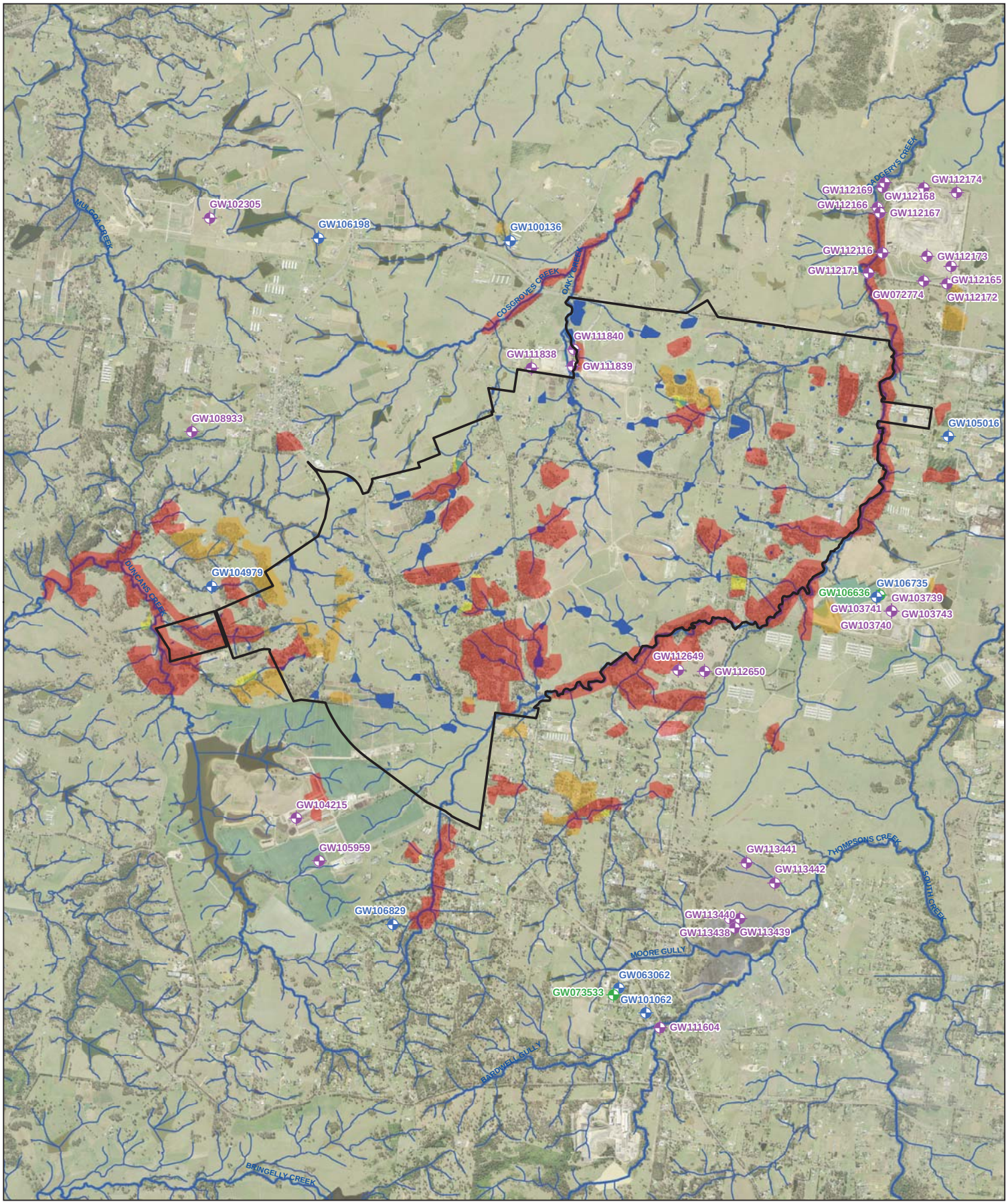
- the groundwater in this area has low beneficial use potential for stock and potable purposes;
- the groundwater contributions to surface water are expected to represent a small part of the overall surface water flows in the area; and
- in terms of groundwater management during construction and operation of the proposed airport, salinity, metals (particularly cadmium, copper, lead and zinc), sulphate, total nitrogen and phosphorus may require further consideration if discharge to surface water is being considered.

3.9 Registered Groundwater Bores

There are in excess of 42 registered groundwater bores within five kilometres of the site centre, which are presented on Figure 5.

Details of the bores are provided in Appendix B. Overall, the available data suggest that groundwater is sparsely used, with only 12 bores for domestic, stock, industrial, farming and irrigation purposes. It is noted that all of these bores are generally screened at significant depth and are expected predominantly to intersect the underlying Hawkesbury Sandstone.

This information suggests that only deeper groundwater in the Hawkesbury Sandstone is suitable for the uses outlined above and that shallow groundwater in the Bringelly Shale is unsuitable for beneficial domestic, stock, irrigation and industrial water use purposes.



LEGEND

- Site Boundary
- Major Watercourses
- Dams (within site boundary)
- Tributaries
- Active Water Supply Wells
- Potentially Active Water Supply Wells
- Wells Not Used For Water Supply
- Vegetation with high groundwater dependence proximal to site
- Vegetation with moderate groundwater dependence proximal to site
- Vegetation with low groundwater dependence proximal to site

Paper Size A3

0 125250 500 750 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Groundwater Impact Assessment

Job Number 21-24265-09
Revision A
Date 14 Jul 2015

Groundwater Receptors

Figure 5

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3.10 Groundwater Dependent Ecosystems

Communities of potential groundwater dependent ecosystems are identified within the Australian Bureau of Meteorology (BoM) Groundwater Dependent Ecosystems (GDE) Atlas.

The airport site has been cleared extensively with the exception of stands of remnant and regrowth vegetation located predominantly along Badgerys Creek and the south western portion of the site. The remaining vegetation generally comprises Cumberland Plain Woodland and River-flat Forest. These stands of vegetation broadly correlate with the areas identified as potentially groundwater dependent ecosystems shown on Figure 5.

Thompsons Creek and South Creek located in the catchment downstream from the airport site have been identified as reliant on the surface expression of groundwater. However, no creeks within or immediately adjoining the airport site are listed as being reliant on the surface expression of groundwater (i.e. groundwater inflow). This information is supported by the electrical conductivity data (see Section 3.8), which suggests that groundwater inflow is a minor component of creek flow.

The water sharing plan for the greater metropolitan groundwater resources lists two high priority groundwater dependent ecosystem types (being wetlands and vegetation communities) within the Sydney central basin porous rock groundwater source. This includes Salt Pan Creek (wetland), Long Swamp (wetland), Longneck Lagoon (wetland), O'Hares Creek (wetland) and potentially Cumberland Plain Woodland (vegetation community). Other than Cumberland Plain Woodland, these features are located outside the catchments intersected by the airport site.

There are a number of surface water dams present across the site. These have been interpreted by site biodiversity investigations (GHD, 2015) to be 'artificial freshwater wetlands' of good condition. These features are expected to have been developed initially as farm dams to capture surface water run-off and are therefore primarily reliant on surface water inputs rather than groundwater. The low permeability clays in which these dams have been developed will limit the connection with surrounding groundwater.

3.11 Conceptual Model

Figure 6 presents an idealised hydrogeological conceptual model for the existing site and highlights the interactions between groundwater and potential systems reliant on groundwater based on the data presented in Section 3. Key findings of the conceptual model are described below.

- There are three groundwater systems potentially interacting with the project that are located within shallow alluvium, weathered clays (intermittent system only) and the underlying shale. The Hawkesbury Sandstone represents a fourth regional aquifer system, used for water supply purposes, located at depths of more than 100 m below ground surface and at the base of the Bringelly Shale.
- The aquifer systems have poor quality (very high TDS) and low yields (as indicated by low hydraulic conductivities), suggesting that overall there is very limited beneficial use potential for potable and stock use.
- Groundwater elevations generally range between less than 1 m and 12 m below ground surface across the site.
- The aquifer extents are interpreted to be at Duncans Creek, Cosgroves Creek and Badgerys Creek where the aquifers discharge and vertically by the presence of very low vertical hydraulic conductivities of the Bringelly Shales (as evident in vertical head gradients). There is minimal hydraulic connection with groundwater beyond these creeks

and with the Hawkesbury Sandstone aquifer underlying the shales (which is used for water supply).

- Groundwater at the site is interpreted to discharge to Duncans Creek, Cosgroves Creek and Badgerys Creek. However, based on water quality data (mainly EC differences between surface water and groundwater across the site) it is expected that the groundwater inputs are small compared to surface water run-off inputs. Previous field observations suggest that flow in the creeks is intermittent and not reliant on groundwater baseflow. Based on this, the overall reliance of surface water features on groundwater inflow is expected to be minor.
- There is potentially sensitive vegetation located along Badgerys Creek and Cosgroves Creek that is potentially reliant on subsurface groundwater. Groundwater in nested piezometers in these areas suggests that there is some hydraulic disconnection between the isolated alluvial aquifers (i.e. different groundwater elevations) over which the vegetation is generally located and the more regional shale aquifer systems. There also appears to be a downward hydraulic head gradient, with the alluvial aquifer leaking to, rather than relying on, water from the shale aquifer system. This suggests that any disturbance of the more regional shale aquifer system during construction and operation would have only a minor impact on the alluvial aquifer system and the groundwater reliant vegetation in these areas. Vegetation located away from the alluvial aquifer is likely to be primarily reliant on rainfall.
- The inherent hydrogeological and geochemical conditions suggest that the existing groundwater environment has limited environmental value and that there will be a low risk of adverse impact to the groundwater environment from the proposed airport development.

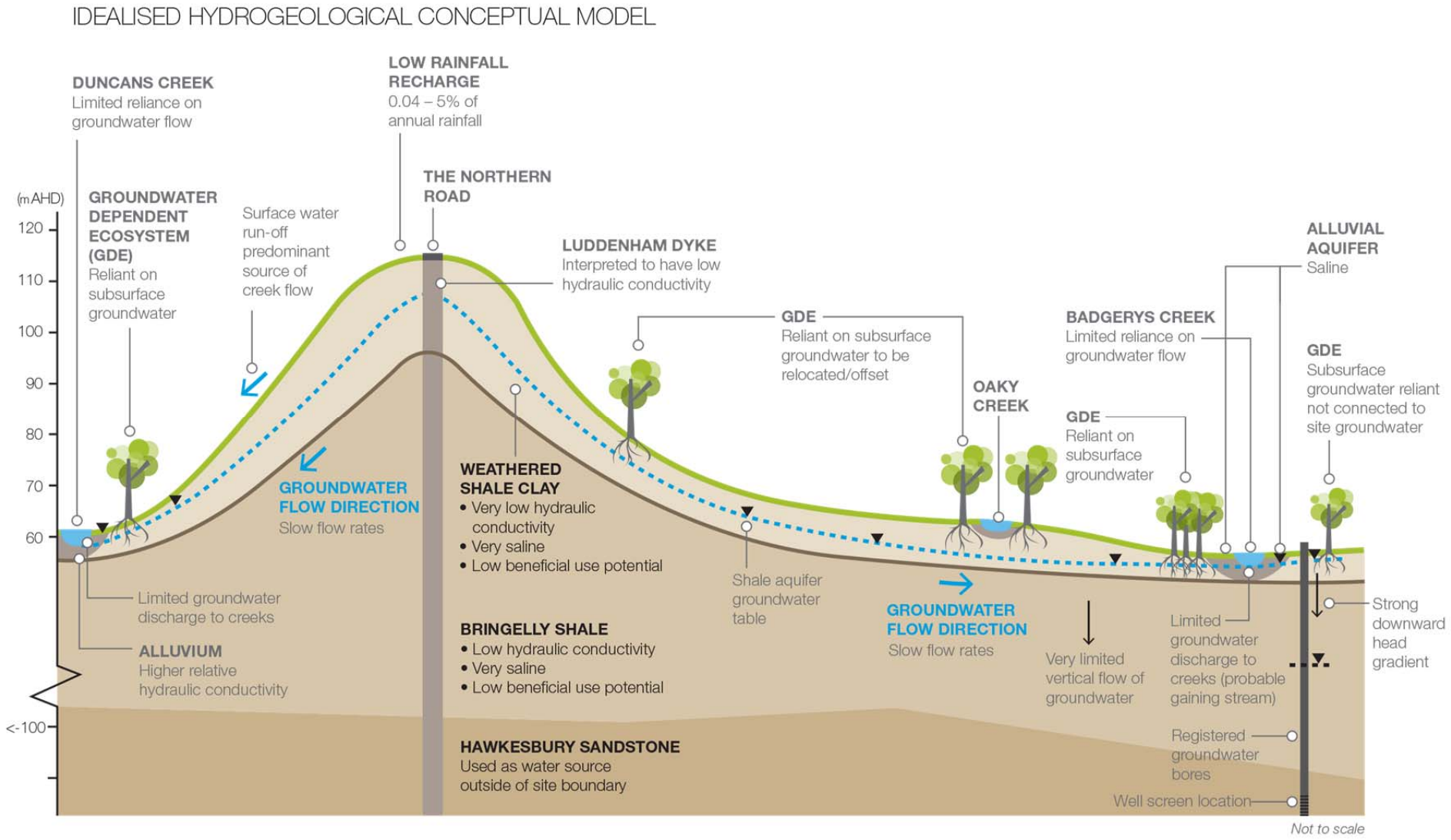

Figure 6 – Conceptual Hydrogeological Model

4. Assessment of Impacts

4.1 Introduction

The aim of this assessment is to consider the potential for development of the proposed Western Sydney Airport to alter the existing groundwater conditions at the site and associated risks to the range of beneficial uses or values of the receiving environment identified in Section 3.

The impact assessment includes a discussion of the key project features/sources that could affect groundwater conditions. These include:

- changes in groundwater recharge;
- groundwater drawdown from subsurface infrastructure and cuttings intersecting the groundwater table; and
- groundwater quality risks.

These sources of impacts have been assessed relative to the surrounding sensitive environmental features/systems identified in Section 3.

The risk/impact to groundwater resources would differ significantly between construction and operation and therefore each of these sources of impact are discussed separately.

The proposed airport would be developed in stages based upon aviation demand. The initial airport development would include a single 3,700 metre runway on a north-east/south-west orientation and aviation support facilities to provide an operational capacity of approximately 10 million annual passengers. The airport may subsequently expand to include two parallel runways and supporting facilities to achieve a capacity of approximately 82 million annual passengers. For the purposes of this assessment, potential impacts associated with the initial and longer term development have been considered together because the potential groundwater impacts are broadly similar and the mitigation and monitoring measures can also be applied to both stages of development.

4.2 Groundwater Recharge

4.2.1 Sources of Recharge Reduction

Construction

A conceptual outline of construction based on the current understanding of construction activities is presented in Figure 7. The key aspects of the airport construction that may limit recharge are listed below.

- The construction of access roads, tracks and the isolation of areas for the stockpiling of construction materials (i.e. the laydown and maintenance areas) could alter groundwater recharge conditions. Compaction of shallow soils associated with construction works in areas of unconsolidated alluvial sediments may also result in reduced groundwater recharge.
- Re-profiling of the land surface would alter the hydraulic properties of the environment as excavated material used for fill is expected to have higher overall permeability and porosity. This may lead to a temporary increase in the potential for rainfall recharge during the bulk earthworks phase of the development.

- As construction progresses, there would be an increasing amount of paved concrete surface and site facilities that would reduce recharge below existing conditions.
- Sedimentation basins may also act as a source of recharge, although the natural clays and shales in this area currently limit recharge. Any additional sediment basins would be constructed by similar methods, limiting the recharge that would occur.
- All existing farm dams would ultimately be removed, which subsequently would eliminate any potential recharge from these sources. The present recharge from these sources is expected to be small.

Overall, minimal change to local groundwater recharge would be expected as the existing shale derived clay soils have low permeability resulting in the majority of rainfall falling at the site being released as stormwater run-off rather than infiltrating to groundwater. It is not expected that existing farm dams at the site contribute a large amount to groundwater and the removal of these during construction would likely have a negligible effect on groundwater recharge.

Operation

A conceptual outline of operation based on the current understanding of proposed construction activities is presented in Figure 8. During operation, the primary cause of recharge reduction would be sealed areas. The estimated sealed areas that would be taken up by the Stage 1 and longer term developments are summarised as follows:

- Stage 1 development – 345 Ha of the total site area of 1,775 Ha (i.e.19 per cent of the total site area); and
- Longer term development – 1,008 Ha of a total site area of 1,775 Ha (i.e. 57 per cent of the total site area).

It is understood that there would be a swale system put in place to receive tarmac run-off and direct water to bio-retention basins. In areas of exposed shales and existing residual clays, there would be limited migration to the underlying groundwater systems, similar to the limited migration to groundwater systems from the existing farm dams on the site. In re-profiled areas that have been infilled, the swales would be clay lined to prevent infiltration to groundwater and hence the potential generation of groundwater quality impacts.

The surface water collected from buildings and other site facilities would be directed into a surface water collection system that includes clay lined swales and a number of bio-retention basins. It is expected that the bio-retention basins would also be lined and that recharge from these systems would be minimal.

Based on the sealed areas for the Stage 1 and longer term Development outlined above, it can be expected that the net reduction in recharge will approximate:

- 19 per cent of existing conditions for the Stage 1 Development; and
- 57 per cent of existing conditions for the longer term development (this is inclusive of the Stage 1 project).

As noted in Section 3, the underlying shale aquifer is of negligible beneficial use and this reduction is not expected to result in substantive impacts to resource volumes. Additionally, impacts to groundwater bores are expected to be negligible as there are no bores located within the saline shale aquifer underlying the site.

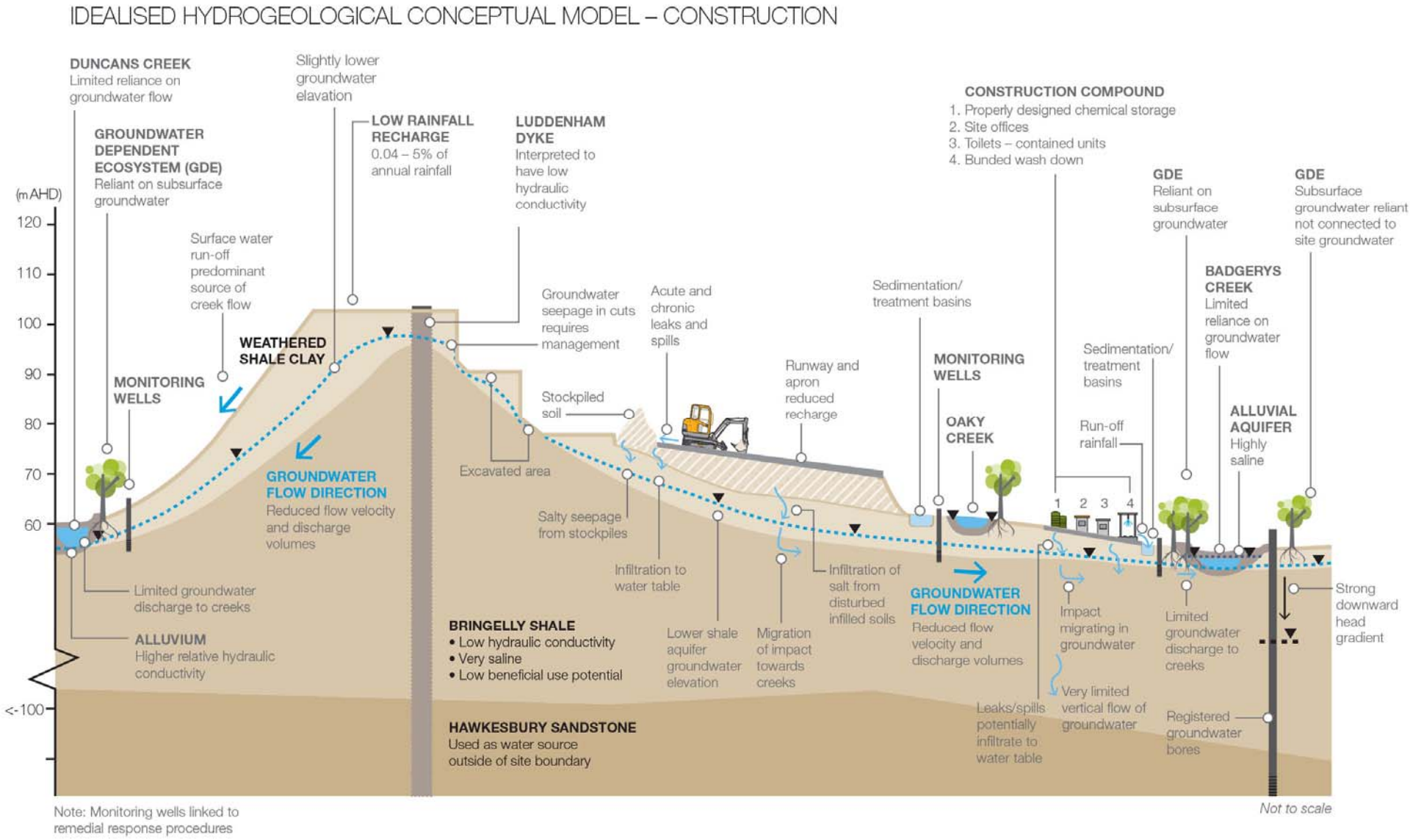

Figure 7 – Conceptualisation of Construction Interactions with Groundwater

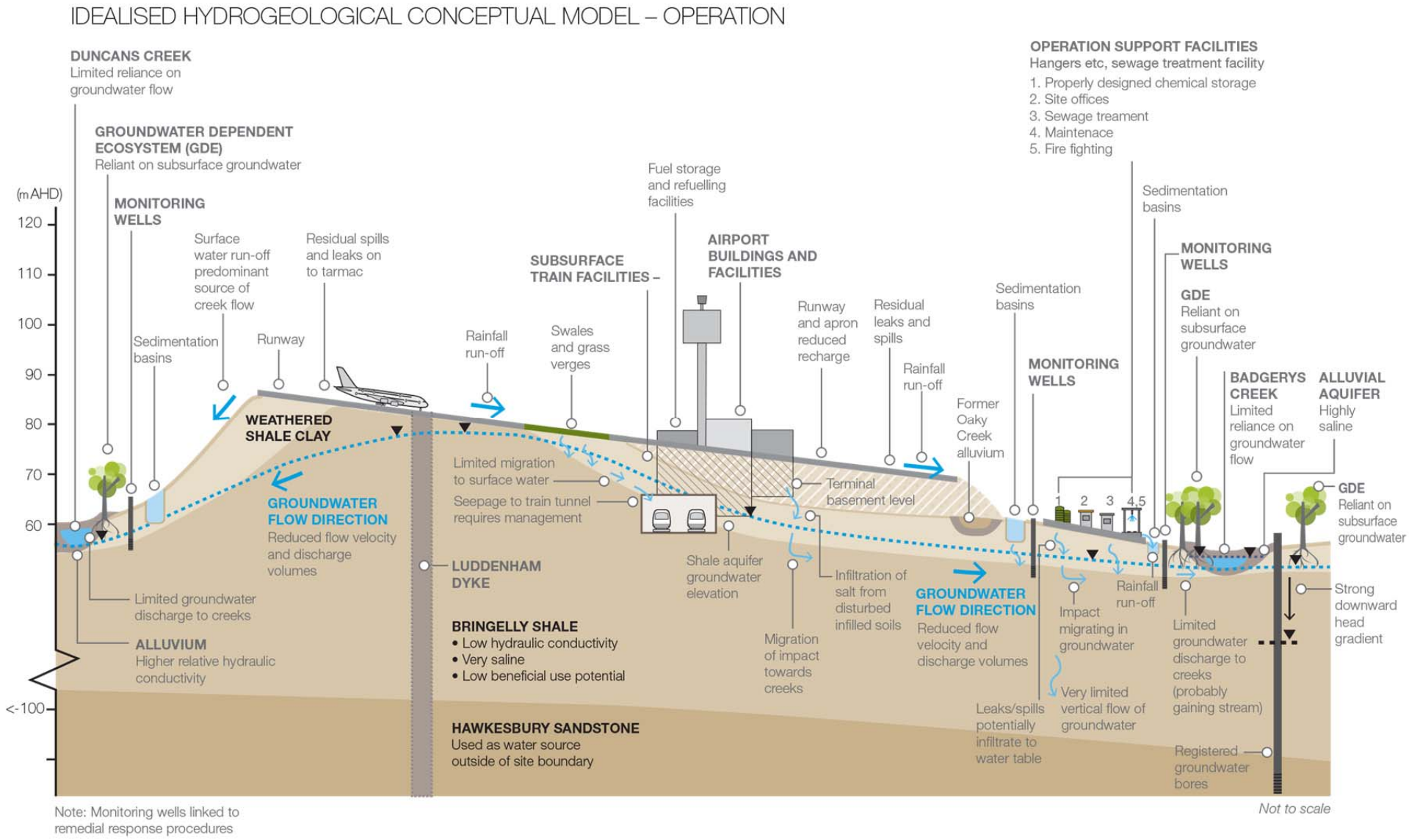

Figure 8 – Conceptualisation of Operational Interactions with Groundwater

4.2.2 Impacts of Recharge Reduction

Artificial wetlands in farm dams are not expected to be in hydraulic connection with groundwater and as such impacts are expected to be negligible. The majority of these features would also be removed as development progresses.

Changes in groundwater elevations from re-profiling the airport site and from reduced recharge beneath paved areas may have a minor impact on vegetation located along the riparian zones of the surface water systems. The impacts to these systems are expected to be minor for the reasons outlined below.

- Groundwater in the alluvial aquifer systems appear to have limited contact with groundwater in the shale aquifers impacted by site works. Historical data also suggest that the alluvial aquifer systems do not rely on the shale aquifer for water supply.
- Rainfall recharge in the alluvial aquifer areas is not expected to change as these areas would not be impacted by site works and changing land use.
- Site works would not result in a significant lowering of surface elevations such that alluvium and the shale aquifers would be drained. There may be a reduction in groundwater flow rates; however the overall changes in level would be expected to be small.
- There would be localised impacts around excavations for the rail connection. This is not however expected to result in significant dewatering of riparian areas. Additional modelling at detailed design may be required to confirm this conclusion.

Changes in groundwater levels may result in a small reduction in discharge to surface water features. The impacts to these systems are expected to be minor for the following reasons.

- Historical water quality data and hydrogeological data (hydraulic testing data) suggest overall groundwater inputs to surface water are small (for example there is a significant difference between the TDS of surface water and the TDS of groundwater aquifers). Therefore the overall recharge reductions of between 19 per cent and 57 per cent are not expected to create adverse impacts. Further, groundwater across the site is highly saline and a small reduction in flows may actually reduce salt loads to surface water features and improve overall water quality.
- While recharge to groundwater might change, it is unlikely that groundwater elevations at discharge points would fall significantly (as they would still be a point of discharge). As such, it is not expected that stagnant pools present in surface waters during dry periods would be prone to drying up as a result of the proposed development.

While the impacts are expected to be minor, a monitoring regime should be implemented. This monitoring would be able to identify and characterise any emergent impacts outside of those expected and would make links to necessary response procedures.

There is a potential risk for settlement of soft sediments associated with reduced rainfall recharge beneath the proposed airport, and dewatering around areas of subsurface infrastructure and up-gradient of cuttings where seepage is occurring. Existing groundwater data suggest that aquifers in residual clay and weathered shales are intermittent and perched and as such, the potential for settlement is expected to be low. The potential for settlement in re-profiled material is being assessed as part of ongoing geotechnical investigations. The design phase should consider potential impacts of further dewatering of soft sediments to characterise the level of risk involved in the process.

4.3 Groundwater Drawdown

4.3.1 Sources of Groundwater Drawdown

Construction

Extensive re-profiling of the site would be undertaken to create a flatter surface for the development of the proposed runway and associated facilities. The works would include excavating areas of higher topography and using the material to infill areas of lower topography. This would result in an expected elevation at the south western end of the northern runway of approximately 93 m AHD and an expected elevation at the north eastern end of the runway of 73 m AHD. These elevations will be higher than the surrounding creeks.

The re-profiling would result in a decrease in groundwater elevations in areas that currently have higher topographical elevation. This is expected to result in reduced groundwater flow rates and hence reduced discharge to surrounding surface features. The re-profiling would not result in dewatering of the groundwater system below the level of the surrounding creeks and there would be no potential for drying up of the creeks.

Establishment of basements in the terminal complex and creation of a station cavern for a future rail connection during the initial construction would likely intercept the underlying shale aquifers and require dewatering and management throughout construction.

Due to low inherent hydraulic conductivities of the geology in these areas, it can be expected that seepage volumes would be relatively small.

The installation of services would generally be shallow and would only intersect very shallow groundwater if at all.

The peripheral sections of the re-profiled area would likely have exposed cuttings that would seep and reduce groundwater levels in the elevated areas around the cuttings.

Operation

The same sources of impact present during construction would be present during operation. Nevertheless, the manifestation of seepage would be different as the construction excavations would be replaced by infrastructure that would change seepage conditions. For example, subsurface infrastructure wall linings could be designed to limit seepage.

4.3.2 Groundwater Drawdown Impacts

Groundwater drawdown and flow risks to surrounding groundwater users and artificial wetlands would be negligible as there would be no hydraulic connection between these features and any subsurface infrastructure.

Due to the hydrogeological conditions, there is expected to be minor potential for impacts to groundwater elevations beneath vegetation along creek riparian zones and for reduction in discharge into creeks. It is recommended that additional modelling should be completed at the detailed design phase to confirm any drawdown impacts, when the nature and design of subsurface structures intersecting groundwater is understood.

There are a number of methods available for reducing seepage and drawdown impacts that could be adopted which include the installation of temporary linings (such as sheet-piling and shotcreting excavations) during construction and permanent linings or grouting during operation.

As drawdown impacts are expected to be minor, a groundwater monitoring programme at potential sensitive receptors (such as creeks with riparian vegetation) is considered to be sufficient to assess for the emergence of any impacts.

4.4 Groundwater Quality

4.4.1 Sources of Groundwater Quality Impact

Construction

Potential groundwater quality risks include isolated spills and incidents occurring during construction and diffuse impacts associated with general construction activities such as use of machinery. Contaminants of primary concern are usually hydrocarbons, however other chemicals such as herbicides, pesticides and fertiliser may also be used during construction. Impact is likely to occur through the infiltration of pollutants into the ground surface or through dirty water retention facilities (such as temporary sediment basins) to the underlying groundwater systems.

Groundwater seepage into excavations for building basements or station cavities would need to be managed by pumping any seepage to stormwater management facilities and/or other suitable treatment systems. Given the background groundwater quality data and the expected chemicals that would be used during construction, the following primary chemicals of concern have been identified:

- pH;
- Total dissolved solids (TDS);
- Metals;
- Total nitrogen;
- Phosphorus;
- Sulphate;
- Petroleum hydrocarbons; and
- Polynuclear aromatic hydrocarbons.

There would be small seeps from cuttings that would also require appropriate management prior to discharge offsite.

Sewage generated during construction would be contained in storage facilitates and removed offsite by an appropriately licensed waste contractor.

Groundwater present in the shallow geology has been identified to have high salinity values. The excavation and use of this material for infilling could permit the release of additional salts into groundwater. This would only occur where increased recharge occurs to fill areas and where a shallow groundwater table develops in the fill material.

Operation

It is expected that the stormwater management system would include a mixture of stormwater drains that would re-direct surface water from the proposed aviation and commercial development areas to the stormwater capture systems, swales and site bio-retention basins.

All chemicals located on-site would be handled and stored in accordance with appropriate standards and would include appropriate bunding, spill management capacity and emergency response systems and procedures.

Run-off from sealed surfaces could potentially contain pollutants associated with normal site activities, acute and diffuse leaks and spills, and accidents from aircraft support vehicles and aircraft.

The surface water system implemented to capture and treat surface water could potentially act as a diffuse source of groundwater quality impacts. The stormwater treatment systems (treatment/bio-retention basins) would be designed to prevent leakage and infiltration to groundwater. This would include the lining of swales where they intersect higher permeability re-profiled material rather than the lower permeability clays and shales that currently exist.

Based on the current understanding of aquifer properties and likely groundwater migration rates, it is expected that any potential impacts would emerge slowly as any groundwater impacted by site activities migrates down the hydraulic gradient.

The primary chemicals of concern associated with site activities are expected to arise from metals and petroleum hydrocarbons (including poly aromatic hydrocarbons). There would also be a risk from fire retardants and other chemicals associated with managing accidents and spills, and solvents used in maintenance facilities.

The potential future subsurface rail connection is anticipated to intersect groundwater. In the instance of a free draining rail alignment, seepage would require collection and management before discharge to any receiving environment.

4.4.2 Groundwater Quality Impacts

As the underlying aquifer system is of low beneficial use, adverse impacts may only potentially emerge when impacted groundwater migrates beneath areas of groundwater reliant vegetation (located in creek riparian areas) and/or discharges into creeks.

Impacts to surrounding registered water bores would be negligible as they are expected to be hydraulically separated from the site by the saline, low hydraulic conductivity shale aquifer.

Groundwater flow velocities are expected to be slow and as such the emergence of any impacts would be slow. A groundwater monitoring approach is considered to be suitable to manage the identification of groundwater quality impacts.

Site management procedures and the operational design of the proposed airport would further limit the potential for groundwater quality impacts and are discussed below with regard to construction and operation.

Construction

The risk posed by construction activities would be low due to stringent management measures imposed during construction as part of a construction environmental management plan (CEMP) that would be developed in accordance with Australian Standards. The CEMP would include methods and procedures for:

- separating clean and dirty water and preventing infiltration of impacted surface water into the underlying groundwater system;
- preventing groundwater seepage from contacting potentially contaminating site activities by minimising ponding of water in active areas and making storage facilities impermeable;
- adequately storing and handling site chemicals;
- identifying and responding to chemical spills and managing their clean-up; and
- monitoring for the emergence of diffuse water quality impacts with subsequent response procedures to remediate any impact.

Proposed monitoring procedures are outlined further in Section 5.

Groundwater seepage would be either transported away from active construction areas and discharged back to the environment and/or removed/discharged offsite to an appropriately licensed treatment facility. While seepage volumes to the subsurface rail corridor, caverns, and at cuttings are expected to be small, seepage minimisation methods may also be adopted to either eliminate or minimise the amount of groundwater seepage generated. These methods could include:

- installing temporary walls (such as shotcrete liners or sheet piling) during construction behind the progressing work area (at cuttings and in any building basements or sub-surface rail corridor); and
- installing liners (if selected) as soon as possible behind the working face.

Based on the water quality conditions discussed in Section 3.8, groundwater seepage into cuttings and the subsurface rail corridor would require some form of treatment (for total dissolved solids, sulphate, metals and nitrogen) before it could be discharged to surface water. The type of treatment system developed would be determined at the detailed design phase, but may include discharge to the surface water treatment system.

Operation

The detailed design and procedures at the proposed airport would facilitate efficient vehicular movements that would be controlled by regimented airport control systems. This would reduce the potential for accidents and also the potential of a spill of hazardous substances.

The system would be designed to minimise infiltration of contaminants to groundwater by redirecting any rainfall and run-off from the airport through a treatment system that would prevent connection to the underlying groundwater systems. The design would include drainage systems and storage systems that are impermeable or minimise leakage.

In the event that any spills did occur, the spill would be directed to surface water capture systems, which would have the capacity to receive a spill with a volume corresponding to that of the expected source. Any surface water capture systems installed would have potential for spillage control or containment. Maintenance areas where solvents are used would be within isolated areas with appropriate storage. Any waste generated would be managed and transported offsite to an appropriately licensed facility.

Surface water quality treatment measures would be implemented to provide capacity to treat first flush from pavement surfaces and reduce the risk of spills discharging onto adjacent land or watercourses. The potential for spillage control or containment would be based on the hydrologic conditions prevailing at the time of the spill. Structures would be designed to limit the potential for infiltration to the underlying groundwater system (i.e. they would be appropriately lined).

Groundwater seepage into cuts, the subsurface rail corridor and station caverns would be treated before being discharged back to the environment and/or removed/discharged offsite to an appropriately licensed treatment facility. Treatment may include discharge to the surface water treatment system if suitable; however, the design of the treatment system would be determined at the detailed design phase. Monitoring would be required to test the effectiveness of the treatment system implemented.

While seepage volumes in subsurface rail corridor areas, and particularly at cuttings, are expected to be small, seepage minimisation methods such as the adoption of impermeable liners may be considered at the detailed design phase.

4.5 Cumulative Impacts

Cumulative impacts to groundwater are expected to be localised to the low value shale aquifer systems beneath the site that discharges to surrounding surface water features.

There would be an ongoing risk to surface water quality from groundwater discharge that would require monitoring and management. If impacts emerge, response procedures would be implemented to mitigate the impacts.

Based on the above, it is considered that cumulative impacts can be effectively managed.

5. Mitigation and Management Measures

5.1 Construction

5.1.1 Groundwater Drawdown

Drawdown impacts are expected to be minor and any mitigation measures would be linked to groundwater elevation monitoring at key sites. If changes are found to be creating adverse impacts to either groundwater reliant vegetation or instream water availability, mitigation measures would be imposed to supplement groundwater supplies. Such measures may include the recharge of treated seepage water or other clean surface water derived on-site to key areas where issues have been identified. Given the low discharge nature of the aquifer systems in these areas, it is expected that required volumes could easily be obtained from surface water run-off supplies.

It is noted that the likelihood of occurrence of groundwater drawdown impacts is expected to be minimal and therefore a reactive approach based on monitoring is considered to be acceptable.

5.1.2 Water Quality

It is expected that the risk posed by construction activities would be low due to stringent management measures imposed during construction as part of the CEMP. The CEMP would include methods and procedures for:

- separating clean and dirty water and preventing infiltration of impacted surface water into the underlying groundwater system. Measures adopted should be in accordance with relevant NSW and Australian guidelines;
- preventing groundwater seepage from contacting potentially contaminating site activities by minimising ponding of water in active areas and making storage facilities impermeable;
- preventing impacted groundwater from entering the surface water management system unless it represents a credible treatment option;
- adequately storing and handling site chemicals;
- identifying and responding to chemical spills and managing their clean-up; and
- monitoring for the emergence of diffuse water quality impacts and implementing response procedures to remediate any impact.

5.2 Operation

5.2.1 Groundwater Drawdown

Drawdown impact mitigation would be the same as that presented for the construction phase.

5.2.2 Water Quality

The design and operation procedures at the proposed airport would facilitate efficient vehicular movements that would be controlled by regulated airport control systems. This would reduce the potential for accidents and spills at the airport including hazardous substances.

The system would be designed to minimise infiltration of contaminants to groundwater by redirecting any rainfall and run-off from the airport through a surface water system that would prevent connection to the underlying groundwater systems. The design would include drainage systems and storage systems that are impermeable or that minimise leakage.

In the event that any spills did occur, the spill would be directed to surface water capture systems, which would have the capacity to receive a spill with a volume corresponding to that of the expected source (e.g. an aircraft refuelling spill). Any surface water capture systems installed would have spillage control or containment systems. Maintenance areas where solvents are used and other facilities such as fire training areas would be within isolated bunded areas with appropriate storage. Any waste generated would be transported offsite to appropriately licensed facilities.

Surface water quality treatment measures would be implemented to provide capacity to treat first flush from pavement surfaces and reduce the risk of spills discharging onto adjacent land or watercourses. Spillage control or containment systems would be based on the hydrologic conditions prevailing at the time of the spill. Containment systems would be designed to limit the potential for infiltration to the underlying groundwater system (i.e. they would be appropriately lined).

There will be a residual risk of diffuse impacts from run-off from the proposed runway and apron areas being directed to and infiltrating through swale systems. The risk of groundwater quality impacts are expected to be low as the swales would collect water from areas that are away from more intensive site activities (which would have additional operational controls in place). As such, a monitoring approach is proposed for managing this risk with subsequent remedial investigations and clean-up responses linked to the emergence of groundwater quality impacts.

5.3 Monitoring

The proposed monitoring to assess impacts from construction and operation activities is presented below.

An airport lessee company would be required to undertake water quality monitoring in accordance with the Airports (Environmental Protection) Regulations 1997.

5.3.1 Groundwater Drawdown

Ongoing monitoring of the groundwater elevations on a quarterly basis should be undertaken to identify changes in groundwater elevations in and around areas near creeks and areas with groundwater dependent ecosystems.

Groundwater monitoring around areas of subsurface infrastructure and cuttings where seepage could occur would also be undertaken to characterise potential groundwater impacts.

Impacts would be considered to exist when groundwater elevation changes fall below expected root zones for sensitive vegetation and below seasonal variations near to creeks. This would instigate additional biodiversity investigations to assess the impact on biodiversity at these sensitive receptors.

Baseline monitoring is recommended for determining existing conditions on which the emergence of impacts could be identified.

Baseline and construction (including earthworks) monitoring would be essential for identifying conditions on which the emergence of impacts during operation could be identified. Quarterly monitoring would be undertaken and continue until such time that data suggest that any identified impacts stabilise or for a minimum period of:

- three years after completion of the Stage 1 Development; and
- three years after completion of the longer term development of the airport (i.e. construction of a potential second parallel runway and associated earthworks).

5.3.2 Water Quality Monitoring

The proposed locations for groundwater monitoring should focus on the early detection of impacts and the protection of sensitive environmental receptors. As such monitoring would occur:

- around and down-gradient of major infrastructure and at depths equivalent to the depth of construction and operation impacts. It is noted that the key sources of groundwater quality impacts would be different during construction and during operation and as such, the monitoring network would need to change also; and
- within areas of identified sensitive vegetation in creek riparian areas and around creeks.

Groundwater monitoring of both the alluvial aquifer and shale aquifers should be undertaken. Some monitoring of fill material should also be undertaken to assess the potential generation of a separate water table within the fill and intensified movement of salt.

Surface water quality monitoring would be down-gradient of key site works and focus on dry periods when groundwater seepage has greater potential to impact on instream conditions.

As the emergence of groundwater quality impacts is expected to be slow, a quarterly monitoring frequency is considered to be suitable. This may be expanded to yearly subject to the findings of a suitable period of preceding monitoring events.

It is expected that the analytical suite used for water quality monitoring would focus on key contaminants expected to be associated with construction activities and the surrounding land use and chemicals that are indicative of overall instream condition. As a minimum the analytical suite should include:

- total dissolved solids;
- suspended solids;
- pH;
- metals concentrations in groundwater for cadmium, iron, lead, nickel, manganese and zinc;
- chloride, sodium and sulphate;
- nitrogen and phosphorus;
- total recoverable hydrocarbons, BTEX and polycyclic aromatic hydrocarbons (PAHs);
- pesticides; and
- aqueous film forming foam substances (during operation only).

Water quality monitoring results exceeding background water quality criteria and/or ANZECC (2000) would instigate further investigations and/or the remediation requirements outlined in the CEMP during construction. During operation the method of response to exceedances would be detailed in a groundwater monitoring plan for the site.

The available surface water and groundwater quality data suggest that there may be potential impacts from discharging collected groundwater seepage back to surface water, and that treatment may be required prior to discharge.

Regardless of the method of treatment proposed, monitoring would be required of the treated water prior to disposal. The frequency for monitoring would depend on the treatment system. Based on the hydraulic properties of the geology in which the subsurface rail corridor is proposed to be located, groundwater seepage volumes are expected to be low. As such, treatment within the surface water management system, or transport off-site to an appropriately licensed treatment facility, may be feasible. This would be determined at the detailed design phase.

It is expected that the criteria to be used for determining the acceptability of water quality for discharge or for the characterisation of 'no impact' would be background groundwater and surface water quality data (using ANZECC 2000 statistical methods), and the ANZECC (2000) freshwater criteria for the protection of 95% of freshwater species.

6. Summary and Conclusions

6.1 Groundwater Flow and Drawdown

Registered Groundwater Bores

Registered groundwater bores are located off-site at significant depth in the Hawkesbury Sandstones that are hydraulically disconnected from the saline Bringelly Shale aquifer located beneath the site. As such, the impacts to registered groundwater bores are expected to be negligible during construction and operation of the proposed airport.

Groundwater Dependent Ecosystems

Impacts to artificial wetlands within the airport site are expected to be negligible as they are located in low permeability clays with limited groundwater interactions and have historically been developed as farm dams to capture surface water run-off.

There are vegetation stands that may be opportunistically reliant on subsurface groundwater. Stands of remnant and regrowth vegetation would be progressively cleared with the ongoing development of the airport site. However, sensitive vegetation would remain along the riparian corridors of Duncans, Oaky and Badgerys Creeks. This vegetation is expected to intersect alluvial deposits which historical data suggest has limited hydraulic connection to the shale aquifers potentially impacted by the establishment of the proposed airport. While there may be minor changes to groundwater flow within the shale aquifers, the overall groundwater fluctuation would be small and any drawdown impacts in areas of sensitive vegetation are expected to be minor.

Further, in riparian areas near to discharge points it can be expected that, while discharge rates would change, overall groundwater fluctuations would be small. Consequently, groundwater drawdown impacts in areas of sensitive vegetation are expected to be minor. There may be enhanced drawdown in localised areas where cuttings or building basements are present. Due to the hydraulic characteristics of the intersected geology, this impact is expected to be very localised. A groundwater monitoring regime would be required to characterise the emergence of these impacts.

It is expected that construction and development of the proposed airport would reduce rainfall recharge and hence reduce groundwater discharge to surrounding creek systems. Historical water quality data and the existing hydrogeological conditions suggest that groundwater discharge forms a very low component of creek flow. This implies that the overall reliance on groundwater discharge is low and that groundwater discharge changes would have minor impacts.

During no-flow periods stagnant pool levels may be linked to surrounding groundwater elevations. While the construction of the proposed airport may reduce overall groundwater discharge rates, it is not expected that groundwater elevations would change significantly at discharge points, such that stagnant pools will drain. Because of this, it is expected that impacts would be negligible.

6.2 Groundwater Quality

Construction

There would be an inherent risk to groundwater quality associated with site activities during construction. The key sources of potential impact would be:

- acute and diffuse spill and leaks from site activities;
- diffuse leakage from site water treatment systems such as sediment dams;
- preferential leakage of salts from the disturbed shale derived material used as fill for re-profiling, although this is not expected to pose a significant additional risk given that groundwater is already very saline; and
- discharge of seepage water into excavations (such as the sub-surface rail corridor), cuttings and surface water if not treated suitably.

The underlying aquifer system is of low beneficial use potential and localised impacts within the aquifers are not expected to represent a potential adverse impact. There is a risk presented by the migration of impact within the saline aquifer beneath shallow sensitive vegetation located along creek riparian areas with discharge to creeks and artificial wetlands in farm dams. The risks are expected to be minor for the following reasons.

- The hydraulic connection between artificial wetlands and underlying groundwater is expected to be limited by low hydraulic conductivity of surficial materials. Historically the farm dams (in which the artificial wetlands are located) have been designed to intercept surface water rather than the saline groundwater.
- The alluvial aquifer systems in the riparian areas of creeks appear to have some hydraulic separation from the underlying shale aquifer (sometimes with higher groundwater elevations). As such, water quality impacts to the alluvial aquifers (on which riparian vegetation may rely) are expected to be minimal.
- Existing water quality data and hydrogeological conditions (low hydraulic conductivity and groundwater flow rates) suggest that overall groundwater discharge comprises a small component of creek flow and therefore instream water quality.

Despite the low risk, a residual risk is present and the construction and operation phases of the proposed airport development would include a number of features to further reduce the potential for impacts. These measures are summarised below in Section 5.1.

Any seepage water generated would need to be treated and managed before discharge to surface water. Recommended mitigation and monitoring measures are outlined Sections 5.1 and 5.3 of this report.

Operation

While the sources of groundwater quality impacts would be slightly different to those present during construction, the overall migration pathways and risk to sensitive receptors would be similar. As noted for construction, there will always be an inherent risk (albeit very low) to water quality at surrounding surface water features and sensitive groundwater reliant vegetation. Recommended mitigation and monitoring measures are outlined in Sections 5.2 and 5.3 of this report.

6.3 Conclusions

The groundwater assessment suggests that the inherent hydrogeological conditions result in a low risk of adverse groundwater impacts from construction and operation of the proposed airport.

There would be minor residual risks present which could be effectively managed using standard onsite procedural controls, engineered solutions and monitoring techniques.

Mitigation and monitoring measures have been recommended to address the identified issues and potential emergent issues that might arise during the construction and development stages of the proposed airport.

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Appendices

Appendix A – Site Groundwater Monitoring Well Data

Table A–1 – Site Groundwater Monitoring Well Data

Well ID	Easting	Northing	Easting	Northing	Consultant	RL (m AHD)	Date of installation	Well depth (m bmp)	Screen Top (m bmp)	Screen Bottom (m bmp)	Water elevation (m bmp)	Water elevation (m AHD)	Date of GWL observation	Interpreted Aquifer	Hydraulic conductivity (m/day)
D1	271752.1	1246954	286840	6245879	Coffey	104.2	5/07/1990	15.20			7.9	96.3	18/07/1990	Bringelly Shale	
D2	271995.5	1247904	287065	6246834	Coffey	97.6	4/07/1990	9.85			3.7	93.9	18/07/1990	Bringelly Shale	
D3	272232.7	1248255	287295	6247189	Coffey	105.7	27/06/1990	10.00			3.35	102.35	18/07/1990	Bringelly Shale	
D4	272063	1248870	287114	6247801	Coffey	98.8	5/07/1990	15.10			2.98	95.82	18/07/1990	Shallow unconsolidated/ Bringelly Shale	
D5	273082.2	1248529	288139	6247480	Coffey	102.5	9/07/1990	20.15			3.9	98.6	18/07/1990	Bringelly Shale	
D6	272714.5	1247595	287790	6246539	Coffey	112.9	2/07/1990	25.10			7.4	105.5	18/07/1990	Bringelly Shale	
D6	272714.5	1247595	287790	6246539	Coffey	112.9	2/07/1990	25.10			9.65	103.25	28/08/1990	Bringelly Shale	
D7	273069.5	1246943	288158	6245894	Coffey	79.4	6/07/1990	10.35			3.95	75.45	18/07/1990	Bringelly Shale	
D8	274012.3	1247535	289089	6246504	Coffey	92.1	27/06/1990	10.05			7.9	84.2	14/09/1990	Bringelly Shale	
D9	274422	1248172	289486	6247149	Coffey	87.5	26/06/1990	10.25			4.2	83.3	18/07/1990	Bringelly Shale	
D9	274422	1248172	289486	6247149	Coffey	87.5	26/06/1990	10.25			4.6	82.9	14/09/1990	Bringelly Shale	
D10	274722	1248891	289772	6247874	Coffey	88	10/07/1990	10.00			4.7	83.3	18/07/1990	Bringelly Shale	
D10	274722	1248891	289772	6247874	Coffey	88	10/07/1990	10.00			6.9	81.1	14/09/1990	Bringelly Shale	
D11	274432.2	1249505	289470	6248482	Coffey	74.1	25/06/1990	10.05			4	70.1	14/09/1990	Shallow unconsolidated/ Bringelly Shale	
D12	276140.9	1250354	291163	6249365	Coffey	59	24/06/1990	10.50			3.2	55.8	18/07/1990	Bringelly Shale	
D12	276140.9	1250354	291163	6249365	Coffey	59	24/06/1990	10.50			3.5	55.5	18/07/1990	Bringelly Shale	
D13	275667.4	1248896	290718	6247897	Coffey	73.5	24/06/1990	10.35			3	70.5	18/07/1990	Shallow unconsolidated/ Bringelly Shale	

Well ID	Easting	Northing	Easting	Northing	Consultant	RL (m AHD)	Date of installation	Well depth (m bmp)	Screen Top (m bmp)	Screen Bottom (m bmp)	Water elevation (m bmp)	Water elevation (m AHD)	Date of GWL observation	Interpreted Aquifer	Hydraulic conductivity (m/day)
D13	275667.4	1248896	290718	6247897	Coffey	73.5	24/06/1990	10.35			3.05	70.45	14/09/1990	Shallow unconsolidated/ Bringelly Shale	
D14	277093.4	1249619	292129	6248648	Coffey	55.2	21/08/1990	10.10			3.8	51.4	-	Shallow unconsolidated/ Bringelly Shale	
D19	273350.7	1249173	288395	6248129	Coffey	88.9	14/08/1990	15.00			5.5	83.4	-	Bringelly Shale	
D22	272171.1	1247389	287250	6246322	Coffey	103.2	15/08/1990	20.00			9.1	94.1		Bringelly Shale	
D23	272062	1248586	287118	6247517	Coffey	105.6	22/08/1990	20.7			9.6	96		Bringelly Shale	
D29	273321.5	1248075	288388	6247031	Coffey	95.1	15/08/1990	10.05			7.6	87.5		Bringelly Shale	
A	273027.8	1244999			PPK Environment	92.91		27.30	24.3	27.3	11.66	81.25		Bringelly Shale	0.0186
B	274549.3	1250139			PPK Environment	71.18		38.50	35.5	38.5	9.39	61.79		Bringelly Shale	0.0518
C	270472.7	1248025			PPK Environment	66.52		26.00	23	26	8.17	58.35		Bringelly Shale	0.022
D	271769.3	1247228			PPK Environment			25.00						Dry	
E Deep	272676	1245812			PPK Environment	78.21		11.30	8.3	11.3	2.85	75.36		Siltstone	0.026
E Shallow	272676.3	1245813			PPK Environment	78.23		5.00	2	5	0.69	77.54		Alluvial	0.536
E Creek Bed	272702.2	1245804			PPK Environment	76.06		0.00			-0.11	76.17		Creek Bed	
F Deep	273675.4	1246712			PPK Environment	69.87		30.30	27.3	30.3	3.9	65.97		Bringelly Shale	0.0162
F Shallow	273675.2	1246710			PPK Environment	69.92		6.00	3	6	2.51	67.41		Alluvial	0.00499

Well ID	Easting	Northing	Easting	Northing	Consultant	RL (m AHD)	Date of installation	Well depth (m bmp)	Screen Top (m bmp)	Screen Bottom (m bmp)	Water elevation (m bmp)	Water elevation (m AHD)	Date of GWL observation	Interpreted Aquifer	Hydraulic conductivity (m/day)
F Creek Bed	273651.5	1246808			PPK Environment	66.2		0.00			-0.11	66.31		Creek Bed	
G Deep	275625.6	1247625			PPK Environment	59.64		24.30	21.3	24.3	5.005	54.635		Bringelly Shale	0.0374
G Shallow	275627	1247625			PPK Environment	59.71		5.00	2	5	4.7	55.01		Alluvial	0.00496
G Creek Bed	275684.1	1247554				55.07		0.00			-0.1	55.17		Creek Bed	
H Deep	273982.6	1245295			PPK Environment	84.06		12.30	9.3	12.3	2.98	81.08		Bringelly Shale	0.0924
H Shallow	273981.3	1245296			PPK Environment	84.03		4.50	1.5	4.5	2.41	81.62		Weathered Shale	0.00269
I	275067.1	1246075			PPK Environment			45.30						Dry	
J Deep	274824.6	1243803			PPK Environment	70.86		42.30	39.3	42.3	5.64	65.22		Bringelly Shale	0.0355
J Shallow	274824.8	1243805			PPK Environment	70.86		4.50	1.5	4.5	3.63	67.23		Alluvial	0.00544
F Creek Bed	274823.3	1243678				68.13		0.00			-0.17	68.3		Creek Bed	
K	274455.5	1249145			PPK Environment	72.01		32.30	29.3	32.3	3.5	68.51		Bringelly Shale	0.00291

Appendix B – Registered Groundwater Bores

Table B–1 – Registered Groundwater Bores

Bore ID	Final Depth (m)	Standing Water Level (m)	Licence Status	Easting	Northing	Distance from Site Centre (approx. m)	Authorised purpose	Intended Purpose
GW112174			ACTIVE	292977	6250986	4972	MONITORING BORE	MONITORING BORE
GW112170			ACTIVE	292657	6251029	4774	MONITORING BORE	MONITORING BORE
GW112169			ACTIVE	292250	6251042	4511	MONITORING BORE	MONITORING BORE
GW112166			ACTIVE	292203	6250844	4331	MONITORING BORE	MONITORING BORE
GW112168			ACTIVE	292271	6251087	4559	MONITORING BORE	MONITORING BORE
GW112167			ACTIVE	292226	6250791	4306	MONITORING BORE	MONITORING BORE
GW112172			ACTIVE	292885	6250097	4339	MONITORING BORE	MONITORING BORE
GW112116			ACTIVE	292252	6250395	4040	MONITORING BORE	MONITORING BORE
GW112173			ACTIVE	292686	6250365	4344	MONITORING BORE	MONITORING BORE
GW072774	30.00 m		ACTIVE	292654	6250124	4168		G/WATER XPLORE
GW112171			ACTIVE	292112	6250198	3802	MONITORING BORE	MONITORING BORE
GW112165			ACTIVE	292922	6250269	4470	MONITORING BORE	MONITORING BORE
GW100136	110.70 m	23.80	CONVERTED	288609	6250514	3012	STOCK	STOCK
GW106198			CONVERTED	286732	6250544	3940	STOCK, DOMESTIC	
GW102305	61.00 m	12.00	CANCELLED	285664	6250741	4841	STOCK	STOCK
GW111840	30.70 m		ACTIVE	289231	6249454	1864	MONITORING BORE	MONITORING BORE
GW111839	30.40 m		ACTIVE	289217	6249289	1701	MONITORING BORE	MONITORING BORE
GW111838	30.00 m		ACTIVE	288816	6249274	1761	MONITORING BORE	MONITORING BORE
GW108933	268.00 m		CANCELLED	285491	6248644	3992	TEST BORE	IRRIGATION
GW104979	180.00 m	42	CONVERTED	285687	6247137	3683	STOCK, DOMESTIC	STOCK, DOMESTIC
GW104215	222.50 m	40	CANCELLED	286513	6244862	3932	STOCK, DOMESTIC	STOCK, DOMESTIC
GW105959	337.00 m	70	CANCELLED	286738	6244446	4085	IRRIGATION, STOCK, FARMING	STOCK, FARMING, IRRIGATION

Bore ID	Final Depth (m)	Standing Water Level (m)	Licence Status	Easting	Northing	Distance from Site Centre (approx. m)	Authorised purpose	Intended Purpose
GW106829	249.00 m	85	CONVERTED	287457	6243826	4212	STOCK, DOMESTIC	STOCK, DOMESTIC
GW113439			ACTIVE	290854	6243885	4004	MONITORING BORE	MONITORING BORE
GW113438			ACTIVE	290755	6243883	3970	MONITORING BORE	MONITORING BORE
GW113440			ACTIVE	290807	6243793	4073	MONITORING BORE	MONITORING BORE
GW113442			ACTIVE	291198	6244233	3839	MONITORING BORE	MONITORING BORE
GW113441			ACTIVE	290919	6244429	3535	MONITORING BORE	MONITORING BORE
GW063062	151.00 m		CONVERTED	289671	6243201	4404	STOCK, INDUSTRIAL, DOMESTIC	STOCK, INDUSTRIAL, DOMESTIC
GW073533	330.00 m			289618	6243139	4463		DOMESTIC
GW101062	220.00 m	45	CONVERTED	289934	6242958	4673	STOCK, DOMESTIC	STOCK, DOMESTIC
GW111604	20.00 m		ACTIVE	290071	6242820	4828	MONITORING BORE	MONITORING BORE
GW106636				292223	6247047	2932		
GW103739	32.98 m		ACTIVE	292339	6246890	3078	MONITORING BORE	TEST BORE
GW106735			CONVERTED	292192	6247030	2905	INDUSTRIAL	INDUSTRIAL
GW103743	27.25 m		ACTIVE	292339	6246890	3078	MONITORING BORE	TEST BORE
GW103741	27.15 m		ACTIVE	292339	6246890	3078	MONITORING BORE	TEST BORE
GW112649	30.12 m	6.8	ACTIVE	290253	6246317	1568	MONITORING BORE	MONITORING BORE
GW112650	30.70 m	8.5	ACTIVE	290509	6246300	1742	MONITORING BORE	MONITORING BORE
GW105016	252.50 m	53	CONVERTED	292895	6248599	3693	STOCK, DOMESTIC	STOCK, DOMESTIC
GW103742	23.93 m		ACTIVE	292339	6246890	3078	MONITORING BORE	TEST BORE
GW103740	32.00 m		ACTIVE	292339	6246890	3078	MONITORING BORE	TEST BORE

Appendix C – Historical Water Quality Data

Table C–1 – Historical Surface Water Data

Appendix C
Table 1
Historical Surface Water Quality

Department of Infrastructure and Regional Development
Western Sydney Airport

			NA	Surfactants	Field	Inorganics						Metals								TRH - NEPM 1999				BTEX & MAH				PAH	Phenols	VOCs	Nutrients					
			Fraction Organic Carbon	Soxhlet Grease	MBAS	Dissolved Oxygen (% saturated) (Field) (Filtered)	Dissolved Oxygen (Lab) (Filtered)	Electrical conductivity (lab)	pH (Lab)	Total Suspended Solids	Turbidity	Cadmium	Chromium (III+VI)	Copper	Iron	Lead	Mercury	Nickel	Zinc	C6 - C9 Fraction	C10 - C14 Fraction	C15 - C28 Fraction	C29 - C36 Fraction	Benzene	Toluene	Ethylbenzene	Xylene Total	PAHs (Sum of total) - Lab calc	Phenols	1,2-dichlorobenzene	Ammonia as N	Total Kjeldahl Nitrogen	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)	Phosphorus
			%	mg/L	µg/L	%S	mg/L	µS/cm	pH Units	mg/L	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Lowland rivers (ANZECC 2000, South East Australia)																																		0.5	0.05
NHMRC 2008 Recreation Waters - Health Criteria									6.5-8.5			0.002	0.05	2	0.3	0.01	0.001	0.02	3					1	25	3	20			1					
ANZECC 2000 FW 95%												0.0002	0.001[#1]	0.0014		0.0034	0.0006	0.011	0.008					950						160	0.9		0.15[#2]			
ANZECC 2000 FW Med-Low Reliability												0.0002		0.0014	0.3	0.0034		0.011	0.008					950	180	80				160			0.7			
ANZECC 2000 Recreational Purposes Guidelines									6.5-8.5			0.005	0.05	1	0.3	0.05	0.001	0.1	5					10							0.01		10	1		
ANZECC 2000 Primary Contact Recreation																																				
ANZECC 2000 Secondary Contact Recreation																																				
ANZECC 2000 Irrigation - Short-term Trigger Values												0.05	1	5	10	10	0.002	2	5															20[#3]		
ANZECC 2000 Irrigation - Long-term Trigger Values												0.01	0.1	0.2	0.2	0.2	0.002	0.2	2															5	0.05
ANZECC 2000 Stock Watering												0.01	1	0.4[#4]		0.1	0.002	1	20																	
Location Code	**Sampled Date Time**																																				
Badgerys Creek B1	4/12/1996	10	<5	<20	63	4.5	1170	6.9	2	1.1	<0.005	<0.005	0.005	0.22	<0.005	<0.001	<0.005	0.013	<20	<40	<200	<200	<1	<1	<1	<1	<1	<10	<1	0.051	5	<0.02	<0.02	-	<0.02
Badgerys Creek B2	4/12/1996	25	<5	220	150	12.2	2900	7.3	33	7	<0.005	0.01	<0.005	1.8	<0.005	<0.001	<0.005	<0.01	<20	<40	<200	<200	<1	<1	<1	<1	<1	<10	<1	0.39	2.9	<0.02	<0.02	-	1.2
Badgerys Creek B3	4/12/1996	<0.01	<5	14,000	24	2.2	1080	6.7	14	5.1	<0.001	<0.01	0.005	<0.005	<0.005	<0.001	<0.02	<0.005	<0.005	<40	<200	<200	<1	<1	<1	<1	<1	<1	1100	<1	0.21	0.7	<0.02	<0.02	0.12	0.26
Badgerys Creek B3	17/09/1998	9	<5	130	107	11.3	1530	6.9	9	46	0.001	<0.005	<0.005	1.93	<0.005	<0.001	<0.005	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.14	1.1	1.16	0.03	2.3	0.35
Badgerys Creek B3	8/10/1998	11	<5	160	13	1.4	1895	7	15	19	<0.001	<0.005	<0.005	1.51	<0.005	<0.001	<0.005	0.02	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.16	1.3	0.01	<0.01	1.31	0.47
Badgerys Creek B3	15/12/1998	17	8	<50	36	2.9	2250	7.2	24	19	<0.0005	<0.005	<0.005	3.02	<0.002	<0.001	<0.005	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.13	1.4	0.02	<0.01	1.42	0.32
Cosgroves Creek C1	10/12/1996	<0.01	<5	16,000	25	2.2	1500	6.7	5	2.9	<0.001	0.018	<0.005	<0.005	<0.005	<0.001	<0.02	<0.005	<0.005	<40	<200	<200	<1	<1	<1	<1	<1	<1	<50	<1	0.12	0.9	<0.02	<0.02	-	<0.02
Cosgroves Creek C3	10/12/1996	<0.01	<5	16,000	25	2.2	1500	6.7	5	2.9	<0.001	0.018	<0.005	<0.005	<0.005	<0.001	<0.02	<0.005	<0.005	<40	<200	<200	<1	<1	<1	<1	<1	<1	<50	<1	0.12	0.9	<0.02	<0.02	<0.02	<0.02
Cosgroves Creek C3	16/09/1998	12	<5	190	65	6.6	1220	6.9	12	16	0.001	<0.005	<0.005	1.76	<0.005	<0.001	<0.005	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	30	<1	0.11	1.2	0.13	0.01	1.3	0.07
Cosgroves Creek C3	7/10/1998	15	<5	120	53	4.9	1820	7	8	10	<0.001	<0.005	<0.005	2.28	<0.005	<0.001	<0.005	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.06	1.2	0.03	<0.01	1.23	0.07
Cosgroves Creek C3	14/12/1998	18	9	100	2	0.2	2150	7.4	6	16	<0.0005	<0.005	<0.005	3.17	<0.002	<0.001	<0.005	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.7	1.7	<0.01	<0.01	1.7	0.05
Duncans Creek D1	10/12/1996	<0.01	<5	12,000	15	1.3	1750	6.7	13	5.2	<0.001	0.01	<0.005	<0.005	<0.005	<0.001	<0.02	<0.005	<0.005	<40	<200	<200	<1	<1	<1	<1	<1	<1	530	<1	0.025	0.2	<0.02	<0.02	<0.02	<0.02
Duncans Creek D1	17/09/1998	10	<5	170	28	2.7	1330	7	10	12	0.001	<0.005	<0.005	1.26	<0.005	<0.001	<0.005	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.02	1.1	0.2	<0.01	1.3	0.03
Duncans Creek D1	8/10/1998	9	<5	60	24	2.2	1950	7	8	10	0.001	<0.005	<0.005	1.29	0.003	<0.001	<0.005	0.04	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	<0.01	0.8	<0.01	<0.01	0.8	0.04
Duncans Creek D1	15/12/1998	10	<5	90	50	4.1	2590	7.1	9	6.2	<0.0005	<0.005	<0.005	0.58	<0.002	<0.001	<0.005	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	<0.01	0.5	<0.01	<0.01	0.5	0.02
South Creek S1	16/09/1998	12	<5	90	105	10.1	673	7.2	12	65	0.001	<0.005	0.006	1.5	<0.005	<0.001	<0.005	0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.04	0.9	0.67	0.02	1.6	0.14
South Creek S1	7/10/1998	10	<5	200	83	7.4	1000	7.1	8	15	<0.001	<0.005	<0.005	1.41	0.002	<0.001	<0.005	0.03	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.06	1.2	0.14	<0.01	1.34	0.12
South Creek S1	14/12/1998	5	<5	50	100	7.7	1600	7	56	38	<0.0005	<0.005	<0.005	0.81	<0.002	<0.001	<0.005	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.24	0.3	0.19	<0.01	0.49	0.01
South Creek S2	16/09/1998	11	<5	120	66	6.6	727	6.9	11	82	0.001	<0.005	0.006	1.81	<0.005	<0.001	0.012	0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.04	1	0.5	0.02	1.5	0.11
South Creek S2	7/10/1998	9	<5	160	60	5.5	989	7	19	32	<0.001	<0.005	<0.005	1.5	<0.005	<0.001	<0.005	0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.03	0.7	<0.01	<0.01	0.7	0.07
South Creek S2	14/12/1998	7	<5	<50	87	6.8	1420	6.8	5	7	<0.0005	<0.005	<0.005	0.35	<0.002	<0.001	<0.005	0.16	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	<0.01	0.4	0.04	<0.01	0.44	0.01
South Creek S3	16/09/1998	12	<5	130	79	7.5	690	6.9	12	40	0.001	<0.005	<0.005	2.03	<0.005	<0.001	<0.005	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	120	<1	0.09	1.1	0.24	0.02	1.4	0.47
South Creek S3	7/10/1998	11	<5	210	44	4.1	645	6.9	14	23	0.001	<0.005	<0.005	3.06	0.003	<0.001	<0.005	0.02	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.21	1.3	0.18	0.04	1.52	0.6
South Creek S3	14/12/1998	12	<5	<50	39	3.1	850	7.4	4	12	<0.0005	<0.005	<0.005	0.66	<0.002	<0.001	<0.005	0.03	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.03	0.8	<0.01	<0.01	0.8	0.05
Thompson Creek T1	10/12/1996	<0.01	<5	16,000	23	2.2	4960	6.4	5	4.9	0.01	0.018	0.005	<0.005	<0.005	<0.02	<0.005	<0.005	<40	<200	<200	<1	<1	<1	<1	<1	<1	4900	<1	0.13	0.5	<0.02	0.026	<0.02	<0.02
Thompson Creek T1	17/09/1998	11	<5	140	50	5.5	2400	7	11	10	0.001	<0.005	<0.005	1.21	<0.005	<0.001	<0.005	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.18	1	0.1	0.01	1.1	0.01
Thompson Creek T1	9/10/1998	13	<5	210	15	1.5	4240	7	9	11	<0.001	<0.005	<0.005	1.39	<0.005	0.01	<0.005	0.03	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.29	1.1	0.02	<0.01	1.12	0.04
Thompson Creek T1	15/12/1998	18	<5	170	46	4.2	9550	7.3	11	14	<0.0005	<0.005	<0.005	1.16	<0.002	<0.001	0.006	<0.01	<20	<20	<100	<100	<1	<1	<1	<1	<1	<10	<1	0.04	1.1	0.04	<0.01	1.14	0.04
Statistical Summary																																				
Number of Results		28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	25	28
Number of Detects		23	2	24	28	28	28	28	28	28	28	10	5	5	23	3	1	2	11	0	0	0	0	0	0	0	0	0	5	0	25	28	16	8	22	23
Minimum Concentration		<0.01	<5	<20	2	0.2	645	6.4	2	1.1	<0.0005	<0.005	<0.005	<0.005	<0.005	<0.002	<0.001	<0.005	<0.005	<20	<20	<100	<1	<1	<1	<1	<1	<1	<10	<1	<0.01	0.2	<0.01	<0.01	<0.02	0.01
Minimum Detect		5	8	50	2	0.2	645	6.4	2	1.1	0.001	0.01	0.005	0.22	0.002	0.01	0.006	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	30	ND	0.02	0.2	0.01	0.01	0.12	0.01
Maximum Concentration		25	9	16000	150	12.2	9550	7.4	56	82	0.01	0.018	0.006	3.17	<0.005	<0.02	0.012	0.16	<40	<200	<200	<200	<1	<1	<1	<1	<1	4900	<1	0.7	5	1.16	0.04	2.3	1.2
Maximum Detect		25	9	16000	150	12.2	9550	7.4	56	82	0.01	0.018	0.006	3.17	0.003	0.01	0.012	0.16	ND	ND	ND	ND	ND	ND	ND	ND	ND	4900	ND	0.7	5	1.16	0.04	2.3	1.2
Average Concentration		9.9	2.9	2743	53	4.8	2014	7	12	19	0.0011	0.0048	0.003	1.3	0.0021	0.0025	0.003	0.016	12	27	63	45	0.5	0.5	0.5	0.5	0.5	244	0.5	0.13	1.2	0.13	0.011	1	0.16
Median Concentration		10.5	2.5	150	48	4.15	1515	7	10.5	12	0.0006	0.0025	0.0025	1.34	0.0025	0.0005	0.0025	0.005	10	10	50	50	0.5	0.5	0.5	0.5	0.5	6	0.5	0.1	1.05	0.02	0.0075	1.14	0.05
Standard Deviation		6.1	1.6	5766	35	3.1	1789	0.23	11	19	0.0018	0.0051	0.0012	0.94	0.00069	0.004	0.0019	0.03	3.9	35	22	25	0	0	0	0	0	940	0	0.15	0.91	0.26	0.009	0.6	0.26
Number of Guideline Exceedances		0	0	0	0	0	0	1	0	0	28	28	28	23	18	28	1	23	0	0	0	0	0	0	0	0	0	0	0	0	25	0	7	0	18	13
Number of Guideline Exceedances(Detects Only)		0	0	0	0	0	0	1	0	0	10	5	5	23	0	1	1	11	0	0	0	0	0	0	0	0	0	0	0	0	25	0	7	0	18	13

Env Stds Comments
#1 Cr(VI) guideline has been adopted
#2 Nitrate (as NO3) value divided by 4.427
#3 25-125 mg/L - requires a site specific assessment
#4 Guideline value for sheep

Monitoring_Zone = 'surface'
G:\21\24265\Technical\Groundwater\WSA_Surface waters 170515

Page 1 of 1

Table C–2 – Historical Ground Water Data

Appendix C
Table 2
Historical Groundwater Results

Department of Infrastructure and Regional Development
Western Sydney Airport

		Inorganics				Metals						Alkalinity	Major Ions							Nutrients				
		Nitrite + Nitrate as N	Bicarbonate as CaCO3	Electrical conductivity (lab)	pH (Lab)	Aluminium	Cadmium	Copper	Iron	Lead	Zinc	Alkalinity (Carbonate as CaCO3)	Calcium	Chloride	Magnesium	Potassium	Sodium	Sulphate	Total Kjeldahl Nitrogen	Nitrate (as N)	Nitrogen (Total)	Phosphorus
		mg/L	mg/L	µS/cm	pH Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ADWG 2011 Aesthetic					6.5-8.5	0.2		1	0.3		3			250			180	250				
ADWG 2011 Health							0.002	2		0.01								500				
Lowland rivers (ANZECC 2000, South East Australia)																					0.5	0.05
NHMRC 2008 Recreation Waters - Health Criteria					6.5-8.5		0.002	2	0.3	0.01	3			250[#1]			180	250				
ANZECC 2000 FW 95%						0.055	0.0002	0.0014		0.0034	0.008									0.158[#2]		
ANZECC 2000 Irrigation - Short-term Trigger Values						20	0.05	5	10	10	5										25[#3]	
ANZECC 2000 Irrigation - Long-term Trigger Values						5	0.01	0.2	0.2	0.2	2										5	0.05
Location_Code	**Sampled_Date_Time**																							
GW A	29/09/1998	0.06	188	29,700	7.43	<0.01	<0.001	0.013	<1	0.004	0.039	<1	518	9660	186	56	6440	4	11.9	0.06	12	0.06
GW B	29/09/1998	0.03	921	28,500	6.72	<0.01	<0.001	0.02	<1	0.005	0.042	<1	650	9450	573	96	4600	4	12.4	0.03	12.4	0.02
GW C	29/09/1998	0.03	866	5,520	7.65	0.06	<0.001	0.002	<0.1	0.022	0.014	<1	42	1120	51	15	935	9	2.5	0.03	2.6	0.42
GW E Deep	29/09/1998	0.06	1140	7,900	7.42	<0.01	<0.001	0.002	<0.1	0.006	0.012	<1	62	1670	163	11	1260	152	0.5	0.06	0.6	0.08
GW E Shallow	29/09/1998	9.78	777	3,990	7.21	0.04	<0.001	0.002	<0.1	0.001	0.008	<1	106	648	113	7	488	93	3.9	9.75	13.7	1.2
GW F Deep	29/09/1998	0.03	621	20,970	7.08	<0.001	<0.001	0.003	<0.1	0.003	0.009	<1	291	6560	516	36	3260	85	5	0.03	5	0.08
GW F Shallow	29/09/1998	0.03	1060	40,800	7.02	0.01	<0.001	0.004	<0.1	0.003	0.017	<1	181	13,800	1500	13	6560	390	0.8	0.03	0.8	0.53
GW G Deep	29/09/1998	0.02	687	23,900	6.94	<0.01	<0.001	0.008	<1	0.004	0.018	<1	446	7740	464	53	3970	1	6.6	0.02	6.6	0.04
GW G Shallow	29/09/1998	0.02	630	14,390	7.5	0.02	<0.001	0.003	<0.1	0.001	0.006	<1	145	4070	364	6	2160	249	1	0.02	1	0.11
GW G4a	15/06/1905	-	-	36,600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW G5	15/06/1905	-	-	31,200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW G6	15/06/1905	-	-	28,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW G7	15/06/1905	-	-	28,800	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW H Deep	29/09/1998	0.02	662	33,600	6.98	<0.01	<0.001	0.006	<1	0.007	0.014	<1	237	10,800	1080	31	5370	1060	1.8	0.02	1.8	0.09
GW H Duplicate	29/09/1998	0.06	167	-	-	0.04	<0.001	0.004	<1	<0.001	0.026	<1	23	9410	799	12	4280	677	1	0.06	1.1	0.46
GW H Shallow	29/09/1998	0.06	155	26,450	7.07	0.04	<0.001	0.004	<1	<0.001	0.024	<1	25	8380	812	12	4270	657	1	0.06	1.1	0.47
GW J Deep	29/09/1998	0.05	649	26,300	6.72	<0.01	<0.001	0.014	1.8	0.002	0.037	<1	605	8300	217	62	4560	1	11.7	0.05	11.8	0.07
GW J Shallow	29/09/1998	0.4	255	28,000	7.51	0.03	<0.001	0.004	<1	<0.001	0.009	<1	54	8010	744	13	4580	494	1.3	0.4	1.7	0.54
GW K	29/09/1998	0.03	939	27,400	7.03	<0.01	<0.001	0.005	<1	0.015	0.018	<1	282	8160	825	59	4180	977	4.5	0.03	4.5	0.06
GW Well D11	13/06/1905	-	-	14,810	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW Well D13	13/06/1905	-	-	1350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW Well D8	13/06/1905	-	-	3010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW Well D9	13/06/1905	-	-	14,290	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW Well G1a	15/06/1905	-	-	17,700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GW Well G3a	15/06/1905	-	-	22,190	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW2D	29/09/1998	0.04	907	-	-	<0.01	<0.001	0.019	<1	0.005	0.030	<1	633	9290	574	91	4530	3	13.7	0.04	13.7	0.11
MW2D Duplicate	29/09/1998	0.03	893	-	-	<0.01	<0.001	0.019	<1	0.005	0.041	<1	675	9290	611	92	4400	3	13.3	0.03	13.3	0.06
Statistical Summary																								
Number of Results		17	17	24	14	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Number of Detects		17	17	24	14	7	0	17	1	14	17	0	17	17	17	17	17	17	17	17	17	17	17	17
Minimum Concentration		0.02	155	1350	6.72	<0.001	<0.001	0.002	<0.1	<0.001	0.006	<1	23	648	51	6	488	1	0.5	0.02	0.6	0.02
Minimum Detect		0.02	155	1350	6.72	0.01	ND	0.002	1.8	0.001	0.006	ND	23	648	51	6	488	1	0.5	0.02	0.6	0.02
Maximum Concentration		9.78	1140	40800	7.65	0.06	<0.001	0.02	1.8	0.022	0.042	<1	675	13800	1500	96	6560	1080	13.7	9.75	13.7	1.2
Maximum Detect		9.78	1140	40800	7.65	0.06	ND	0.02	1.8	0.022	0.042	ND	675	13800	1500	96	6560	1080	13.7	9.75	13.7	1.2
Average Concentration		0.63	683	21474	7.2	0.017	0.0005	0.0078	0.42	0.005	0.022	0.5	293	7409	564	39	3814	287	5.5	0.63	6.1	0.26
Median Concentration		0.03	777	25100	7.075	0.005	0.0005	0.004	0.5	0.004	0.018	0.5	237	8380	573	31	4280	93	3.9	0.03	4.5	0.09
Standard Deviation		2.4	321	11113	0.3	0.018	0	0.0065	0.42	0.0058	0.013	0	244	3560	380	32	1672	363	5.1	2.4	5.4	0.31
Number of Guideline Exceedances		0	0	0	0	1	17	17	11	9	15	0	0	17	0	0	17	6	0	2	17	15
Number of Guideline Exceedances(Detects Only)		0	0	0	0	1	0	17	1	9	15	0	0	17	0	0	17	6	0	2	17	15

Env Stds Comments
#1 Adopted from Aesthetics
#2 Nitrate (as NO3) value divided by 4.427
#3 pH<6.5: GL for pH>6.5 = 55 ug/L
#4 25-125 mg/L - requires a site specific assessment
#5 Guideline value for sheep

Data Comments
#1 ESDAT Combined. Some analytes are reported multiple times; the lowest non-detect or the highest detect is used.
#2 ESDAT Combined with Non-Detect Multiplier of 0.5.
#3 ESDAT Combined.

Monitoring_Zone = 'groundwater'
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Page 1 of 1

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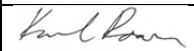
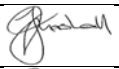
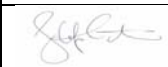
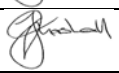
A	Stefan Charteris	Karl Rosen		Greg Marshall		17.07.2015
B	Stefan Charteris	Stefan Charteris		Greg Marshall		25.08.2015

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WESTERN SYDNEY AIRPORT



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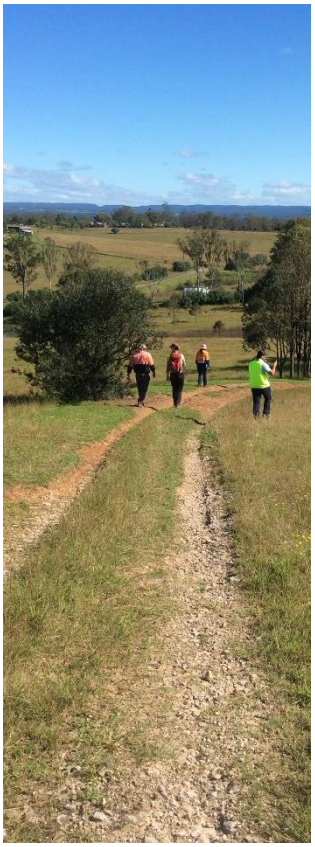
VOLUME 4
TECHNICAL REPORTS

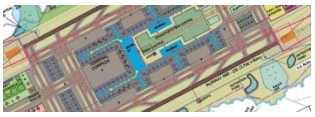
Appendices M–O

VOLUME 4

Appendix M1
Aboriginal cultural heritage











Western Sydney Airport

Aboriginal Cultural Heritage Assessment

Unrestricted access version

October 2015

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Report Register

The following register documents the development and issue of this document.

Issue No.	Notes/Description	Issue Date
v. 1.6	Chapters 1 -5, Draft for GHD comment	3 June 2015
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v. 2.3	Full draft report for WSU review	16 July 2015
v. 3.8	Revised draft addressing first round WSU comments	7 August 2015
v. 3.10	Revision of section 1.1 and addressing changes in revised landuse planning	13 August 2015
v. 3.12	Revised draft addressing second round WSU comments and EIS chapter revisions (A.1)	28 August 2015
v. 3.13	Revision of figure formatting/orientation	31 August 2015
v. 3.18	Refinement following WSU mitigation workshop and feedback	14 September 2015
v. 3.19	Preparation of restricted and unrestricted access versions after review by Dept of the Environment	5 October 2015

Table of Contents

1. INTRODUCTION 1

1.1 Background 1
1.2 The Airport Site 1
1.3 Staged Development 3
1.4 Aims and objectives 3
1.5 Report contributors 3
1.6 Information access 4
1.6.1 Copyright 4
1.6.2 Restricted information 4
1.6.3 Confidentiality 4

2. METHODOLOGY 5

2.1 Legislation and Guidelines 5
2.1.1 Environment Protection and Biodiversity Conservation Act 1999 5
2.1.2 Heritage and consultation principles and protocols 8
2.1.3 Implementation of protocols for the Western Sydney Airport 9
2.1.4 Summation of Aboriginal stakeholder issues and project team responses 13
2.1.5 Field participation 15
2.1.6 Stage 4 Comments on the Draft EIS 16
2.2 Consultation with other stakeholders 16
2.2.1 Liverpool City Council 16
2.2.2 NSW Office of Environment and Heritage 16
2.3 Review of previous work and heritage registers 16
2.3.1 Sources 16
2.3.2 Excluded and revised recordings 17
2.4 Field inspection and surface survey 17
2.5 Test excavation 17
2.6 Recording parameters 24
2.6.1 A paradigm shift from surface to subsurface evidence 24
2.6.2 Terminology used 24
2.6.3 Site numbering 27

3. LANDSCAPE CONTEXT 28

3.1 Regional overview 28
3.1.1 The Sydney Basin 28
3.1.2 The Cumberland Plain 28
3.1.3 Current and palaeo-climate 29
3.2 The airport site 32
3.2.1 Topography 32
3.2.2 Soil Landscapes 32
3.2.3 Drainage network 33
3.2.4 Vegetation 33
3.2.5 Land-use 33
3.3 Landform classification 34
3.4 Review of geotechnical borehole data 39

4. CULTURAL CONTEXT 41

4.1 Ethno-history 41
4.2 Tribal and cultural affiliations 42
4.3 Overview of early post-European Aboriginal history 45
4.4 Previously identified cultural values 49
4.4.1 1985 Draft EIS 49
4.4.2 1997 – 1999 EIS assessment 50

5. ARCHAEOLOGICAL CONTEXT 52

5.1 Sydney regional context 52
5.2 The Cumberland Plain 54
5.3 The local district of the airport site 57
5.4 Previously recorded Aboriginal sites in the local district around Badgerys Creek 57
5.5 Previous archaeological investigations within the airport site 61
5.5.1 1978 MANS Study 61
5.5.2 1985 Second Sydney airport site selection program 61
5.5.3 1997 Draft Environmental impact statement 61
5.5.4 1997 EIS Auditors report 71
5.5.5 1999 Supplement to the 1997 EIS 71
5.5.6 1999 Supplement auditor's report 71
5.5.7 1999 Environment Australia assessment report 71
5.5.8 2014 AMC Environmental survey 72
5.6 Current predictive regional model 74
5.7 Previously recorded sites within the airport site 76

6. RESULTS OF ARCHAEOLOGICAL INVESTIGATION 81

6.1 Survey and Test Excavation Locations 81
6.2 Site Recordings 81
6.2.1 Surface recordings 84
6.2.2 Subsurface recordings 93
6.3 Analysis 99
6.3.1 Overview of the artefact assemblage, by test location 99
6.3.2 Overview of assemblage characteristics 106
6.3.3 Analysis of assemblage variation across landforms 114
6.3.4 Assemblage density relative to landform 116
6.3.5 Discussion of assemblage density relative to landform 125
6.4 Discussion: stone artefact analysis and the predictive model 129
6.5 Conclusions of the artefact analysis 132
6.6 The archaeologically sensitive landscape 133

7. RESULTS OF STAKEHOLDER CONSULTATION 136

7.1 Aboriginal cultural values 136
7.2 Archaeological values 138
7.3 Suggested mitigation and management strategies 138
7.4 Non-Aboriginal stakeholder views 139

8. SIGNIFICANCE ASSESSMENT 141

8.1 Assessment Criteria 141
8.1.1 The Burra Charter 141
8.1.2 Commonwealth assessment criteria 141
8.2 Individual site assessments 142
8.2.1 Artefact occurrences 142
8.2.2 B40 - Possible Aboriginal scarred tree 143
8.2.3 B120 – Grinding grooves 144
8.3 The archaeologically sensitive landscape 151
8.3.1 Assessment against all criteria 151
8.4 Potential for nomination of places to the Commonwealth Heritage List 153

9. ASSESSMENT OF IMPACTS 154

9.1 Impact Categories 154
9.1.1 Construction 154
9.1.2 Operational 154
9.1.3 Cumulative 154

9.2 Initial airport development 155
9.2.1 Construction *155*
9.2.2 Operation *156*
9.2.3 Cumulative *156*
9.3 Longer Term Development 160
9.3.1 Construction *160*
9.3.2 Operation *160*
9.3.3 Cumulative *160*
9.4 Greater Blue Mountains World Heritage Area 162
10. MITIGATION AND MANAGEMENT STRATEGIES 164
10.1 Terminology 164
10.2 Discussion 164
10.3 Initial airport development 166
10.3.1 Mitigation *166*
10.3.2 Management Strategies *167*
10.4 Longer term development 170
10.4.1 Mitigation *170*
10.4.2 Management Strategies *170*
11. REFERENCES 172
APPENDIX 1 ABORIGINAL CONSULTATION DOCUMENTATION 189
A1.1 Public Notice inviting registration by Aboriginal stakeholders 190
A1.2 List of registered Aboriginal stakeholders and representatives 191
A1.3 Native Title Search 194
A1.4 Presentations 197
A1.4.1 Background paper and draft methodology *197*
A1.4.2 Presentation at Stakeholder Meeting 8 April 2015 ..... *205*
A1.4.3 Minutes of Stakeholder Meeting 8 April 2015 ..... *214*
A1.4.4 Supplementary Stakeholder Meeting *223*
A1.4.5 Aboriginal stakeholder submissions on proposed assessment methodology *224*
A1.4.6 Example of Invitation to participate in the field program *230*
APPENDIX 2 INVENTORY OF ABORIGINAL HERITAGE SITES WITHIN THE AIRPORT SITE 232
APPENDIX 3 LANDFORM VARIABLES RECORDED FOR EACH TEST PIT 239
APPENDIX 4 GLOSSARY OF TECHNICAL TERMS 249
APPENDIX 5 MAPPING OF LANDFORMS AND TEST LOCATIONS 260
A5.1 Landform mapping 261
A5.2 Test pit locations 279
APPENDIX 6 GEOARCHAEOLOGICAL OVERVIEW OF THE HISTORICAL BOREHOLE DATA, WESTERN SYDNEY AIRPORT 280
A6.1 Introduction 281
A6.2 Methodology of this study 282
A6.3 Data sources reviewed 284
A6.4 Geology across the airport site 285
A6.5 Post-Triassic and Quaternary geology and deposits 286
A6.6 Landform and regolith relationship across the airport site 287
A6.7 Geoarchaeological review of historic borehole and test pit data sources 287
A6.8 Interpretation of borehole data 288
A6.9 Review of data – specific "archaeologically significant" examples 289
A6.10 Discussion 291
A6.11 References 294

APPENDIX 7 SUMMARY OF PREVIOUS HERITAGE INVESTIGATIONS, AND OUTLINE OF CHANGES IN ARCHAEOLOGICAL APPROACH SINCE 1997 295

A7.1 OUTLINE OF CHANGES IN ARCHAEOLOGICAL APPROACH SINCE THE 1997 EIS 296

A7.1.1 A paradigm shift from surface to subsurface archaeological evidence 296

A7.1.2 Terminology used for the predicted archaeological resource 296

A7.1.3 Implications for the assessment of significance 297

A7.2 SUMMARY OF PREVIOUS HERITAGE INVESTIGATIONS CONDUCTED WITHIN THE LOCAL DISTRICT OF THE AIRPORT SITE 299

APPENDIX 8 PROTOCOLS TO FOLLOW IN THE EVENT OF UNANTICIPATED DISCOVERY OF ABORIGINAL SITES 307

A8.1 PROTOCOL TO FOLLOW IF ABORIGINAL OBJECT(S), OTHER THAN HUMAN REMAINS, ARE ENCOUNTERED 308

A8.2 PROTOCOL TO FOLLOW IN THE EVENT OF THE DISCOVERY OF SUSPECTED HUMAN REMAINS 309

1. Introduction

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 The Airport Site

The land which forms the subject of this assessment is defined as all land owned by the Australian Government situated at Badgerys Creek. These lands are shown in Figure 1.1 and comprise approximately 1,700 hectares.

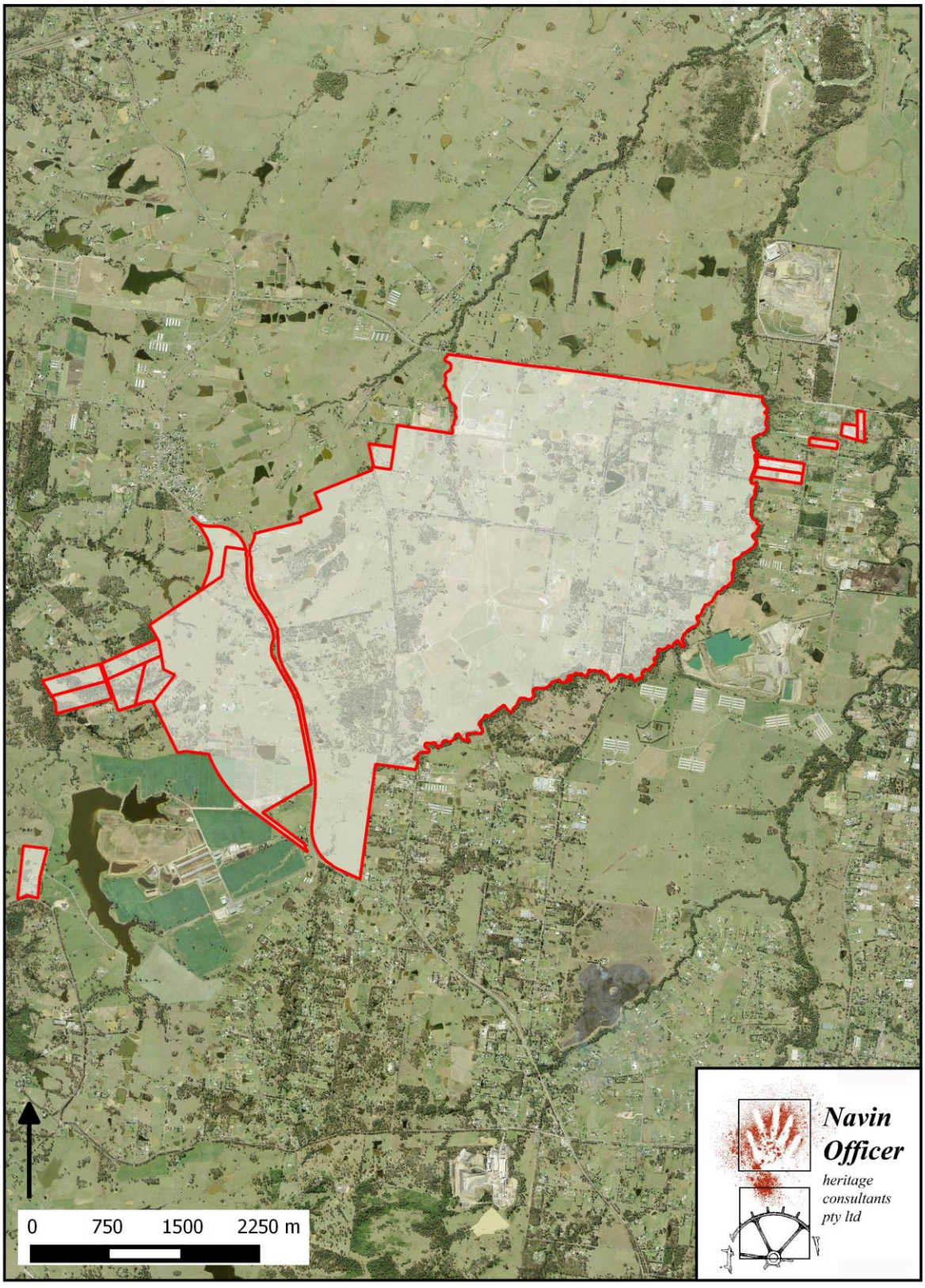


Figure 1.1 The location of all Australian Government owned lands at Badgerys Creek. These lands were the subject of the Aboriginal cultural heritage assessment.

1.3 Staged Development

This assessment evaluates the potential impacts of a proposed initial development referred to as Stage 1, and an indicative concept of longer term development.

1.4 Aims and objectives

The general aims of this assessment were:

- to document and assess the Aboriginal cultural heritage values of the airport site;
- to provide an assessment of the potential impacts of the proposed airport development; and
- to draft mitigation and management strategies to be adopted in the event that the airport proposal is implemented.

Specific objectives of the assessment included:

- to build upon, and effectively apply, the corpus of existing information previously generated about the airport site, and in particular from the 1997-1999 Second Sydney Airport proposal EIS process (NOHC 1997, PPK Environment and Infrastructure 1999), and the 2014 Environmental Field Survey (SMEC 2014, AMC 2014);
- to address, as appropriate, issues raised in response to the 1997-1999 Second Sydney Airport proposal EIS assessment by the independent auditor and the then Department of the Environment and Heritage;
- to conduct an assessment program which effectively addressed assessment aims within the determined limitations of the investigation scope;
- to conduct an assessment of Aboriginal cultural values based on an inclusive program of Aboriginal stakeholder consultation, and based primarily on the views communicated by those stakeholders; and
- to conduct an archaeological assessment of the airport site which acknowledges the limitations of an approach based on surface sites and focuses instead on an investigation of the subsurface archaeological evidence.

1.5 Report contributors

Aboriginal consultation for this investigation was conducted by Kelvin Officer, Nicola Hayes, Jo Dibden and Oliver Macgregor.

The fieldwork program was directed by Kelvin Officer and Nicola Hayes. Field personal included Jo Dibden, Lucy Blackam, Julia MacLachlan and Anna Kotarba.

Stone artefact analysis was conducted by Oliver Macgregor, with supplementary contributions by Jill Huntley.

Specialist geoarchaeological analysis was contributed by Anthony Barham.

This report was written by Kelvin Officer, Oliver Macgregor, Anthony Barham, Nicola Hayes and Jill Huntley.

Please refer to Sections 2.3.1 and A1.2 for a list of Aboriginal stakeholder entities and their field representatives who participated in, and contributed to, this investigation.

1.6 Information access

1.6.1 Copyright

Copyright to this report rests with the Western Sydney Unit except for the following:

- The Navin Officer Heritage Consultants logo and business name (copyright to this rests with Navin Officer Heritage Consultants Pty Ltd).
- Generic content and formatting which is not specific to this project or its results (copyright to this material rests with Navin Officer Heritage Consultants Pty Ltd) subject to the licence provisions of the contract.
- Descriptive text and data relating to Aboriginal objects which must, by law, be provided to the NSW Office of Environment and Heritage or other statutory authorities for its purposes and use.
- Information which, under Australian law, can be identified as belonging to Indigenous intellectual property.
- Content which was sourced from and remains part of the public domain.

1.6.2 Restricted information

This is an 'unrestricted access' version of this report and has been made available for use by a general audience. Consistent with sensitive information protocols, site specific map-grid references and large scale site mapping have been removed from this version. This follows directions by statutory authorites and Aboriginal stakeholder groups. Where information has been removed or modified, a note in italics has been inserted for the information of users.

No information provided by Aboriginal stakeholders in this report has been specifically identified as requiring access restrictions due to its cultural sensitivity.

1.6.3 Confidentiality

The content of this report is not considered to be confidential provided that it is only published as part of the public release of the Western Sydney Airport Draft EIS, and that any restricted information, as specified in Section 2.11.2 is excluded from public access versions of the report.

2. Methodology

2.1 Legislation and Guidelines

This assessment has been prepared:

- in accordance with the provisions and requirements of the *Environment Protection and Biodiversity Conservation Act 1999*;
- in consultation with the Australian Government Department of the Environment (DoE); and
- in accordance with the *Guidelines for the Content of a Draft Environmental Impact Statement – Western Sydney Airport* (DoE 2015c) (EIS guidelines) for Western Sydney Airport.

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The objectives of the Act include: the protection of the environment, especially those aspects of national significance; to promote the conservation of biodiversity and ecologically sustainable development; and to recognise the role of indigenous people and their knowledge in realising these aims.

The EPBC Act provides a legal framework for the protection and management of matters of national environmental significance (MNES). MNES include, among other things, World Heritage properties and National Heritage places.

The EPBC Act also applies to actions that have a significant impact on the environment where the actions affect, or are taken on, Commonwealth land, or are carried out by a Commonwealth agency.The EPBC Act adopts a broad definition of the environment that is inclusive of cultural heritage values. In particular, the 'environment' is defined to include the social, economic and cultural aspects of ecosystems, natural and physical resources, and the qualities and characteristics of locations, places and areas (s528).

Specific requirements for the Western Sydney Airport EIS

On 23 December 2014, a delegate for the Minister for the Environment determined that the construction and operation of a Western Sydney Airport at Badgerys Creek (EPBC 2014/7391) is a controlled action because the proposal has the potential to have a significant impact on matters of NES and other matters protected under Part 3 of the EPBC Act. The delegate also determined that the proposal is to be assessed by preparation of an Environmental Impact Statement (EIS). On 29 January 2015 the Department of the Environment released guidelines for the content of a Draft EIS for this project which require the following in relation to Aboriginal heritage:

The EIS must include:

- A description of the World Heritage/National Heritage values of the Greater Blue Mountains Area World Heritage property/National Heritage Place, as described in the Statement of Outstanding Universal Value and including reference to the World Heritage criteria the area is listed for as well as the integrity of the property.
- A description of the environment in all areas of potential impact, including all components of the environment as defined in Section 528 of the EPBC Act including heritage values and places.
- A description of all of the relevant impacts of the action.
- The EIS should identify and address cumulative impacts, where potential project impacts are in addition to existing impacts of other activities (including known potential future expansions or developments by the proponent and other proponents in the region and vicinity).

- If the conclusion is made that any relevant controlling provision or element of a relevant controlling provision will not be impacted by the proposed action, then justification must be provided for how this conclusion has been reached. This includes any heritage items/places likely to be on site and other relevant elements of the environment that may be impacted by the proposed action.

- A full heritage impact assessment and the findings of the further program of archaeological survey that was foreshadowed in the referral for this project.

- The identification and assessment of impacts to the environment should include removal and degradation of heritage items/places (historic, natural and indigenous).

- Provide information on proposed avoidance and mitigation measures to manage the relevant impact of the action on a matter protected by a controlling provision.

- The EIS must take into account relevant agreements and plans that cover impacts or known threats to a matter protected by a controlling provision, including those for the Greater Blue Mountains Area World Heritage property.

- Specific and detailed descriptions of the proposed avoidance and mitigation measures based on best available practices.

- Details of the likely residual impacts upon a matter protected by a controlling provision after the proposed avoidance and mitigation measures have been taken into account.

A report on the Environmental Survey of Commonwealth Land at Badgerys Creek: Aboriginal Heritage, prepared by Australian Museum Consulting and dated October 2014 (AMC 2014), was one of the referral documents for Western Sydney Airport under the EPBC Act. Recommendation one of that report stated that the EIS assessment "should address" the requirements of the NSW Office of Environment and Heritage (OEH) document: *Aboriginal cultural heritage consultation requirements for proponents 2010* (DECCW 2010b). Recommendation 2 stated that the EIS should comply with the requirements of the OEH document: Code of Practice for Archaeological investigation of Aboriginal Objects in New South Wales (DECCW 2010a).

It should be noted that many of the requirements specified in these two OEH documents relate to Part 6 of the *National Parks and Wildlife Act 1974*, most provisions of which do not apply to Commonwealth lands. Consequently, recommendations one and two of the Australian Museum Consulting report have been followed where appropriate during the conduct of this assessment.

The National Heritage List

The National Heritage List is a schedule of places which the Minister for the Environment considers to have ‘National Heritage Value’ based on prescribed ‘National Heritage Criteria’.

There are no places within the airport site that are included on the National Heritage List (date of search: 24 June 2015).

The Commonwealth Heritage List

The Commonwealth Heritage List is a schedule of places owned or controlled by the Commonwealth, which the Minister for the Environment considers to have ‘Commonwealth Heritage Value’.

The EPBC Act places a range of obligations on Commonwealth agencies with regard to places included on the Commonwealth Heritage List. These include:

- a responsibility to undertake an assessment process to identify which of the places they own or control have Commonwealth Heritage values;

- establish and maintain a heritage register, as part of the heritage strategy, which is a list of places that a Commonwealth agency owns or controls that sets the Commonwealth Heritage values (if any) of each place;

- development of a heritage strategy applicable to all listed places controlled by the agency;

- preparation of a management plan for each Commonwealth Heritage listed place;

- ensuring that no action is taken which has, will have, or is likely to have an adverse impact on the National heritage values of a National Heritage Place, or the Commonwealth heritage values of a Commonwealth Heritage Place, unless there is no feasible or prudent alternative and all reasonable measures to mitigate impact have been taken; and

- including a covenant in any sale or lease contract for land which includes a Commonwealth Heritage Place which stipulates the protection of the Commonwealth heritage values of that place, unless such an action is found by the agency to be unnecessary, unreasonable or impractical.

There are no places within the airport site that are included on the Commonwealth Heritage List (date of search: 24 June 2015), or the DIRD Heritage Register (date of search 25 August 2015).

The Australian Heritage Council

The Australian Heritage Council is an independent body of heritage experts established through the *Australian Heritage Council Act 2003*. It replaces the Australian Heritage Commission as the Australian Government's independent expert advisory body on heritage matters.

The Council's role is to assess the values of places nominated for the National Heritage List, Commonwealth Heritage List, and the list of overseas places of historic significance to Australians. The Council provides advice to the federal Minister for the Environment on conserving and protecting listed values. The Council may also nominate places with heritage values to these lists.

It is the Council's duty to promote the identification, assessment and conservation of heritage and to advise the Minister on a range of matters relating to heritage. It also engages in research and promotional activities.

Commonwealth heritage management principles

Schedule 7B of the *Environment Protection and Biodiversity Conservation Regulations 2000* (Regulation 10.03D) lists the Commonwealth Heritage Management Principles. These principles are:

1. The objective in managing Commonwealth Heritage places is to identify, protect, conserve, present and transmit, to all generations, their Commonwealth Heritage values.

2. The management of Commonwealth Heritage places should use the best available knowledge, skills and standards for those places, and include ongoing technical and community input to decisions and actions that may have a significant impact on their Commonwealth Heritage values.

3. The management of Commonwealth Heritage places should respect all heritage values of the place and seek to integrate, where appropriate, any Commonwealth, State, Territory and local government responsibilities for those places.

4. The management of Commonwealth Heritage places should ensure that their use and presentation is consistent with the conservation of their Commonwealth Heritage values.

5. The management of Commonwealth Heritage places should make timely and appropriate provision for community involvement, especially by people who:

    a) Have a particular interest in, or associations with, the place; and

b) May be affected by the management of the place.

6. Indigenous people are the primary source of information on the value of their heritage and that the active participation of indigenous people in identification, assessment and management is integral to the effective protection of indigenous heritage values.

7. The management of Commonwealth Heritage places should provide for regular monitoring, review and reporting on the conservation of Commonwealth Heritage values.

2.1.2 Heritage and consultation principles and protocols

The Burra Charter

The Australian ICOMOS Charter for the conservation of places of cultural significance (the Burra Charter, as adopted in November 1999) provides principles for the treatment of places of cultural significance. The Charter also provides specific guidance for physical and procedural actions that should occur in relation to significant places. This assessment has been prepared in accordance with those principles.

Table 2.1 lists definitions from the Burra Charter (pp21-22) of key terms used in this assessment.

Table 2.1 Key terms used in this assessment as defined in the Burra Charter

Term	Definition
Conservation	means all the processes of looking after a *place* so as to retain its *cultural significance*. It includes *maintenance* and may according to circumstance include *preservation, restoration, reconstruction and adaptation.*
Maintenance	means the continuous protective care of the *fabric*, contents and setting of a *place*, and is to be distinguished from repair. Repair involves *restoration* or *reconstruction* and it should be treated accordingly.
Restoration	means returning the EXISTING *fabric* of a *place* by removing accretions or by reassembling existing components without the introduction of new material.
Adaptation	means modifying a *place* to suit proposed compatible uses.
Preservation	means maintaining the fabric of a place in its existing state and retarding deterioration
Reconstruction	means returning a *place* as nearly as possible to a known earlier state and is distinguished by the introduction of materials (new or old) into the fabric.

Australian Government Aboriginal consultation guidelines

Guidelines for consultation regarding indigenous heritage places and values are outlined in an Australian Heritage Commission publication entitled 'Ask First, A guide to respecting Indigenous heritage places and values (Australian Heritage Commission 2002). This publication provides an overview and guidance on the principles and conduct of Aboriginal stakeholder consultation within possible arenas of Australian government involvement. The principles and guidelines outlined in this document were drawn upon in the design and conduct of the program of Aboriginal stakeholder consultation adopted for this assessment.

The NSW Office of Environment Aboriginal consultation protocol

The NSW Office of Environment and Heritage (OEH) has produced a document titled: *Aboriginal cultural heritage consultation requirements for proponents 2010* (DECCW 2010b), (the 'NSW OEH Protocol'), that sets out the requirements for 'consulting with those Aboriginal people who can provide information about the significance of Aboriginal cultural heritage as part of the heritage assessment process' (ibid:1). The environmental survey of Commonwealth Land at Badgerys Creek,

conducted by Australian Museum Consulting in 2014 recommended that the EIS assessment should address these OEH consultation requirements (AMC 2014: recommendation 1). The OEH protocol was accordingly used as a guide for the conduct of the program of Aboriginal stakeholder consultation. The protocol was applied based on the understanding that:

- it outlines current best-practice within NSW;
- it provides a clear procedural, timing and resourcing structure; and
- its application would meet procedural expectations now established within the NSW Indigenous stakeholder community.

The protocol specifies four stages of consultation:

Stage 1 - Notification of the project and identification and registration of stakeholders

Stage 2 - Presentation of information about the project and the proposed assessment methodology

Stage 3 - Gathering information about cultural significance, and

Stage 4 - Review of draft cultural heritage assessment report

2.1.3 Implementation of protocols for the Western Sydney Airport

Stage 1 Notification of the project proposal and identification and registration of stakeholders

A public notice advising of the project assessment and inviting registrations from interested Aboriginal parties was placed in the following local newspapers. A copy of the notice is provided in Appendix 1 - Section A1.1).

- Blacktown Advocate - Wednesday 18 February, 2015
- Liverpool Leader - Wednesday 18 February, 2015
- Fairfield City Champion - Wednesday 18 February, 2015
- Camden Advertiser - Wednesday 18 February, 2015
- Penrith Press - Friday 20 February, 2015
- Macarthur Chronicle Tuesday 24 February, 2015

Letters were sent to the following organisations seeking the identification of Aboriginal stakeholders for the purpose of inviting their participation in the consultation program (dated 13 February 2015):

- Gandangara Local Aboriginal Land Council
- Office of the Registrar *Aboriginal Land Rights Act (1983) NSW*
- Native Title Services Corporation Limited
- Liverpool City Council
- Greater Sydney Local Land Services
- Office of Environment and Heritage

A search was conducted of the National Native Title Tribunal registers on 13 February 2015 (refer to Section A1.3, Appendix 1). The search returned no relevant entries for the airport site.

Letters were sent to the following recipients, inviting registration from parties suggested by others as potential stakeholders, or considered likely by NOHC (dated 3 March 2015):

- Walbunja Aboriginal Corporation
- NSW Aboriginal Land Council

- Darug Tribal Aboriginal Corporation
- Gandangara Local Aboriginal Land Council
- Darug Aboriginal Land Care Incorporated
- Gundungurra Aboriginal Heritage Association Inc
- Tharawal Local Aboriginal Land Council

Letters were sent to the following recipients, inviting registration from parties suggested by the NSW OEH and not already directly contacted by NOHC (dated 6 March 2015):

- Darug Tribal Aboriginal Corporation (additional address)
- Warragil Consultancy Services
- Wurrmay Consultancy
- Goobah Developments Pty Ltd
- Gunyuu (emailed 9/3)
- Badu
- Wullung
- Yerramurra
- Nundagurri

The closing date for stakeholder registrations was 24 March 2015.

Thirty four registrations were received from the following entities prior to the commencement of the fieldwork program on 4 May 2015:

- Badu
- Bilinga CHTS
- Butucarbin Aboriginal Corporation
- Cubbitch Barta Native Title Claimants Aboriginal Corporation
- Darug Aboriginal Cultural Heritage Assessments
- Darug Aboriginal LandCare
- Darug Custodian Aboriginal Corporation
- Darug Land Observations
- Darug Tribal Aboriginal Corporation
- Deerubbin Local Aboriginal Land Council
- Dhinawan-Dhigaraa Culture and Heritage Pty Ltd
- EORA
- Gangangarra
- Goobah
- Gandangara Local Aboriginal Land Council
- Gundungurra Aboriginal Heritage Association Inc.
- Gunyuu
- Kamilaroi-Yankuntuatjara Working Group
- Kawul Cultural Services
- Mungunya (sic) CHTS
- Murrumbul

- Ngunawal
- Ngunawal Heritage Aboriginal Corporation
- Nundagurri
- Tharawal Local Aboriginal Land Council
- Tocomwall Pty Ltd
- Wandandian
- Walbunja
- Wingikarah CHTS
- Warragil Cultural Services
- Wullung
- Wurrumay
- Yerramurra

Consistent with the NSW OEH protocol, all late registrations received during the assessment program have been accepted and the subject entities invited to participate in all subsequent consultation actions, as appropriate. Seventeen registrations have to date (6 August 2015) been received following the completion of the fieldwork program:

- Bidawal
- Bulling Gang Elders
- Curwur Murre Elders
- Dharug
- Djiringanj
- Elouera
- Gadung Elders
- Golangaya Elders
- Gulla Gunar Elders
- Kuringgai
- Murrin
- Ngarigo
- Peter Falk Consultancy
- Tharawal
- Thauaira
- Walbunja Elders
- Walgalu

Stages 2 and 3 Presentation of information about the project, proposed assessment and gathering information about cultural significance

A combined background paper and draft methodology for the Aboriginal cultural heritage assessment was sent to all registered stakeholders on 26 March 2015 with an invitation to provide comment on both the methodology and any known Aboriginal cultural values relevant to the airport site (refer to Section A1.4.1, Appendix 1). Consistent with recommendation 2 of the 2014 report of the environmental survey of Comonwealth land at Badgerys Creek by Australian Museum Consulting (AMC 2014), the draft methodology was based on scoping and excavation techniques specified in the Code of Practice for Archaeological investigation of Aboriginal Objects in New South Wales

(DECCW 2010a), Submission of written comments was invited by 23 April 2015, and the commencement of a three week field program was proposed on the 27 April 2015.

A meeting with the invited attendance of all registered stakeholders was held at St Marys on 8 April 2015. (refer to Section A1.4.3, Appendix 1). An introduction to the airport proposal, an outline of previously conducted assessment work in the airport site, and the proposed draft methodology for the Aboriginal cultural heritage assessment were presented and discussed at this meeting. The agenda and minutes of this meeting are included in Section A1.4.3 of Appendix 1.

A majority of representatives present at the 8 April 2015 meeting expressed a desire to discuss a number of issues directly with a representative of the Department of Infrastructure and Regional Development. These issues included:

- the scope of the archaeological field program;
- representation of Aboriginal stakeholders in the field program;
- field program pay rates;
- the use of wet sieving;
- potential distribution of a list of all registered participants to all registered stakeholders;
- Native Title; and
- management of recovered cultural material.

A supplementary stakeholder meeting was subsequently held at the same venue on 23 April 2015, with the participation of the General Manager of Environment, Legal and Communication, Western Sydney Unit, Department of Infrastructure and Regional Development. The agenda of this meeting is presented in Section A1.4.4 of Appendix 1. Responses from the GHD EIS assessment team to most of the issues raised by stakeholders regarding the proposed methodology were presented and further discussed at the meeting. An exception was the conditions of employment for stakeholder representatives in the field program.

As a consequence of the timetabling of the supplementary meeting, the stakeholder response submission date was extended to 30 April 2015, and the commencement of the field program revised to 4 May 2015.

A finalised set of conditions of stakeholder field participation was delivered to each stakeholder as part of a formal Invitation for Employment on 30 April and 1 May 2015. Stakeholder participation in the field program was conditional upon formal acceptance of the conditions. All 33 stakeholders registered at that time opted to accept the conditions and were represented in the subsequent field program.

2.1.4 Summation of Aboriginal stakeholder issues and project team responses

The following tabulation (Table 2.2), provides a summation of the main issues presented by stakeholders at the two meetings and in written submissions. Each issue is paired with a response from the EIS assessment team, including input from NOHC, noting where revisions or other actions were instigated in response. A detailed tabulation of the issues raised is presented in Section A1.4.5, of Appendix 1.

Table 2.2 Summary of Aboriginal stakeholder issues regarding the assessment methodology and EIS team responses

Issues raised by Stakeholders	Response by the EIS team
The scope of previously conducted archaeological survey across the airport site has been limited. More surface archaeological survey, such as 100% coverage, should be undertaken as part of this assessment.	The archaeological survey conducted for the 1997 EIS achieved a survey coverage of just over 50% of the current airport site. Given the low number of surface artefacts encountered during the 2014 re-inspection of selected 1997 site recordings (AMC 2014), the repeat conduct of systematic surface survey was considered unlikely to provide any analytical conclusions significantly different to the 1997 survey. However, a program of field survey and reconnaissance was conducted with stakeholders over one week in order to obtain an overview of the airport site, and to evaluate optimal subsurface testing locations As the objective of the current assessment was to focus on the assessment of the potential subsurface archaeological resource across the airport site, archaeological field work concentrated on test excavation.
A large number of stakeholders expressed the view that the proposed scope of the archaeological test excavation program was too limited. It was proposed that there be substantial increases in the number of test locations, test pits and allocated field time	The scope of the test excavation program was drafted within a framework which sought to balance minimum analytical requirements and the resources and timeline available for the investigation. In response to stakeholder concerns, the field team was increased in number from five, to 11 stakeholder representatives per day. This allowed a significant increase in scope by increasing the number of test pits that could be completed per day, and potentially the number of test locations which could be investigated in the allocated time. An undertaking was made to review the progress of the field program at the end of each week relative to the testing aims and targets. Consideration was given in each review about the need to extend the field program based on an appreciation of the accumulating field results.
Many stakeholders considered that there had not been enough time allocated for the assessment.	The scope of the test excavation program was drafted within a framework which sought to build upon the work already conducted during the 1997 EIS, and to balance minimum analytical requirements with the resources and timeline available to the investigation. It is useful to note that the current assessment has the advantage of access to an already developed corpus of survey data and analysis. This meant that the conduct of a time intensive surface survey of the airport was neither considered necessary nor consistent with the priority for an assessment of subsurface archaeological potential.
Some stakeholders considered that there had not been enough information provided about the airport project.	At the time of the assessment, the design, configuration and capacity of the proposed airport was still subject to development and change. Unfortunately this meant that only general information and objectives about the project could be communicated to stakeholders.

Issues raised by Stakeholders	Response by the EIS team
Some stakeholders considered that there had not been enough support for the assessment methodology prior to the testing program. In particular, there was not enough justification for and documentation of the representativeness of the possible test locations.	The selection of test locations was based on a priority to include a representative range of the large and small scale landform types and topographic variables present within the airport site. Reference was also made to current predictive site location models so that well substantiated and low potential variables were not re-tested. For this reason, a large database of representative data, such as the proportion of each landform type/variable within the airport site, was not presented in support of the test location selections. Given the land-use history of the airport site, a greater priority was the minimisation of exposure to areas of substantive ground surface disturbance. This was one of the priorities fulfilled during the first week of field reconnaissance and orientation in which the potential test locations were shortlisted.
Some stakeholders considered that the large number of stakeholder registrations indicated that many did not have a strong association with the airport site. There were suggestions that the number of registered stakeholders who were to participate in the field program should be limited, such as to include only those representing Darug heritage, or those who had participated in person at the meetings.	The primary role is acknowledged of those cultural values expressed and derived from individuals and their lore which are related to local country, tribal identify and tradition. However, a principle in both the Commonwealth and State guidelines of stakeholder consultation is that of inclusiveness. This is required so that the potential submission of relevant information from unexpected or unanticipated sources is not excluded from the process. Similarly, descendants from a subject area may now be resident in variously distant locations, or may identify primarily with other tribal groups. These physical and social dynamics make the potential exclusion of stakeholders based on perceived identity or allegiance, unhelpful and counterproductive. Based on the emphasis on inclusive representation by the adopted protocols, it was decided to provide equal opportunity to all registered stakeholders to nominate field representatives to participate in the field program.
Many stakeholders considered that the proposed roster system for dividing field participation across all registered stakeholders was too restrictive. It was suggested that all stakeholders be represented on every day of programmed fieldwork.	Given the number of registered stakeholders at the time (33), and the assessment team's commitment to an inclusive process of consultation and field participation, the suggested daily inclusion of all stakeholders in fieldwork would have resulted in an inefficient use of resources and a counterproductive set of logistical requirements.
Most stakeholders considered that the draft methodology proposal for a roster of five stakeholder representatives per day was too small.	In response to these concerns, the size of the field team was increased from five to 11 stakeholder representatives per day. This significantly increased the potential for discussion amongst stakeholders during the first week of field inspections, as well as expanding the scope of the investigation by increasing the number of test pits that could be completed per day.
Most stakeholders considered that the proposal to conduct dry sieving was not appropriate for the Cumberland Plain and should be replaced with a wet sieving methodology.	A wet sieving methodology was adopted for the test excavation program.

Issues raised by Stakeholders	Response by the EIS team
A number of stakeholders concluded that their views had not been adequately taken into consideration.	All views expressed by stakeholders were given careful consideration. In many cases suggested actions, principles or policy could not be realised or developed because they were incompatible with project objectives, the adopted consultation protocol or the resourcing constraints of the project.
The cumulative impact of large developments on the Cumberland Plain have not been affectively mitigated or managed in the past. The cumulative impact of the airport project will be a critical component of the assessment and needs to be taken into consideration by the assessment.	It was acknowledged by the team that cumulative impacts on cultural values are an important component of the net impact of any development proposal and would be addressed in the assessment.
The possible conditions of fieldwork employment were extensively debated. A number of disparate positions regarding potential conditions of employment and pay rates were presented by various stakeholders however no consensus opinion emerged.	The assessment team gave careful consideration to all stakeholder suggestions and issues raised on this matter. An offer of employment was made based on the following: • Equal representation of all registered stakeholders • Field participation to be spread across the full field program according to a roster drafted by NOHC • One representative per registered stakeholder per rostered day • A single hourly rate and allowance package applicable to all field participants • All field participants to be proficient in 'Sites Officer' field skills (unfortunately it was not possible to offer a junior or unskilled/trainee position) • Consideration of employment conditions offered at other similar, recent Aboriginal cultural heritage assessment programs involving Commonwealth agencies.
One stakeholder group suggested that a review of previously conducted geotechnical testing data should be conducted as a precursor to selecting optimal test excavation locations. The provision of all previously conducted data to interested stakeholders was suggested.	It was agreed that data from geotechnical testing conducted within the airport site, conducted previously (where available), and for the current EIS assessment, will be reviewed and applied where applicable in the Aboriginal cultural heritage assessment.

2.1.5 Field participation

All Aboriginal stakeholders who were registered at the time, opted to participate in the fieldwork program. A roster was established which allowed for the participation of all stakeholder representatives by defining three sub-groups. Each group participated for five field days which were spread over the three week field program, mostly across paired days. Eleven stakeholders were represented on each field day. A list of all field representatives is provided in Section A1.2, Appendix 1.

The field program was divided into two components:

Week One — A primary objective of the first week was to provide an opportunity for stakeholders to identify and discuss cultural and intangible values



	associated with the airport site. In this week, stakeholder representatives were given an opportunity to become familiar with the site's characteristics and to inspect the diversity of landforms present. This was achieved through both reconnaissance inspections, and the systematic on-site evaluation of each of the proposed archaeological test locations.
Weeks Two and Three	In the following two weeks, representatives were employed in the systematic conduct of archaeological test excavations across a shortlisted number of test locations, selected and evaluated in the first week.

2.1.6 Stage 4 Comments on the Draft EIS

All registered Aboriginal stakeholders will be provided with, or advised where to locate a copy of, the draft EIS report and specialist Aboriginal cultural heritage report, and invitated to provide a written response on its findings and proposed mitigation and management strategies. This comment period will coincide with the statutory period for public display of the Draft EIS and submission of comments. All responses will be documented, reviewed and addressed in finalising the EIS.

2.2 Consultation with other stakeholders

2.2.1 Liverpool City Council

A meeting with the Heritage Officer for Liverpool City Council, was held on the 28 May 2015 with Kelvin Officer (NOHC) and Erin Williams (RPS) from the EIS assessment team. A general outline of the project and assessment approach was provided, followed by a discussion of potential issues and priorities.

2.2.2 NSW Office of Environment and Heritage

A meeting with a senior archaeologist with the Heritage Branch, Office of Environment and Heritage (OEH) was held on 29 May 2015, with Kelvin Officer (NOHC) and Erin Williams (RPS) from the EIS assessment team. A general outline of the project and assessment approach was provided, followed by a discussion of potential issues and priorities. A representative from the Office with responsibility for Aboriginal heritage was unable to attend the meeting. Given that the OEH would not have a statutory role in the assessment of the EIS, it was explained by the attending OEH officer that limited resources and competing priorities had not enabled additional attendance.

2.3 Review of previous work and heritage registers

2.3.1 Sources

A range of archaeological and historical data was reviewed for the airport site and its surrounds. This review was used to:

- determine the nature and status of known Aboriginal sites within and around the airport site;
- facilitate site prediction on the basis of known regional and local site patterns; and
- place the area within an archaeological and heritage management context.

The review of documentary sources included heritage registers and schedules, local histories, and archaeological reports. A primary information source was the Aboriginal Heritage Information Management System (AHIMS) maintained by the NSW OEH together with its associated files and catalogue of archaeological reports.

Searches were undertaken of the following heritage registers and schedules:

- Aboriginal Heritage Information Management System (AHIMS) (NSW OEH) (accessed 9 January 2015 and 18 June 2015);
- World Heritage List;

- The National Heritage List (Australian Heritage Council);
- The Commonwealth Heritage List (Australian Heritage Council); and
- The Register of the National Estate (Australian Heritage Council).
- The Heritage Register of the Department of Infrastructure and Regional Development

Searches of these registers and listings revealed that Aboriginal sites and places are only included within the AHIMS register.

2.3.2 Excluded and revised recordings

A review of original site recording field data generated by the 1997 EIS archaeological survey was conducted for all recordings within the airport site. These records comprised the original field site card forms, annotated topographic mapping and print photography. All of the map grid coordinates from this program were generated from visual interpretation of 1:25,000 topographic mapping, without the aid of reliable GPS technology. When complemented with contemporary mapping applications and aerial photography, it was possible to refine and correct a number of the site locations. As a consequence, one recording, a modified tree (B8, AHIMS site no. 45-5-2634) was found to be situated outside of the airport site on the southern side of Badgerys Creek. Due to an original 1997 mapping error, the tree tentatively ascribed to this recording by AMC in 2014 is not the tree recorded in the 1997 survey (AMC 2014:53). All revised map coordinates have been incorporated into the site inventory for this investigation (Appendix 2).

A review of the AHIMS register data revealed one recording which had been plotted within the airport site, based on an erroneous map grid reference. This site is 'EG6' (AHIMS site no. 45-5-2562) and was recorded in 1999 along a proposed easement of the eastern gas pipeline. This site is situated 5 km to the east of the airport site.

2.4 Field inspection and surface survey

A three week fieldwork program was conducted which comprised an initial week devoted to Aboriginal consultation and a review of possible test excavation locations, and two weeks in which archaeological test excavations were conducted. The field program extended from 4 to 22 May 2015. This program reflected the objectives of the assessment, which were the identification of Aboriginal cultural values and the testing of the subsurface archaeological resource.

The field program comprised the following:

Week One	Stakeholder orientation and reconnaissance
	Identification and discussion of cultural and intangible values
	Review of potential test locations and development of a prioritised list
Weeks Two and Three	Conduct of archaeological test excavation program

The systematic conduct of surface archaeological survey across the airport site was not attempted. However, a number of sites were identified and recorded during the process of accessing and inspecting potential test excavation locations.

2.5 Test excavation

As outlined in the results of the consultation program (refer Table 2.2), the draft methodology for the test excavation program was modified by the inclusion of wet sieving and increasing the number of stakeholder representatives per field team. All adopted field program methodologies were consistent with the *Code of Practice for Archaeological investigation of Aboriginal Objects in New South Wales* (DECCW 2010a) where appropriate.

The aim of the test excavation program was to characterise the nature and occurrence of the subsurface archaeological resource by conducting archaeological test excavations within a representative selection of landform types present within the airport site.

The methodology, developed in consultation with Aboriginal stakeholders, anticipated the conduct of test excavations in at least ten representative test locations, with around ten hand dug archaeological test pits executed at each location, each with dimensions of 1 x 0.5 m. The pits were to be arranged at regular intervals along straight line transects to sample micro-topographic variation.

The initial desktop pre-selection of test excavation locations involved the following steps, considerations and priorities:

- Classification and mapping of archaeologically relevant landform units present across the airport site (refer to Chapter 3);
- Consideration and avoidance of areas displaying substantial ground disturbance;
- Identification of areas of early nineteenth century non-Aboriginal occupation, with a view to testing for the presence of 'contact' archaeological material;
- Consideration of existing and well-established Aboriginal site location criteria with the aim of avoiding the need to replicate test results from low potential areas, such as high gradient or poorly drained micro-topographic contexts;
- Selection of at least one of each of the large-scale landform units identified at the airport site;
- Selection of at least one test location from each of the main catchments;
- Selection of test locations from throughout the horizontal and vertical topographic range of the airport site;
- Preference given to locations with 4WD, or better, access; and
- Exclusion of properties where permission to access had been withheld.

Based on the above desktop selection criteria, 38 potential archaeological test locations were pre-selected. Following on-site review and field inspection of each location, with the participation of Aboriginal stakeholders, the locations were prioritised and a shortlist developed.

In four instances, potential locations were paired and combined to form two single test locations (test locations 8 &10, and 26 & 27). The location and summary descriptions of the pre-selected locations are presented in Table 2.3 and Figure 2.1.

Archaeological test excavations were conducted at 13 of the 38 preselected potential locations. With the pairing of four of these, there was a total of eleven test locations.

All excavation was conducted by hand, using spades, hand trowels, and where necessary picks. All sieving was conducted by hand using pressurised water sourced from a water truck. All artefactual material, including European materials (but excluding plastic and imported gravels) was recovered and subject to itemised description in the laboratory.

Sieve (square aperture) meshes used were:

- 12.5 millimetres (0.5 inch), as necessary, and always as a (nested) top mesh, and/or
- 3.13 millimetres (5/32 inch).

All pits were backfilled with sieved spoil and/or imported clean fill, using a bobcat.

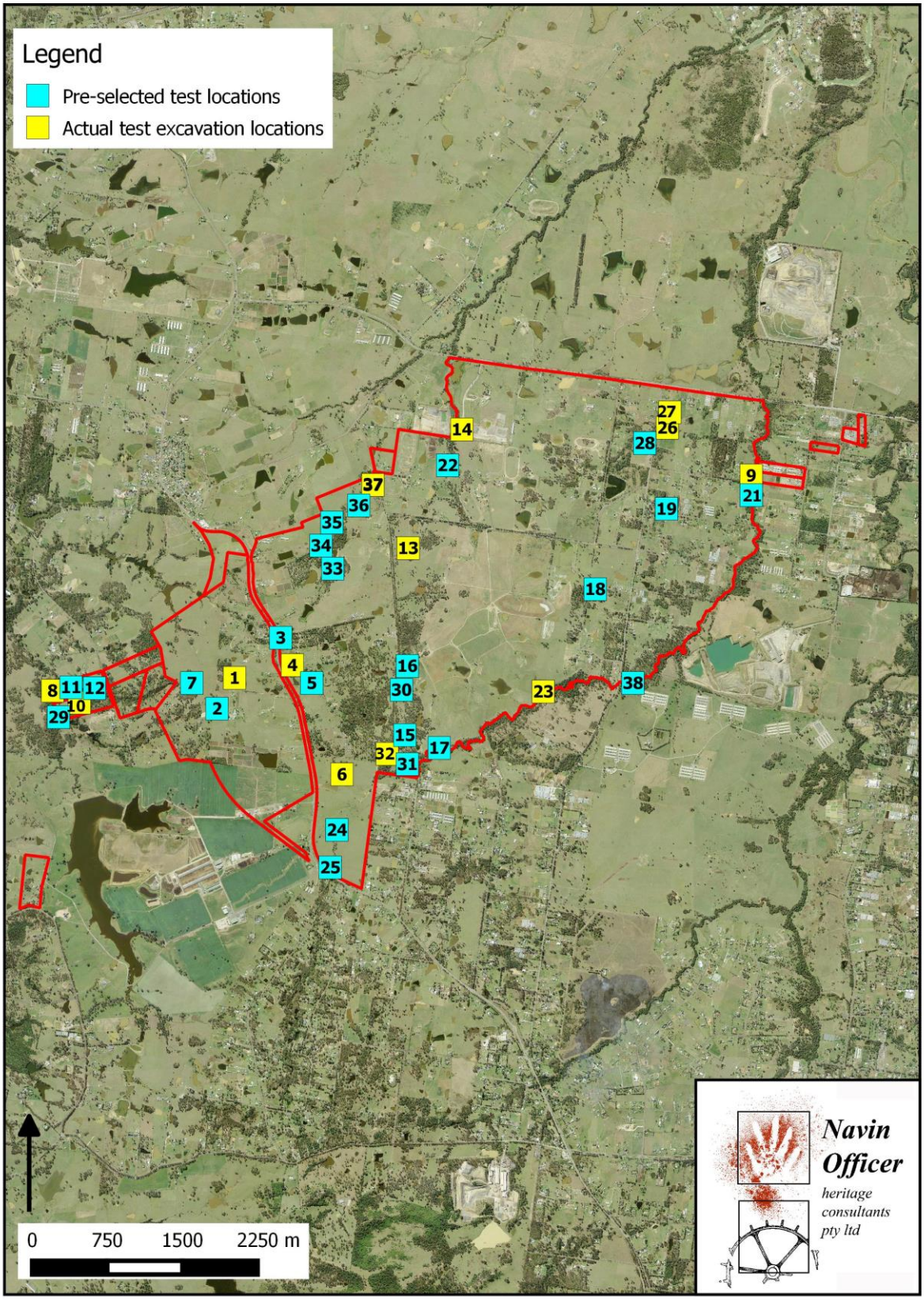


Figure 2.1 General location of pre-selected and actual test excavation locations across the Airport Site.

Table 2.3 List of potential test locations identified from desktop analysis, and review comments following field inspection.
Bolded numbers indicate locations where archaeological test pits were conducted.

Test location no.	Landform types	Location	Property Numbers	Map page numbers (refer to Appendix 5)	Comments
1	Major watershed ridgeline crest and upper slopes	Major watershed ridgeline, just north of Vicarys Winery	404786 & 404794	12	Good access, pasture improved
2	Major watershed ridgeline crest and upper slopes	Major watershed ridgeline, Vicarys Winery	404757	12	Good access, but close to/includes building disturbance zone
3	Secondary watershed ridgeline crest and upper slopes	Prominent ridgeline formed from basaltic dyke (highest elevations in airport site)	404607	6 & 12	Avoidance of historic church site and burial sites exclude most of location, poor access, quartz flakes present, surface sandstone outcrops
4	Secondary watershed ridgeline crest and upper slopes	Prominent ridgeline formed from basaltic dyke (highest elevations in airport site)	404766	12	Good access, relatively undisturbed
5	Secondary watershed ridgeline crest and upper slopes	Prominent ridgeline formed from basaltic dyke (highest elevations in airport site)	404768	12	Steep access, highly disturbed by quarrying
6	Mid slopes, basal slopes, valley floor, minor spurline crest, alluvial flats	Adjacent to third and fourth order streamline on east side of The Northern Road	404772	12	Good access, pasture improved, exclude western side of creek
7	Tributary watershed ridgeline and secondary spurline	Spurs and ridgelines descending to fifth order streamline, Duncans Creek	404753 & 404810	11	Constrained access, powerline disturbance, native grasses and thus reduced disturbance in places, artefacts on western side of track
8	Basal slopes, valley floor, alluvial flats	Adjacent to fifth order streamline, Duncans Creek, at western end of airport site	404808	10	Good access, native grasses and thus reduced disturbance, could be combined with location 10
9	Basal slopes, valley floor, alluvial flats, possible levee deposit	Basal slopes, flats and banks of fifth order streamline, Badgerys Creek, at eastern end of Gardiner Road near eastern end of airport site	404681	9	Good access, avoid impact to historic buildings, some cultivation impact, artefacts evident on surface and in adjacent road reserve

Test location no.	Landform types	Location	Property Numbers	Map page numbers (refer to Appendix 5)	Comments
10	Mid slopes, basal slopes, minor spurline crest	Minor spurline adjacent to fifth order streamline, Duncans Creek, at western end of airport s	404801	10 & 11	Good access, native grasses and thus reduced disturbance, could be combined with 8
11	Basal slopes, valley floor, minor spurline crest, creek banks	Adjacent to second order streamline, close to confluence with Duncans Creek	404808	10	Good access, native grasses and thus reduced disturbance, TL 8/10 is a better option
12	Basal slopes, valley floor, minor spurline crest, creek banks	Adjacent to second order streamline, close to confluence with Duncans Creek	404808	11	Obscured by scrub
13	Secondary spurline crest, \minor spurline crest	Centrally located upper catchment context on E side of Anton Lane	404601	7	Good access, native grasses and thus reduced disturbance, avoid disturbance areas associated with airstrip
14	Mid slopes, basal slopes valley floor, minor spurline crest	Adjacent to east bank of fourth order streamline, Oaky Creek	404587	1	Good access, native grasses and thus reduced disturbance, locally elevated micro-topography
15	Mid slopes, basal slopes, minor spurline crest	Rise between minor second and third order streamlines close to Badgerys Creek	404796 & 404600	13	Constrained access, some disturbance, surface artefacts (AHIMS site no. 45-5-2699, B46)
16	Secondary watershed ridgeline crest	East of Anton Road, high catchment context	404600	13	Difficult access, very boggy, recently ploughed, very disturbed
17	Valley floor, alluvial flats	Banks and flats adjacent to fifth order streamline, Badgerys Creek	404796	13	Constrained access, requires creek crossing, immediately downslope of former 'Stanfield' farmstead
18	Secondary spurline crest, upper slopes	Small saddle on spurline west of Badgerys Creek Road	404640 & 404639	8	Highly disturbed (intensive agriculture), European rubbish, TL27 a better alternative
19	Tributary watershed ridgeline crest, upper slopes	North of Pitt Street	404688	9	Constrained access, stock animals
20	Valley floor, alluvial flats, possible levee deposit (low rise adjacent to creek)	West bank and flats adjacent to fifth order streamline, Badgerys Creek, at east end of Leggo Street	404732	9	Flooded and under water

Test location no.	Landform types	Location	Property Numbers	Map page numbers (refer to Appendix 5)	Comments
21	Valley floor, alluvial flats, possible levee deposit (low rise adjacent to creek)	West bank and flats adjacent to fifth order streamline, Badgerys Creek, at east end of Leggo street	404670	9	Constrained (waterlogged) access, highly disturbed adjacent to creek, flats disturbed by levelling and cropping
22	Valley floor, basal slopes, minor spurline crest, creek banks	Banks and slopes adjacent to third and fourth order streamlines, Oaky Creek and tributary	404594	1 & 7	Consent for property access unavailable
23	Mid slopes, upper slopes, minor spurline crest, basal slopes	Elevated minor spurline/bench adjacent to Tributary watershed ridge, and fifth order streamline, Badgerys Creek	404600 & 404610	14	Access weather dependent, adjacent to grinding groove site (B120), adjacent to former 'Spredenburg' farmstead
24	Valley floor, minor spurline/low rise, alluvial flats	Rise adjacent to fourth order streamline, Badgerys Creek, close to Northern Road crossing	404772	17	Ground water-logged, constrained access, all pasture improved, some disturbance
25	Valley floor, minor spurline/low rise, alluvial flats	Rise adjacent to fourth order streamline, Badgerys Creek, close to Northern Road crossing	404772	17	Access difficult, access to east side of creek constrained, pasture improved, flats are waterlogged
26	Valley floor, alluvial flats	Banks of fourth order stream line (unnamed in NE portion of airport site)	404571 &404569	3	Good access, avoid half of area subject to fill and dumped debris, downslope of 'Pennell's', farmstead in area of site B88 (AHIMS site no. 45-5-2665), could be combined with TL27
27	Basal slopes and upper slopes, secondary spurline crest	Spurline adjacent to Elizabeth Drive	404572	3	Good access, avoid adjacent Scout Hall block which is highly disturbed, adjacent to former 'Pennell's' farmstead, could be combined with TL26
28	Valley floor, basal slopes, minor spurline	Adjacent to fourth order stream line (unnamed in NE portion of airport site)	404565	2 & 3	No access to northern side of Creek, access constrained by scrub, surface artefacts on S side of creek (AHIMS site no.45-5-2763, B87)
29	Basal slopes, knoll	Knoll adjacent to fifth order streamline, Duncans Creek	404801	10	Poor access, test area obscured by scrub, shallow soil

Test location no.	Landform types	Location	Property Numbers	Map page numbers (refer to Appendix 5)	Comments
30	Midslopes, minor spurline crest	Adjacent to second order streamline in mid valley context, south of Antons Lane	404600	13	Difficult access, very boggy, recently ploughed, very disturbed
31	Valley floor, alluvial flats, possible levee deposit	Alluvial flats between former and current bed of fifth order streamline, Badgerys Creek	404796 & 404771	13	Constrained access across creek, low disturbance levels
32	Mid slopes, basal slopes, valley floor, minor spurline crest, alluvial terrace	Minor spurline adjacent to fifth order streamline, Badgerys Creek	404796	13	Good access, some cross drains, good micro-topographic variation, close to sites B45 and B46 (AHIMS site nos. 45-5-2663 & 2699)
33	Basal slopes, secondary spurline	Spur situated between two second order streamlines draining into tributary of Cosgroves Creek	404604	6	Constrained access, boggy creek crossing, under power line easement, surface artefacts adjacent to creek
34	Basal slopes, secondary spurline	Spur situated between two second order streamlines draining into tributary of Cosgroves Creek	404604	6	Constrained access, boggy creek crossing, some erosion and track disturbance, surface artefacts
35	Mid slopes, basal slopes	Western fall of valley of third order streamline tributary of Cosgroves Creek	404603	6	Steep and problematic access
36	Basal slopes, valley floor, minor spurline crest	Eastern fall of valley of third order streamline tributary of Cosgroves Creek	404603	6	Constrained access, limited micro-topographic variation, upstream of dam 100 m upstream of former 'Haines' farmstead
37	Valley floor, basal slopes, minor spurline crest, creek banks, elevated rise/terrace	Banks and slopes adjacent to third order streamline (tributary of Cosgroves Creek)	404603 & 404602	6	Good access, good micro-topographic variation, stock animals, surface artefact on embankment, from 0 – 100 m downstream of former 'Haines' farmstead
38	Valley floor, alluvial flats	Alluvial flats and banks of fifth order streamline, Badgerys Creek	404655	15	Constrained access, boggy ground, stock animals, either side of early European creek crossing 'to Mr Bell's' (1859)

2.6 Recording parameters

2.6.1 A paradigm shift from surface to subsurface evidence

This assessment incorporates site data generated by the 1997 EIS investigation. Some of the current conclusions and assessments drawn from this data differ from those made in 1997. This is due to an emerging and better understanding of the nature of the subsurface archaeological resource.

It is now established that Aboriginal stone artefacts in subsurface contexts are distributed across the full spectrum of landscape variation. The areal incidence of this distribution is discontinuous and uneven, but broad and relative categories of artefact incidence can be reliably predicted according to landform types and variables. A corollary understanding is that the location and boundaries of recorded surface sites relate more directly to patterns of erosion and land-use, factors which determine ground surface exposures, than to patterns in Aboriginal occupation. A consequence of this is that measures generated solely from surface site recordings, such as site frequency, density (areal incidence), and even the identification of discrete potential archaeological deposits, can have reduced relevance unless coupled with analysis of the unexposed archaeological resource.

Current predictive modelling now allows the extrapolation of subsurface artefact incidence data to untested landforms of the same type. The nature of the predicted archaeological resource can now be mapped in terms of broad area landforms and topographic variables.

The integration of surface and subsurface information which characterises current best practice can be understood as a shift in paradigm - from one which is site-based and focused on surface evidence, to one focused on the subsurface resource that may be revealed by both surface sites and test excavation.

This development has introduced a parallel shift in analysis from sites to landscapes. When predictive modelling is generated by, or substantiated from, locally applicable and excavation-derived datasets, it provides a basis for making significance assessments applicable to landform suites and landscapes. The assessment conducted for this investigation adopts a landscape approach based on the predictive value of the test excavation program. This is complemented by the results of the previous 1997-1999 EIS assessment methodology which employed a site based approach.

A more detailed discussion of the shift in approach from surface to subsurface evidence is provided in Appendix 7.

2.6.2 Terminology used

Potential archaeological deposit (pad)

This classification is typically applied to a relatively small and discrete location, defined spatially either by geomorphological, disturbance, or administrative criteria. Within such an area, there is a predicted likelihood that subsurface archaeological material is present, and that this material would warrant archaeological investigation in order to determine its scientific, cultural, or statutory value and status. The latter qualification is necessary to avoid the inclusion of predicted low or very low subsurface artefact incidences which is an expected trait across a majority of assessed landscapes.

Archaeologically sensitive landscape (asl)

Large and broad-area assessments often necessitate the identification of the archaeological resource at a broader level such as landform type or a combination of topographic variables. To define these as potential archaeological deposits would be inaccurate. This is because of the expected discontinuous distribution of archaeological material across the defined zone and the very low incidence within some included small-scale landforms. The terminology ‘archaeologically sensitive’ landscape is used to indicate an area in which sites and/or pads are known or predicted to occur at a scale or frequency which necessitates management action in the future.

Both the categories: archaeological deposit, and archaeologically sensitive landform, can be used on their own where there is evidence of archaeological material, or with the prefix ‘potential’, where

there is a lesser degree of supporting evidence. For a specific deposit, direct evidence of archaeological material would be needed to remove a 'potential' prefix, such as from a visible soil profile section or test pit.

The basis for the identification of archaeologically sensitive landforms in this assessment is the conduct and results of the test excavation program. Only locales with direct evidence of archaeological material are classified as sites.

Aboriginal site

An Aboriginal site is a place or location which relates to past or contemporary Aboriginal occupation. Aboriginal sites can be divided into those that are identified from archaeological evidence (archaeological sites), and those related to intangible cultural values, such as revealed by oral tradition and lore, or from the historical record. A site may include both archaeological and intangible heritage values.

Stone artefact occurrences

A spatially discrete distribution of stone artefacts in an open context, (that is not situated within a rock shelter or cave), is the most commonly recorded site type in Australia. In the past, these recordings were subdivided into 'isolated finds', when based on the discovery of single artefact, and 'open camp site' or 'artefact scatter' when comprised of more than one artefact.

As a consequence of the growing body of evidence that surface artefact occurrences are an unreliable indicator of both subsurface deposits, and bounded subsets relevant to past activity, the typology for recording artefact occurrences has become less interpretive and now refers to artefact occurrences.

This investigation adopts the following typology:

Surface artefact occurrence	One or more stone artefacts which occur within a specified surface area, and which are distinguished from other recordings by defined criteria, such as the boundary of ground surface exposures, landform type, or an arbitrary separation distance
Subsurface artefact occurrence	One or more stone artefacts which occur within a specified deposit, and which have been revealed as a result of natural or human excavation. The boundaries of a recording may be strictly tied to known artefacts (such as test pits or erosion scarps) or consist of an interpretation base on topographic or disturbance variables. Subsurface artefact occurrences can also be described as archaeological deposits

Given the varied incidence of ground surface exposure and deposit disturbance within the airport site, a specification of 60 metres has been adopted for recordings identified from surface survey evidence. The 60 metre parameter was also employed in the 1997 EIS survey recordings (NOHC 1997).

Where a site has been identified from subsurface evidence, (and in the context of the current investigation this is solely based on the evidence from test pits), then pits have been grouped into sites based on relevant landform boundaries.

Background scatter

Background scatter is a term used generally by archaeologists to refer to artefacts which cannot be usefully related to a place or focus of past activity (except for the net accumulation of single artefact losses).

There is no single concept for background discard or 'scatter', and therefore no agreed definition. Commonly agreed is that background discard occurs in the absence of 'focused' activity involving the

production or discard of stone artefacts in a particular location. An example of unfocused activity is occasional isolated discard of artefacts during travel along a route or pathway. Examples of 'focused activity' are camping, knapping and heat-treating stone, cooking in a hearth, and processing food with stone tools.

Scarred Trees

The scarred tree classification refers to a tree with a scar or scars of assessed Aboriginal origin. Most such scars are the result of the removal of bark or wood. The identification of a scar as Aboriginal in origin is dependent on a set of inter-related interpretive criteria, and is often associated with varying degrees of recorder confidence or surety. For this reason classifications are often prefixed as possible, probable or most likely. The credibility of alternative causal explanations such as natural traumas and other types of human scarring must be tested for each scar.

Scarred trees are now included in the more inclusive site type classification of *modified tree* or *culturally modified tree*. Scarred trees make up a large proportion of this category. Each tree is normally considered to be a separate site.

A range of diagnostic criteria has been developed to assist in the identification of Aboriginal scarred trees. The following criteria are based on archaeological work conducted by Simmons (1977) and Beesley (1989), and the field manual for Aboriginal scarred trees developed by Long (2005):

1. The scar does not normally run to ground level: (scars resulting from fire, fungal attack or lightning nearly always reach ground level). However, ground termination does not necessarily discount an Aboriginal origin (some ethno-historical examples of canoe scars reach the ground);

1(a). If a scar extends to the ground, the sides of the original scar must be relatively parallel: (natural scars tend to be triangular in shape;

2. The scar is either approximately parallel sided or concave, and symmetrical: (few natural scars are likely to have these properties except fire scars which may be symmetrical but are wider at the base than their apex. Surveyors marks are typically triangular, and often adzed);

3. The scar should be reasonably regular in outline and regrowth: scars of natural origin tend to have irregular outlines and may have uneven regrowth;

4. The ends of the scar should be 'shaped', either squared off, or pointed (often as a result of regrowth): (a 'keyhole' profile with a 'tail' is suggestive of branch loss);

5. A scar which contains adze or axe marks on the original scar surface is likely to be the result of human scarring. Their morphology and distribution may lend support to an interpretation of an Aboriginal origin: (marks produced after the scarring event may need to be discounted);

6. The scar must date to the time of Aboriginal bark exploitation within its region: The traditional Aboriginal exploitation of bark probably ceased in most regions between 100 and 150 years ago. However, in some locations associated with Aboriginal settlement, the Aboriginal removal of bark may have continued to the present day, or restarted as part of new cultural movements; and

7. The tree must be endemic to the region: (and thus exclude historic plantings).

Field identification of Aboriginal scars, is based on surface evidence only and will not necessarily provide a definitive classification. In many cases the possibility of a natural origin cannot be ruled out, despite the presence of several diagnostic criteria or the balance of interpretation leaning toward an Aboriginal origin. For this reason interpretations of an Aboriginal origin are qualified by the recorder's degree of certainty. The following categories were used:

- Aboriginal scar - This is a scar where an Aboriginal origin is considered the most likely. The scar conforms to all of the criteria and a natural origin is considered unlikely and improbable;

- Probable Aboriginal scar - This is a scar that conforms to all of the criteria and where an Aboriginal origin is considered to be the most likely. Despite this, a natural origin cannot be ruled out; and

- Possible Aboriginal scar - This is a scar which conforms to all or most of the criteria and where an Aboriginal origin cannot be reliably considered as more likely than alternative natural causes. The characteristics of this scar will also be consistent with a natural cause.

2.6.3 Site numbering

The site numbering adopted for this assessment follows the protocol adopted in the 1997 EIS investigation.

All recordings were given a consecutive 'B' number following on from the last site recording (B112) within the 1997 EIS Badgerys Creek assessment area.

In the 1997 investigation, the 'B' prefix was intended to differentiate Badgerys Creek from Holsworthy recordings. The 'B' prefix has been retained for the current assessment in order to group all the Badgerys Creek area sites together, and to flag their related assessment history.

3. Landscape context

3.1 Regional overview

3.1.1 The Sydney Basin

The airport site is located on the central western margin of the Cumberland Plain (Figure 3.1). The Cumberland Plain is a centrally positioned landscape unit of the much larger Sydney Basin. The Sydney Basin is a large sedimentary structure, six kilometres thick, made up of fine-grain lithologies originally laid down in a foreland basin through late Permian and Triassic time (Herbert 1997). The Basin covers an area of 64,000 km^2, (the onshore component being 36,000 km^2) and extends over 1500 km from Port Stephens to Batemans Bay. The Basin is situated between the New England and Lachlan Foldbelts.

The surface topographies of the basin display an elongated saucer shape. The gently undulating lowlands of the Cumberland Plain are situated approximately at its centre. The basin rises steeply in the west and more gently in the north and south where the landscapes are dominated by sandstone and characterised by steeply incised plateaus (Young and Young 1988). The rock types around the margins of the basin are dominated by sandstones, such as the Hawkesbury Sandstone around Sydney, and are older than the overlying and softer shales across the centre which form the Cumberland Plain. Basaltic dykes and volcanic plugs occur throughout (Haworth 2003; Hazelton and Tille 1990). Triassic Wianamatta Group shales overlay the Hawkesbury Sandstone and outcrop throughout the plateaus, on the Cumberland Plain, and Moss Vale tablelands (Haworth 2003; Hazelton and Tille 1990; Sullivan and Hughes 1983).

The climate of the Sydney region is warm and temperate; orographic effects result in more precipitation and less temperature variation along the coast.

3.1.2 The Cumberland Plain

The airport site is located on the western side of the northern portion of the Cumberland Plain (Figure 3.1). The northern Cumberland Plain is that section of the Plain where the creek lines drain north and west to the Hawkesbury River (McDonald and Rich 1993). The Cumberland Plain is in a centrally positioned portion of the inner Sydney Basin which consists of rolling and low gradient topographies which have developed on the shale dominated bedrocks of the Wianamatta Group of middle Triassic age.

The Wianamatta Group makes up the uppermost portion of the Triassic depositional sequence and was laid down as epimarine, intertidal, back-swamp and alluvial sediments during a period of marine regression (the exposure of former seabed), and progradation (the seaward and progressive deposition of shoreline deposits) (Jones and Clarke 1991; Smith 1979).

The Wianamatta Group consists of, in order of deposition up-sequence:

a) the Ashfield Shales Formation, grading from shales to fine sandstones and siltstone laminates, (Smith 1979), laid down in shallow marine and lacustrine conditions. Outcrop is very limited on the Cumberland Plain;

b) the Minchinbury Sandstone Formation, a quartz lithic sandstone normally up to 6 m thick which exhibits low angle, cross-bedding indicative of a prograding bar barrier or beach system; and

c) the Bringelly Shales, predominantly consisting of claystone and siltstones with thin laminate layers and locally discontinuous, thin and often sinuous sandier units (former channel deposits).

The Cumberland Plain comprises three broad physiographic units:

- the River Plain, comprising the alluvial flats associated with the Nepean-Hawkesbury River, and the Eastern, South and Ropes Creeks (approximately 11 per cent of the plain);

- the Dissected Plateau, where stream incision into the underlying sandstone has occurred, particularly around the margins of the Plain (approximately 33 per cent of the plain); and
- the Shale Slopes, formed on the Ashfield and Bringelly Shales (approximately 56 per cent of the plain) (Dept of Environment and Planning 1984).

The airport site falls within the Shale Slopes unit. The area of the airport site, approximately 17 km^2, comprises around 1.2 per cent of this unit.

Some characteristics of the Shale Slopes unit include:

- gently undulating, rounded hills and valleys with a low degree of vertical differentiation – this has a consequence that the more elevated country, the network of ridges and spurlines (also known as interfluves), do not pose a major obstacle for, and have less strategic value in, cross-country movement and control;
- mature landforms;
- deep texture contrast soils which are clayey and stiff;
- surface hydrology characterised by a dendritic pattern of drainage lines;
- native vegetation structures dominated by grassy woodland and open forests; and
- broad area flooding and associated aggradation of sediments across valley floor contexts.

3.1.3 Current and palaeo-climate

The climate in southeast Australia during the Holocene period (the last 10,000 years) was relatively stable, with environmental changes of a smaller amplitude and shorter duration than those experienced in the late Pleistocene (Attenbrow, 2004:204). Slightly wetter conditions than those of today persisted between ~7000 BP (Before Present) and ~5000 BP, and the overall trend from ~3800 BP to ~1500 BP was to cooler, drier conditions.

The last1000-1500 years saw small increases in temperature and rainfall equivalent to those currently experienced. After 3000 BP, the El Niño-Southern Oscillation (ENSO) began to operate as it does now, resulting in more marked seasonality and variation in precipitation patterns. Evidence for the end of cooler and drier conditions in the mid Holocene shows regional variance, but the transition back to warmer and wetter conditions on the southeast coast began at about 2000 BP (Attenbrow 2002:206-7). The scale of impact from mid-Holocene cooler and drier conditions produced changes in the extent of vegetation communities, rather than a total change of vegetation (Attenbrow 2002:37; Haworth 2003; Nanson and Young 1983; Young and Young 1988).

The contemporary climate of the Penrith area is humid and subtropical with hot summers and mild winters. The average summer temperature range is 17.9 ºC to 29.8 ºC and in the winter 6.2 ºC to 18.6 ºC. The average January maximum temperature is 29 ºC and the average July minimum is 5 ºC (based on 50 years of data (1956-2006).

Since the mid twentieth century, average annual rainfall in South Creek catchment has been less than 800 millimetres and varied only slightly from the area where it arises south of Bringelly to the confluence with the Hawkesbury River in the north (Bringelly 760 mm, St Marys 759 mm, Windsor 757 mm) (DEC 2005a). A higher proportion of the annual total rainfall occurs in the warmer months of the year and summer rainfall is less variable than winter rainfall. Average rainfall only exceeds evaporation in June, with the difference between rainfall and evaporation being greatest in December (Rae 2007).

Across the airport site, the mean monthly rainfall ranges from 126 millimetres (February) to 23 mm (July) (dataset: 1999 – 2013). Seasonal mean maximum temperatures range from 28.8 ºC in summer to 18.1 ºC in winter, and mean minimum temperatures from 16.5 ºC in summer to 4.7 ºC in winter. The dominant wind direction is southwesterly in all seasons. Wind direction is more constant in

autumn and winter than in spring and summer. Mean wind speeds are relatively constant throughout the year ranging from 5 to 7 knots (BOM 2015).

The following seasonal divisions for the Sydney region have been recorded by D'harawal knowledge holders (http://www.bom.gov.au/iwk/dharawal/index.shtml).

- January/February/March (*Burran*) - Hot and dry
- April/May/June (*Marrai'gang*) - Wet, becoming cooler
- June/July (*Burrugin*) - Cold, frosty, short days
- August (*Wiritjiribin*) - Cold and windy
- September/October (*Ngoonungi*) - Cool, getting warmer
- November/December (*Parra'dowee*) - Warm and wet

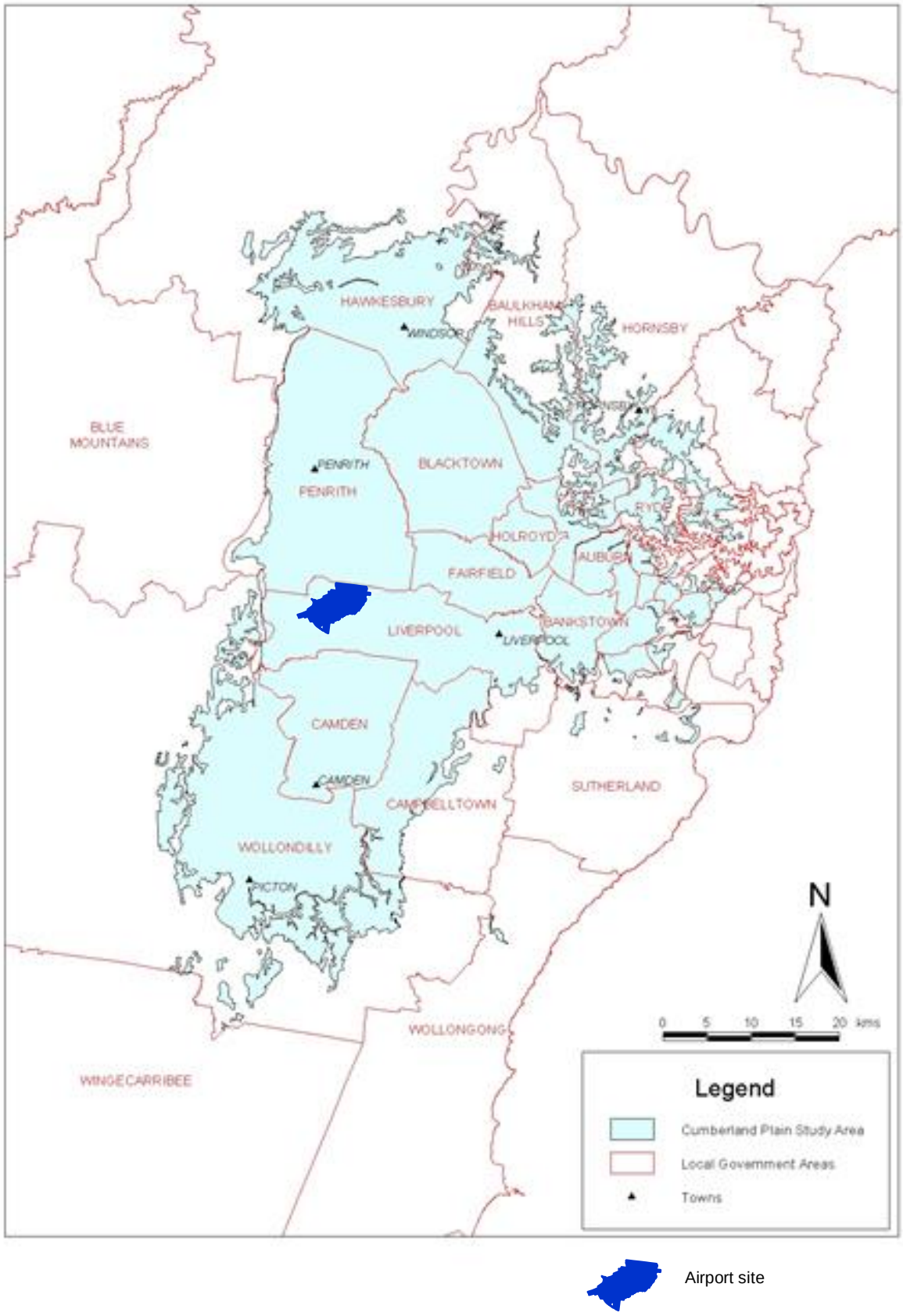


Figure 3.1 The Cumberland Plain (after Office of Environment and Heritage web site: http://www.environment.nsw.gov.au/threatenedspecies/MapOfTheCumberlandPlain.htm)

3.2 The airport site

3.2.1 Topography

The landscape of the airport site is typical of the Shale Slopes component of the Cumberland Plain, with low relief, undulating and low gradient topography, and a medium drainage line density. Ground elevation varies of from 118 to 43 m AHD. The Bringelly Shale outcrops throughout the area. Surface exposures of Minchinbury Sandstone also occur in isolated locales. A post-Triassic basaltic dyke outcrops along a north-west south-east alignment in the western half of the airport site. The resistant nature of this rock has formed higher slope gradients and a small area of moderately graded undulating terrain. The steeper slopes contain screes of volcanic gravels.

Small areas of naturally occurring surface silcrete gravels occur across some portions of the airport site. These may constitute a surface lag (ancient remnant gravels from a now fully eroded deposit), or relate to as yet poorly mapped subsurface remnants of ancient weathering (refer to Appendix 6).

3.2.2 Soil Landscapes

The mapped soil-landscapes within the airport site are: Blacktown, Luddenham and South Creek (Bannerman and Hazelton 1990).

Blacktown soil-landscape

The Blacktown soil-landscape dominates the Cumberland lowlands and has developed on the predominantly shale bedrocks of the Wianamatta Group. It is characterised by local relief of between 10 and 30 metres and gradients of mostly less than 5 per cent, but up to 10 per cent. Crests and ridges are typically broad and rounded, with convex upper slopes grading into concave lower and basal slopes. Outcrops of shale occur in association with eroded areas but were not a feature of the pre-European landscape. Soils are shallow to moderately deep (<100 centimetres) hardsetting mottled texture contrast soils including red, brown podzolics on crests, and yellow podzolic types on lower slopes and flats (podzolic soils are characterized by moderate leaching which produces an accumulation of clay). These soils can be generalised as comprising friable top loams which overlie hard-setting clay loams and compact mottled clays (Bannerman and Hazelton 1990:28-31).

Luddenham soil-landscape

The Luddenham soil-landscape occurs only in the western end and possibly also the northern margin of the airport site. It has developed on predominantly shale bedrocks of the Wianamatta Group, often in association with Minchinbury sandstone. It is characterised by low rolling to steep hills with local relief in the 50 to 120 metre range and low to moderately inclined slopes, mostly between 10 and 15 per cent. Ridges and hill crests are convex and narrower than for the Blacktown category. Moderately inclined side slopes grade into narrow concave drainage lines. Soils include shallow dark podzolic soils to massive earthy clays on crests, moderately deep (70 – 150 centimetres) red podzolics on upper slopes, and moderately deep yellow podzolics and prairie soils on lower slopes and flats. These soils can be generalised as comprising friable top loams which overlie hard-setting clay loams and basal clays (Bannerman and Hazelton 1990:63-66).

South Creek soil-landscape

The South Creek soil-landscape occurs throughout the present active floodplains and valley floor flats of the Cumberland Plain drainage network. This landform has formed from Quaternary alluvium derived from the Wianamatta Group shales and where situated upstream, the Hawkesbury sandstone. The topography is mostly flat or gently sloping alluvial plain with occasional terraces and levees providing low relief. Slopes are less than 5 per cent and local relief is under 10 m. Soils are often very deep with layered sediments over bedrock or relict soils. Soil types include structured plastic clays or structured loams adjacent to drainage lines, red and yellow podzolics on terraces, and structured or leached clays, and yellow solodic soils (Bannerman and Hazelton 1990:68-71).

3.2.3 Drainage network

Most of the airport site falls within the upper catchment of South Creek, a north draining tributary of the Hawkesbury River with a course length of 64 km and a catchment area of around 620 km^2 (Rae 2007). The far western portion of the site forms part of the immediate catchment of the Nepean River, via the north and west draining minor tributary of Duncans Creek. The watershed ridgeline between the South Creek and Nepean River catchments in the airport site is situated along the northern half of The Northern Road and then southwards and west of this road along the ridge containing Vicarys Winery (Figure 3.3). This watershed is significant in terms of the hydrology of the Cumberland Plain but for most of its length, provides an unimposing topographic feature as a broad and low gradient ridgeline.

The airport site is dominated by upper catchment terrain, with most of its drainage lines originating from headwaters situated within the site and reaching stream orders of three and four. The stream order analysis conducted for the Aboriginal heritage analysis identified two fifth order streamlines: Badgerys Creek along the southern and eastern boundary, and Duncans Creek just outside of the western site boundary. The headwaters of Badgerys Creek are situated three kilometres upstream of the airport site, and its confluence with South Creek occurs four kilometres downstream. The southern and eastern fall of the Badgerys Creek catchment occupies the southern margin of the site, and two tributaries of Cosgroves Creek, including Oaky Creek, drain to the north. These tributaries reach orders of three and four.

Only the fifth order section of Badgerys Creek (approximately downstream of Mersey Road) is classed as perennial on the NSW Land and Property Information 1:25,000 topographic map series.

3.2.4 Vegetation

The vegetation across most of the Cumberland Plain prior to European land-use comprised an open eucalypt woodland in which the trees were widely spaced and the ground cover dominated by grasses (Perry 1963). The woodland would have been dominated by Grey Box (*Eucalyptus moluccana) and Forest Red Gum (E. tereticornus).* Native grasses included *Themeda australis* and *Aristida* spp, with *Lomandra* spp. occurring as a common herb. Along the riparian corridors forest communities would have included Rough-barked Apple (*Angophora floribunda*) and *Casuarina cunninghamiana* together with *Acacia* spp (Benson and Howell 1990).

Most of the original native vegetation has been cleared from the airport site and is now dominated by agricultural grasslands or cultivated fields with scattered Eucalypt and exotic trees and pockets of open Eucalypt woodland or shrubland. The remaining native vegetation includes pockets of native grassland and mostly regenerating woodland or forest. Older growth Eucalypts, dating from the early twentieth century may remain as isolated occurrences.

3.2.5 Land-use

Since the early 1800s, non-Aboriginal land-use of the airport site has been primarily agricultural and consisted of varied phases of stock grazing, cropping, orcharding, dairying and market gardening. A pattern of increasingly smaller subdivision commenced in the mid nineteenth century and culminated in the delineation of numerous rural residential lots associated with post war immigration. A broader spectrum of activities characterised the middle and later twentieth century including market gardening, hobby farming, animal husbandry such as poultry farming, horse and dog breeding and training, and some light industrial functions. Acquisition of the land by the Australian Government began in the 1980s and the nature of residency changed from freehold to tenancy. This was associated with a slow process of depopulation and loss of long-term residents which has accelerated in recent times. A reduction in intensive agricultural activity since the late twentieth century has facilitated forest and woodland regrowth.

All of these activities can be expected to have had a substantial impact on the Aboriginal archaeological resource, especially where resident in the top soil and the plough zone. Vegetation clearance and repeated ploughing and cropping will have removed nearly all trees with the potential for Aboriginal scarring. Artefact occurrences will have been impacted by soil loss, lateral and vertical soil movement across the land surface, and to a depth of the relevant plough zone.

3.3 Landform classification

The following landform categories have been applied in the mapping and analysis of topographic variables across the airport site (refer to Figure 3.3 and Appendix 5). Table 3.1 summarises the proportion of various landform divisions within the airport site.

An objective of this typology was to simplify landscape variation into a concise set of types which were relevant to current archaeological modelling and applicable within an initial-phase test excavation program. Some of the categories, such as fluvial corridors, and first and second order spurline crests, occur only in conjunction with other units, such as valley floor, and basal slopes, whereas an underlying subset of large scale categories can be defined independent of other categories, and don't overlap each other, such as valley floor, basal, mid and upper slopes.

Large-scale, independent landform categories

Valley floor	Level and low gradient ground forming the floor of a valley and comprised predominantly of alluvial landforms such as drainage channels, banks, flats, levees and terraces.
Basal slopes	Low gradient slopes with a characteristic concave cross-section, which occur between the alluvial valley floor and steeper mid valley slopes. This is an intermediate zone and may include buried valley floor alluvium, or remnant high terrace deposits. This zone is characterised by discontinuous locally elevated landforms, separated by drainage lines, and including low bedrock based spurs, and colluvial and fan deposits.
Mid slopes	The side-slopes of valleys and ridges which are situated in a middle valley context and may constitute the steepest grades along a base to crest profile. This zone may include variously graded first and second order spurlines.
Upper slopes	The upper side-slopes of ridges and spurs characterised by a convex cross section, and which include, or extend up to the 'break-of-slope' transition to the lower gradients or flat ground of the spur or ridge crest.
>2nd order crests	The crests of ridges which define the upper watershed of locally prominent watersheds. The attributed order of spurs and ridgelines is partly qualitative, and based on relative prominence and relative position within the dendritic network of interfluves.

Smaller scale categories which may occur in combination

Crests

Crest	The upper ground surfaces of a ridge or spurline, situated between the break-of-slope on either side. The level and low gradient upper portion of a ridge or spur as revealed in a transverse cross section.
Fifth order ridge crest	The highest order of ridgeline within the airport site and delineates the upper portion of the watershed between the immediate tributaries of the Nepean River and South Creek.
Fourth order ridge crest	This order of ridgeline separates the upper portion of the internal catchments of South Creek tributaries, such as between Cosgroves and Badgerys Creeks).
Third order ridge crest	This order of ridgeline separates the upper portion of the internal tributary catchments of Badgerys Creek tributaries, such as Oaky Creek.

Secondary spurline crest	This order of spurline typically separates second order streamline catchments
First order spurline crest	This order of spurline comprises all minor spurlines and typically delineate first order stream gullies and valleys. These spurs often constitute the lowest and free-ended unit of the dendritic ridge and spurline network.

Drainage line order

The order of the airport site drainage lines was determined using the Strahler classification system (Strahler 1952). This system allocates a progressive 'order' number according to the order of adjoining and upstream tributaries (refer to Figure 3.2). The classification of first and second order streamlines was based on a manual and visual interpretation of one metre contour topographic mapping. All stream classifications are illustrated in mapping presented in Appendix 5.

The stream order analysis conducted for this cultural heritage assessment was generated independently of the depiction of streamlines on the NSW Land and Property Information 1:25,000 topographic map series (and its associated dataset, Hydroline). This was necessary because the Hydroline data does not classify or depict all streamlines. As a consequence, some stream order classifications differ from those presented by Hydroline. The Hydroline dataset has been applied in other separate analyses for this EIS, where and as required, according to relevant methodological standards. The stream orders presented in this heritage analysis have been generated with the objective of identifying Aboriginal site location determinants. Any differences in stream classification across separate disciplines are a consequence of different formal methodologies rather than errors in fact.

According to the stream order analysis conducted for this analysis, Badgerys and Duncans Creeks are fifth order streams, and are the highest order streamlines within or adjacent to the airport site.

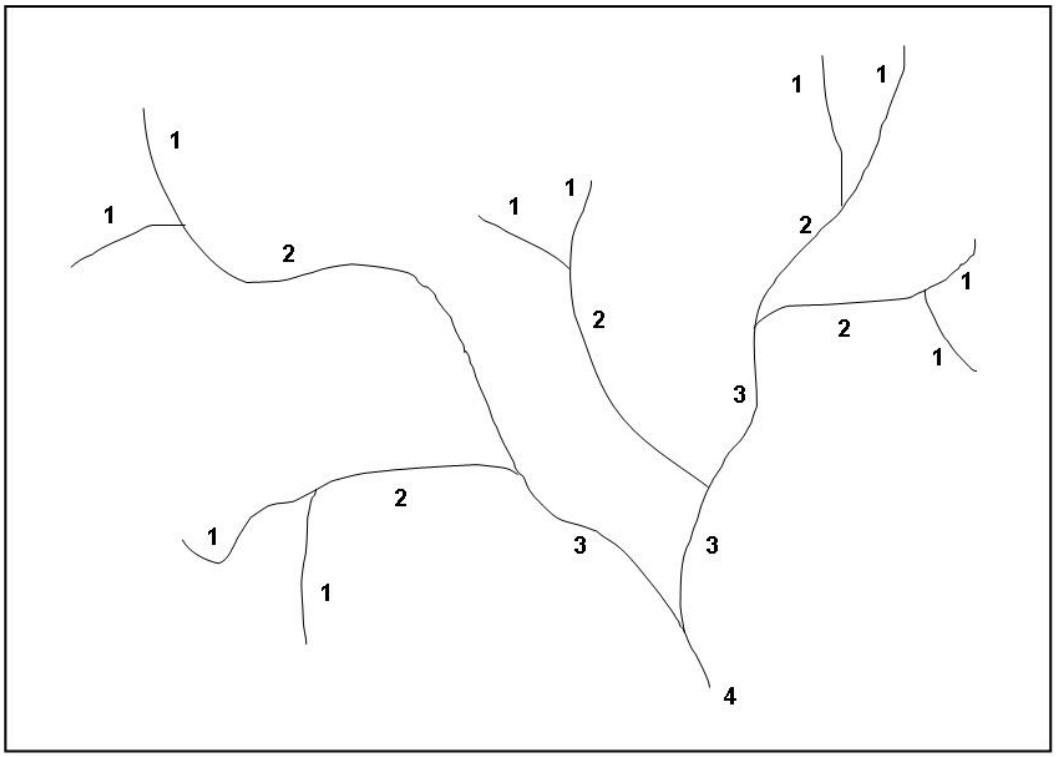


Figure 3.2 Diagram showing the allocation of drainage line order according to the Strahler classification system (Strahler 1952, 1954).

Riparian corridors (100 m)

Riparian corridors were delineated around all second or larger streamlines, and defined as a 100 metre radius around the drainage line. The distance of 100 metres is derived from the current predictive Aboriginal site location model which observes that most site recordings occur within 100 metres of streamlines. It is important to note that this corridor definition is based on archaeological parameters and the predictive model for Aboriginal archaeologiclal site. It does not correspond with other riparian definitions which may be applied by other floral, faunal or hydrological studies for the Western Sydney Airport EIS.

Gradient

flat	Surfaces of between zero and two per cent, typically found on the valley floor, some sections of basal and upper slopes, and some crest areas on spurs and ridges
low	Slopes of between two and five per cent, typically found on basal, mid and upper slopes and occurs over some crest areas on spurs and ridges
low to moderate	Slopes of between five and 10 per cent, typically found on mid and upper slopes
moderate	Slopes of between 10 and 20 per cent, typically found in limited locations across the airport site in upper slope contexts on ridgelines.

Table 3.1 Net calculations for the incidence of landform categories within the airport site

Landform category or feature	Area (ha)	net linear distance (km)
Riparian corridor (100 m either side of drainage line)		
2nd order streamline corridor	394.3	21.3
3rd order streamline corridor	173.5	9.3
4th order streamline corridor	66.4	3.8
5th order streamline corridor	76.8	6.9
Ridge and spur crests		
1st order	187.1	34.5
2nd order crest	83.7	13.1
3rd order crest	55.2	9.1
4th order crest	51.0	6.7
5th order crest	15.3	3.0
Large scale independent categories		
Total area of 3rd, 4th and 5th order crests	122.5	18.8
Valley floor	184.0	-
Basal slopes	214.2	-
Mid and Upper slopes	1324.4	-
Total area[1]	***1845.1***	-

Note 1. The area total includes Australian Government owned lands which are non-contiguous with the airport site

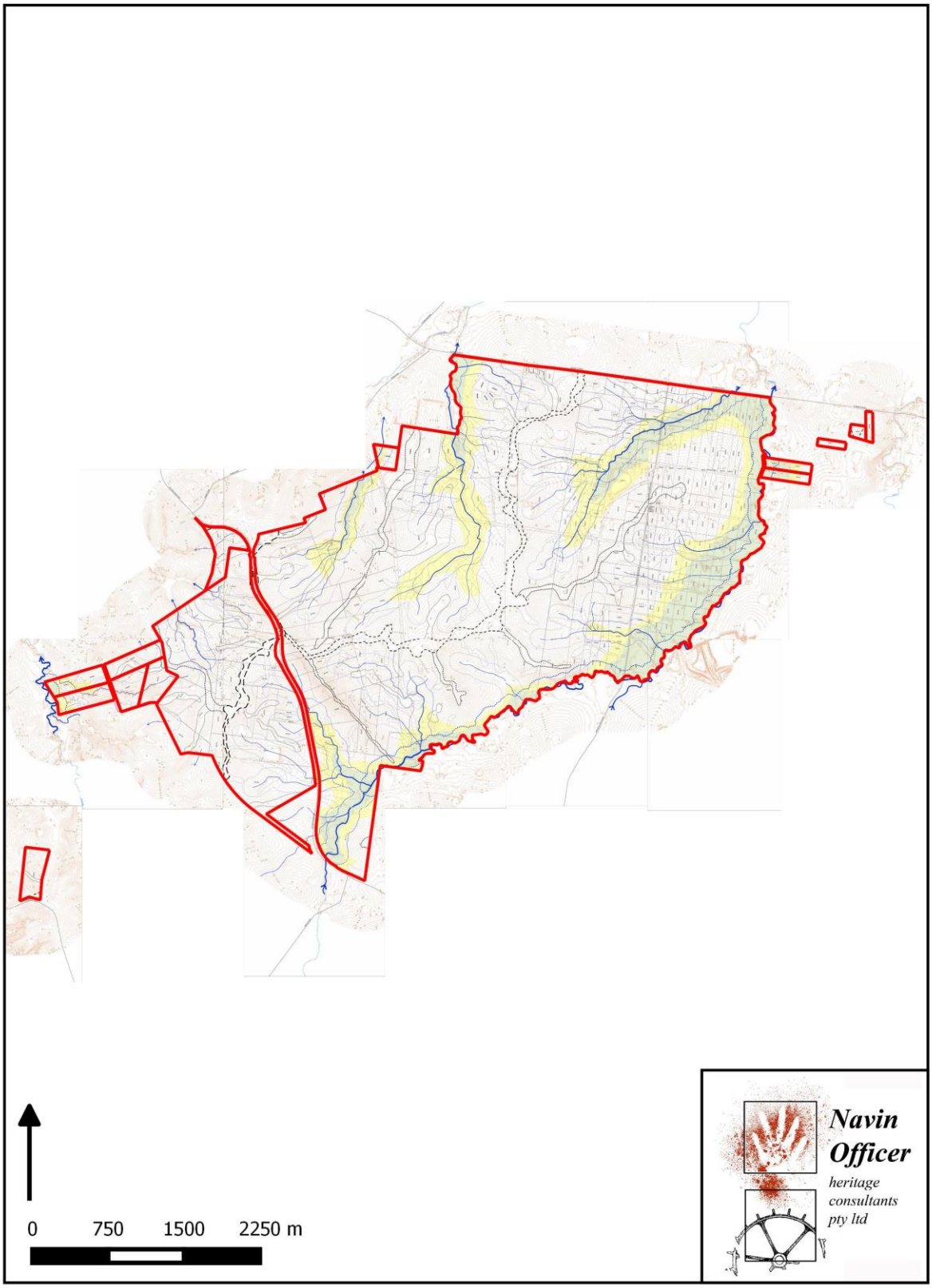


Figure 3.3 Mapped landform units and drainage corridors across the airport site (boundary shown in red, (refer to next page for key and Appendix 5 for large scale mapping).

Key to landform mapping

Drainage lines

First order — *not delineated*

Second order

Third order

Fourth order

Fifth order



Crests

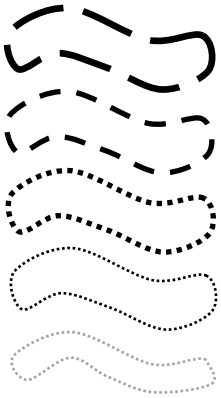
(5) Major watershed (Nepean R – South Creek)

(4) Secondary watershed (Cosgroves Creek – Badgerys Creek)

(3) Tributary watershed (eg Oaky Creek)

(2) Secondary spurline

(1) Minor spurline or locally elevated ground



Valley Context

Valley Floor Flats/infill sediments

Basal valley slopes

Upper and mid valley slopes



Riparian zone

100 metre radius around:

Second order drainage line

Third order drainage line

Fourth order drainage line

Fifth order drainage line

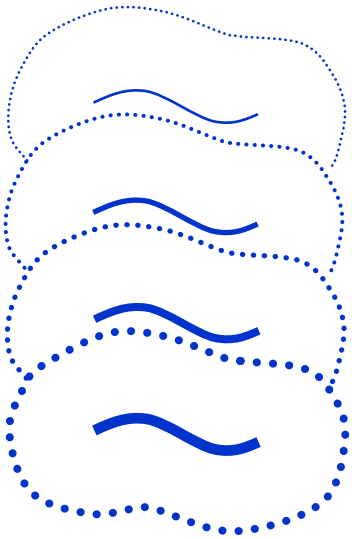


Figure 3.3 cont. Key to landform mapping presented in Figure 3.3. Note that the Figure 3.3 map is greatly reduced and this key is shown at a larger scale for clarity. Please refer to Appendix 5 for greater detail.

3.4 Review of geotechnical borehole data

A review of previous geotechnical testing data from the airport site was conducted in 2015. This study had the following objectives:

- to assess the potential of available geotechnical data to assist with archaeological evaluation of the terrain, soils and sediments forming regolith across the airport site;
- to specifically address whether geotechnical data may assist in establishing whether palaeosols or buried soils may exist within the airport site; and
- examine whether geotechnical data may assist in establishing the potential for archaeological assemblages to occur at depth, associated with palaeosols or potentially stratified beneath deposits of alluvium or colluvium.

The full report of this review is provided in Appendix 6.

The review suggested there would be considerable value in integrating a model of the near-surface geometry of unconsolidated deposits over bedrock (a regolith model based on geotechnical data) with requirements set for any post-EIS archaeological salvage program. The geotechnical data are sufficiently detailed to permit direct comparison with archaeological field results from subsurface testing (e.g. as depths of topsoil; recorded depths to subsoil; evidence or not of saprolite or bedrock rockhead near surface). In areas where shallow archaeological excavations have been completed (often to 0.3-0.5 metres to “clay”), geotechnical data can provide broad cross-checks of the stratigraphy likely to lie below the depths investigated. However, as spatial variation in near surface regolith depths is high, such cross-checking will only provide broad areal information.

Notwithstanding this future application, the historic geotechnical data was found to have neither sufficient spatial coverage, nor consistency of investigative method, to profitably drive a full geoarchaeological model applicable to the conduct of the Draft EIS archaeological test excavation program. In particular, field verification of historic data would be needed ahead of investigating deeper regolith for archaeological purposes.

Most data indicated quite shallow depths to bedrock. As the majority of data points are on interfluves and plateau areas, this does not help resolve whether, for example, small narrow areas of significant archaeological deposit might exist at the edge of small tributary valley floors, or under small colluvial fans. A general limitation of the data reviewed is therefore adequacy of spatial coverage across all landform elements.

A small number of individual locations were seen where stratified unconsolidated deposits, some showing grading, or fining upwards trends could be inferred from the logs. Most sequences of this type relate to observations of “gravel” some of which were specifically described as “silcrete” or quartzose or quartz. Such deposits are clearly described as stratifying above saprolite and are often within 2-3 m of the present land surface. The records thus pinpoint locations where useful additional supplementary archaeological investigations might take place. The data does not, however, allow the mapping of units or areas. More data points and much more detailed analysis of elevation, topography and deposit relationships would be needed to assign “archaeological significance” unequivocally. While there is clear evidence of weathering, possible stratification and locations worth testing, evidence of age is weak. Such units need not relate to the period of human occupation of Australia – broadly the last 50,000 +/-5000 years BP. Gravels, where logged near the surface have potential, but could be millions of years old and represent minor unmapped upstream remnants (or age-equivalents) of the “Rickabys Creek Gravels”.

No palaeosols were seen in logged data which suggested unequivocally recent (late Pleistocene or Holocene) ages. No records were observed that identified wood, or peat, tufa or other types of clearly recent sediments with unequivocal dating potential, despite waterlogging and high tables within 5 m of the surface in many logs.

The data examined did not provide a basis for thinking that its application in the Draft EIS test excavation program would provide substantial improvement. This is because of significant skew in patterns chosen for borehole transects, notably a preference for interfluve and plateau locations.

It was concluded that a more efficient approach would be to marry the historic geotechnical data, with the array of new borehole and test pit data recently acquired for the Draft EIS, and for future and post-EIS investigations. The combined data could generate a geospatial "net" and mode:

a) with much improved coverage of the geometry of shallow regolith cover over bedrock (superficial deposits); and

b) a specific relationship to scheme "cut and fill" geometry.

The historic data do not provide sufficient coverage to drive deep archaeological investigations, especially in "high risk" landforms such as upper (1st order) tributary floors and slope margins.

The larger post-EIS data set model could be used to verify and cross-check outcomes from archaeological assessment testing conducted for the current investigation. In particular, areas of "uncertainty" can be refined where combined archaeological testing and geotechnical sources of data show either:

a) high archaeological potential at depth; or

b) areas and zones of "high uncertainty and risk" predicted from geotechnical data - which justify deeper archaeological investigations at specific "known" points in the landscape.

Building and applying this geometry model using a geoarchaeological methodology could form one part of the archaeological salvage strategy to be conducted in the event of development approval. The methodology would require the application of geoarchaeological criteria for interpreting geotechnical data. A common Digital Terrain Model (DTM) and geo-referencing system would be required to integrate data.

4. Cultural context

4.1 Ethno-history

References to the Aborigines of the Sydney region are found in the journals, diaries and general writings of the early colonists, explorers and settlers. The ‘natives' were one of the main subjects of interest to those who arrived in the First Fleet and ‘all the journals contain frequent references to them' (Fitzhardinge 1961:102).

Accounts written by early visitors to Australia which document the more obvious details of Aboriginal life include Bradley (1786), Collins (1798), Hunter (1793), Phillip (1789), Tench (1789, 1793, 1961) and White (1790). Although these early commentators were not trained in anthropology or linguistics, they provided some useful information regarding the Aborigines around the Sydney region.

Tench (1789:79) describes the equipment of the Aborigines as ‘Exclusive of their weapons of offence, and a few stone hatchets very rudely fashioned, their ingenuity is confined to manufacturing small nets, ...and to fish-hooks made of bone, neither of which are skilfully executed’. Tench also notes the use of bark canoes for fishing (Tench 1789:81-82).

Comments were made on the types of Aboriginal shelters observed. These were described as consisting ‘only of pieces of bark laid together in the form of an oven, open at one end, and very low, though long enough for a man to lie at full length in … they depend less on them for shelter, than on the caverns with which the rocks abound' (Tench 1789:80). Collins observed that the huts were ‘often large enough to hold six to eight people' (Collins 1798:555). These shelters were often grouped together.

Early observers reported a distinction between the food and lifestyles of the coastal and hinterland Darug. Watkin Tench noted from a conversation with two Darug people on the Hawkesbury-Nepean in 1791 that hinterland people: "depend but little on fish, as the river yields only mullets, and that their principal support is derived from small animals which they kill, and some roots (a species of wild yam chiefly) which they dig out of the earth." He also noted that coastal Aborigines appeared to have no knowledge of the region west of what is now known as Parramatta (Tench 1961:230).

Within a short period of time after white settlement, the Sydney Aboriginal population was greatly reduced as a result of two epidemics (most probably) smallpox. The first occurred only a short time after settlement in 1789 and the second in 1829-1831 (Butlin 1983). The first outbreak of the disease is believed to have killed 50 per cent of the Aboriginal population (Collins 1798:53, Ross 1988:49, Tench 1961:146, Turbet 1989:10). Loss of life on such a scale caused a major social reorganisation of Aborigines around the area (Ross 1988:49) with 'remnants of bands combining to form new groups' (Kohen 1986:30). Therefore the anthropological observations and other observations by chroniclers of the time do not depict the pre-settlement situation accurately.

An article written by ‘a Medical Gentleman of Bunbury Curran’, a district east of Ingleburn, and published in 1820, describes ‘the mortal efficacy of the late influenza that raged throughout the Colony for many weeks with increased violence, and particularly among the scattered tribes of natives.’ After describing ‘a great mortality’ amongst the Aborigines regardless of health or age, during the winter, it notes that ‘they had for the most part quitted the thinly wooded and more open tracts of the interior and betaken themselves to the sea coast and bushy and broken country, where there were quantities of honey, and where they would undoubtedly remain until they return in the summer’ (Sydney Gazette 1820: Dec 16)

There are other accounts dating from the early 1800s that provide more detailed references to Aboriginal life in the Sydney region. However the information must be interpreted and used with caution due to the immense changes that occurred in the Aboriginal population and society during the early years of settlement (McDonald 1994:34).

Detailed anthropological work focussing on a systematic documenting of Aboriginal society was not undertaken until the late 19th century, beginning with R.H. Mathews' work (Mathews 1895, 1898, 1901a, 1901b, 1901c, 1904, 1908, Mathews and Everitt 1900). His anthropological work was,

however, undertaken with a greatly changed population of people after more than a hundred years of contact. It does not therefore represent the situation at the time of contact or reflect pre-contact society. He documented some myths and also vocabulary of Aboriginal groups around the Sydney region.

For a more detailed review and outline of information on Sydney's Aboriginal past, the reader is referred to Val Attenbrow's recently revised book of the same title (Attenbrow 2010).

4.2 Tribal and cultural affiliations

A number of authors have variously interpreted the available evidence and drafted maps of the pre-contact and contact territories of Aboriginal people in the Sydney region (Capell 1970, Eades 1976, Kohen 1986, 1988, Mathews 1901a, 1901b, Ross 1988, Tindale 1974). The location and nature of boundaries between Aboriginal groups in the Sydney region that existed in 1788 are now difficult to reconstruct because of the lack of reliable data available from that time. The primary data is limited by the scope and interests of the early observers (members of the First Fleet and settlers) who did not unfortunately document how Aboriginal people distinguished their differing social and territorial groupings. In addition, early European and anthropological descriptions may not relate to pre-European social structures. The population of Aboriginal people around Sydney was depleted by disease and impacted European land incursions and many survivors could have relocated and/or joined other groups.

Although most discussion about the distribution of tribal groupings necessarily involves the interpretation of recorded language, it is useful to outline the probable social organisation of the populations encompassed by these 'tribal' groupings.

Aboriginal society was comprised of a hierarchy of groups with fluid boundaries between them, the smallest being the `family' and the broadest being a culture area (Peterson 1976). The family comprised of a man with one or more wives, their children and often a parent of one of the adults. A second level of organisation involved the band, which was a group of several nuclear families. Bands, in turn, followed a regional network which comprised groups of several bands.

The next level of social organisation was the tribe. At each successive level from family through to tribe, there were less common or shared beliefs amongst the individuals making up that particular group. At the level of a tribe, the members shared common initiation ceremonies and spoke closely related languages (Peterson 1976). Anthropologists previously used the term `tribe' to denote concrete political, cultural, economic, geographical and linguistic units, however today they recognise geographic variability in the way that Aboriginal people perceive themselves and their relationship to one another (Peterson 1976).

The identification of tribal boundaries by the early anthropologists, later ethnographers and subsequent linguists have often involved contrasting conclusions, both regarding geographic extent, and whether a distinction relates to a clan, dialect or language (Capell 1970, Eades 1976, Kohen 1986, Mathews 1901a and b, Ross 1988, Tindale 1974). Since the 1970s, archaeologists and anthropologists working in the Sydney region have adopted the nomenclature for linguistic groups compiled by Capell (1970), and amended by Eades (1976), (Attenbrow 2010). These schemes all place the airport site within the area of the Darug. Debate continues whether the use of Darug was exclusively inland or extended in dialect form to the coast on the Sydney Peninsula (Attenbrow 2010:33, Kohen 1993, Ross 1988,).

Historical and linguistic sources present a range of spellings for the Darug. These comprise:

Dhar'-ook	(Mathews and Everitt 1900:265)
Dharook	(Mathews and Everitt 1900:265)
Dhar'rook	(Mathews 1901a:140, 1902:49)
Dharruk	(Mathews 1901d:128,151,155; 1903:259, 271; Capell 1970:21)
Dharook	(Capell 1970:20)
Dharuk	(Capell 1970:Map 1)

This report adopts the modern spelling ‘Darug’ which is preferred by many members of contemporary Darug community (Attenbrow 2010:32).

At the turn of the twentieth century, anthropologist R .H. Mathews placed the Dharruk to the north of the Thurrawal [(or Tharawal), south of the Georges River], and extending northwards along the coast to the Hawkesbury River and inland to Windsor, Penrith and Campbelltown (Mathews 1901a:155). He also noted that the Dhar’-ook dialect closely resembled Gundungurra, the language to the south west, and was spoken at Campbelltown, Liverpool, Camden, Penrith and possibly as far east as Sydney where it merged with the Thurrawal (Mathews and Everitt 1900).

Some names of social subdivisions within the Darug language groupings (probably bands) have survived to the present day (Murray and White 1988:20, Darug Weavers website). Most of these relate to the Sydney peninsula and riverine hinterland however some from the western and central Cumberland Plain include:

Mulgoa (‘Mulgowey’)	along the Nepean between Mulgoa and Castlereagh
Booroboorongal	along the Nepean from Castlereagh to beyond Richmond.
Wawarawarry	Eastern Creek/Blacktown
Gommerigal (tongarra)	on both sides of South Creek
Cannemegal (Warmuli)	Prospect
Cattai	Windsor
Muringong	Cowpastures/Camden
Burraberongai	Richmond

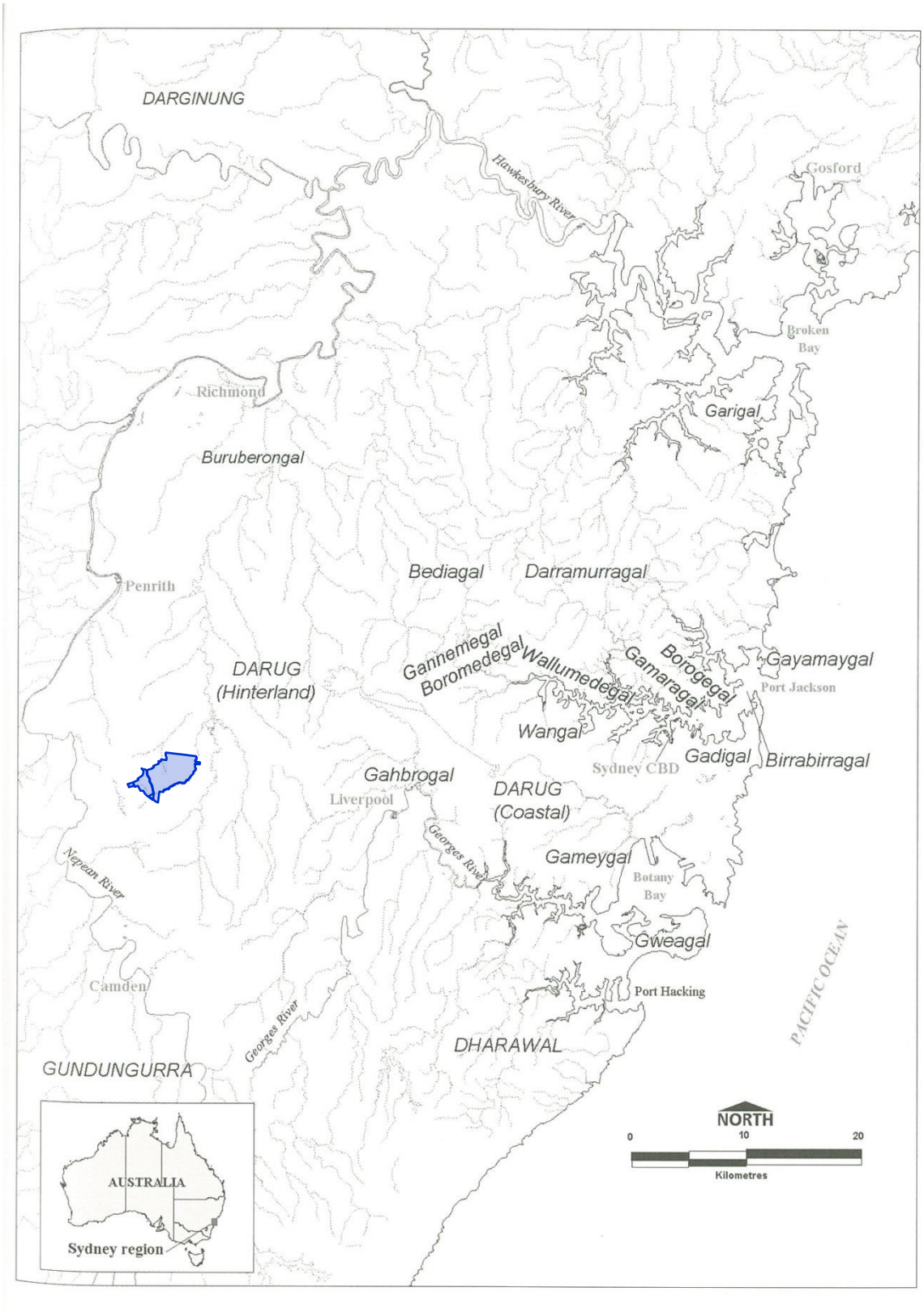


Figure 4.1 The airport site (blue) relative to a recent compilation by Attenbrow of language, clan and other named groups in the Sydney region based on early historical sources (base figure: Attenbrow 2010: Figure 3.3).

4.3 Overview of early post-European Aboriginal history

The Darug peoples bore the first impact of Sydney's European settlement due to their lands being situated on the Sydney peninsula, and the adjoining hinterlands of the Cumberland Plain. The Peninsula and its embayments became the residential and commercial focus of the settlement, while the fertile lowlands and woodland of the hinterland were developed for agricultural production and the granting of freehold lands. The Cumberland Plain was an integral component of Darug territory and cultural identity, from which they were incrementally excluded and dispossessed by European land-use and occupation.

In the five decades following the establishment of the Sydney Cove colony, the impact of European incursion saw a steep decline in the Darug population, loss of economic autonomy, and a break-down in traditional social organisation and practice. Despite this, the Darug and their descendants maintained their local presence and adapted as necessary to survive as a minority in a drastically changed cultural and social landscape.

A critical factor in the breakdown of Darug society was their exclusion from traditional grounds for hunting and procuring food. An example is the Darug's use of the fertile banks of the Hawkesbury River to cultivate wild yams. Their collection method included replanting a portion of the tuber, to ensure they did not deplete the resource for the following season. The fertility of the river banks was however quickly recognised by the European colonisers and their transformation of these lands to cropping was in direct competition with the Dharug (Goodall 1996:27). By 1795, the majority of the yam beds had been replaced by European crops (Kohen 1993:63). Such conflicts over land and resources occurred throughout the 1790s (Keating 1996:13).

In 1804, Governor King promised a delegation of Aborigines that there would be no further grants of land on the lower Hawkesbury near Portland Head, thus leaving some of the riverbank for yam production (Wiley 1979:175). This promise was however dishonoured after King departed in 1807 (Goodall 1996:28).

The Cumberland Plain Aborigines were originally evident to Europeans only through their incidental observations of camp remains and notched trees, during their infrequent expeditions into the Sydney interior. Subsequent personal encounters were often reported to be peaceable and belied the later violent encounters prompted by increasing territorial incursion (refer to accounts by Captain Tench in 1790 (Collins 1798) and Governor Macquarie in 1802 and 1815 (Macquarie 1956).

A rare record of Aboriginal observations of the Europeans and their alien culture survives in a rock art site from the Cowpasture area which includes three large drawings of bulls which probably represent the original polled cattle which escaped to the area from the first fleet (Lyon and Urry 1979).

Although no reliable appraisal of the number of Aborigines living in the Sydney region was made by early observers, it has been estimated that the population density was between 2-4 individuals per square kilometre (Maddock 1972). Following European settlement, the Aboriginal population went into steep decline, and in less than a century, many aspects of traditional Aboriginal life and society could no longer be practised or were prevented by European practice or policy. In 1821, Reverend William Walker listed nine 'tribes' in the Sydney region, of which only three could be described as 'numerous' - Broken Bay, Cowpasture and Five Islands (Illawarra). The others such as the people of the Liverpool area had been reduced to fewer than twenty persons (Wiley 1979).

The incremental westward encroachment of European settlement across the Cumberland Plain sparked conflict and retaliation from some sections of the Darug. The fatal spearing of Governor Phillip's gamekeeper, John McIntyre by Pemulwuy in 1790 was the catalyst for the 'first (but unsuccessful) punitive expedition' against Aboriginal people on the Cumberland Plain (Attenbrow 2003:14). Pemulwuy (c.1750- 1802), was a Darug warrior, thought to be from the Botany Bay area, north of the Georges River, from the Bediagal or 'woods tribe'. With the support of other members of his community, he waged armed warfare against the European intruders (Kohen 2005:318-9, Comber 2014).

From 1792, Pemulwuy led raids on settlers at Prospect, Toongabbie, Georges River, Parramatta, Brickfield Hill and the Hawkesbury River. In December the following year, David Collins reported an attack by Aborigines who 'were of the Hunter's or Woodman's tribe, people who seldom came among us, and who consequently were little known'. He also reported that 'Pe-mul-wy, a wood native, and many strangers, came in' to an initiation ceremony held at *yoo-lahng* (Farm Cove) on 25 January, 1795. Collins thought him 'a most active enemy to the settlers, plundering them of their property, and endangering their personal safety'. Raids were made for food, particularly corn, or as 'payback' for atrocities: Collins suggested that most of the attacks were the result of the settlers' 'own misconduct', including the kidnapping of Aboriginal children (Kohen 2005, Comber 2014).

Conflict was ‘waged in earnest between 1797 and 1805 during which time the farms in the Parramatta-Toongabbie area and the Hawkesbury and Georges River districts were raided’ in retaliation against ‘random killings and massacres by white colonists’ and dispossession from traditional lands. Retaliatory attacks were made on colonists who ventured out of the settlements, away from their farms, or into the bush (Attenbrow 2003:14 and 15).

At the same time the government, explorers and some settlers maintained friendly relations with individual Aboriginal men, who they relied on as guides and interpreters, as well as their communities who were given freedom to come and go from settlements (Collins 1798: Vol 1 Ch 24, 26, Comber 2014).

Governor Hunter was not ignorant of the cause of much of the conflict between settlers and Aboriginal people. He placed blame for some incidents squarely with the settlers, also acknowledging that the forces of law and order rarely took this into account.

Subsequent Governors such as King were less sympathetic to the double-standards that were being imposed (Brook and Kohen 1991:16). On 1 May, 1801, Governor King issued a government and general order that Aborigines near Parramatta, Georges River and Prospect could be shot on sight, and in November a proclamation outlawed Pemulwuy and offered a reward for his death or capture (Kohen 2005). Pemulwuy evaded capture until 1802 when he was shot and killed by Henry Hacking during an armed patrol (Kass et al 1996: 49; Kohen 2005; Comber 2014).

In 1809, two Darug men, Bundle and Tedbury (a son of Pemulwuy), were recorded menacing and stealing from travellers as well as driving sheep off properties around the Cook and Georges Rivers area (Liston 1988:6-7; Keating 1996:13). Tedbury had become attached to John Macarthur who allowed him to reside on his Elizabeth Farm property. In 1810, Tedbury was shot and killed by Edward Luttrell at Parramatta (Kohen 2005).

There were more severe conflicts between 1814 and1816 when the area was gripped by a severe drought (Perry 1963:30). Aboriginal raids on crops angered European farmers, who retaliated. Governor Macquarie advised caution and stated that the loss of part of ones' crop was a small price to pay for peace (Liston 1988:9). Tensions however escalated and Aborigines and Europeans were killed in the ensuing struggles. Several incidences occurred on Nepean River properties in the Bringelly district where both Europeans and Aborigines were killed (Organ 1990:56).

Despite expressions of sympathy with their plight, in 1816 Governor Macquarie ordered the mobilisation of military detachments to ‘drive away these hostile Tribes from the British Settlements’. As ‘a counter balance for the restrictions’, natives were offered land on which to establish themselves as settlers, as well as the necessary tools and stores for six months. As attacks on settlers were reported at the Nepean, Grose Valley, Hawkesbury and South Creek, restrictions were also imposed on Aboriginal people between Sydney and Parramatta. General Orders were that those found in the vicinity were to be detained (*Sydney Gazette* 11 May 1816:1; HRA I/9:139-145, 365; Brook & Kohen 1991:21, 23, 32). At the same time, Land Grants previously given to Aboriginal people were rescinded.

There were three punitive expeditions as a result of Macquarie’s direction, two of which had Aboriginal guides (variously claimed to be Tharawal or Darug) which were not surprisingly, unsuccessful. In 1816, a regiment headed by Wallis perpetrated a massacre of fourteen Aboriginal men, women and children at Appin (Keating 1996:18, Liston 1988:12-13, Organ 1990:75ff).

Two years before in 1814, Lachlan Macquarie had proposed the 'Native Institute' a school for Aboriginal children in Parramatta with the object of 'conveying Education and Habits of Industry'. The school was central to an assimilation policy instituted by Macquarie and was established under the guidance of an ex South Sea Island missionary named William Shelly. Plans involved a two year trial period for a live-in school, catering for six boys and six girls, with the appropriation and clearing of land for a settlement, and the provision of food to pupils while they remained at the settlement.

In 1814, Macquarie also announced a meeting or conference with Aboriginal tribes to be held in December at the Parramatta Market Place. The intended purpose of the meeting was multiple:

- to introduce and explain the purpose and function of the Native Institute, and in future years to provide an opportunity for parents to visit attendees;

- to establish an annual meeting with the attendance of representatives of 'District Tribes', based on places of usual 'resort'. Tribes would elect a Chief, who the Governor would 'distinguish with an 'honorary badge'', and who would be responsible for resolving problems within the tribe, and accountable to the Governor for their conduct; and

- to consider requests for the allocation of land from Aboriginal people who wished to become settlers (Brooks and Kohen 1991:65-6; Comber 2015).

About sixty-Aboriginal people attended the first meeting. The Sydney Gazette report speculated that others had not come because they doubted the Governor's motives, or feared that their children may be forcibly taken away (Sydney Gazette 31 Dec 1814:2).

The Native Institute officially opened in Parramatta the following year with three children who were already being tutored by Shelley and four other children who were chosen as a result of the Market Place meeting. Their ages ranged from four to eight and they were identified as being from Richmond, Prospect, Caddie (Cattai Creek), Portland Head and South Creek. Later enrolments would be from the Hawkesbury, Cowpastures, Botany Bay, Newcastle and Kissing Point. Enrolments remained relatively low with the numbers increasing to 23 in 1820 (Brook and Kohen 1991; Comber 2015).

In 1819, Macquarie made the first land grant to Aboriginal people, granting 30 acres to Colebee and Nurragingy on Richmond Road at the intersection of what is now Rooty Hill Road. These grants formed the nucleus of an Aboriginal settlement which by the 1820s, had become known as 'Black Town'. In 1821, Michael Yurringgy, a 'native constable' of Richmond, and his son Robert married two girls from the school, Polly and Betty Fulton, and were each granted lands in the same area.

After the death of Colebee, ownership of his grant was transferred to his younger sister Maria Lock in 1843. Maria died in 1878 with a significant Black Town land holding of 60 acres. This was equally shared amongst her nine surviving children. By the 1920s, the Lock lands were deemed by the government to be an Aboriginal Reserve (subsequently known as Plumpton) and title was revoked by the Aborigines Protection Board (Parry 2005).

In 1823, Governor Brisbane moved the Native Institute to land adjoining the new Black Town settlement. In the following year, Brisbane dismissed the committee and placed the school under the control of the Church Missionary Society. At the end of the year, however, the Institute was closed as part of an amalgamation of native and orphan schools (Office of Environment and Heritage website, Blacktown Native Institution).

The Aboriginal conference became an annual event and was coupled with a 'feast' for those attending. Macquarie and a number of subsequent governors used the 'Native Meeting' to manage tensions between Aborigines and settlers, promote the Native Institute, and distribute clothes and blankets. With the exception of 1815, the conference was held each year until 1835 (Turbet 1989:120). Almost 300 Aboriginal people attended in 1818, and in 1821 a record number of around 340 attended a farewell to Lachlan Macquarie (Willey 1979). Despite attendance of 287 in 1832, the government's interest in its continuation declined, its function having been reduced to a distribution of blankets without the liaison conducted by earlier Governors (Brook and Kohen 1991:102). The conference was discontinued in 1835 (Turbet 1989:12).

By 1821, all of the airport site had been the subject of European land grants, with a majority of the area falling within a 6710 acre grant made to John Blaxland in 1813 (Robinson 1953, O'Sullivan 1977). This pattern of land alienation was repeated across most of the Darug lands. The establishment of European ownership imposed a cumulative sequence of constraints on traditional Aboriginal land-use. The effect, over the course of a relatively short period of time, was to severely limit access to traditional food and habitation sites and to disrupt the normal seasonal round of movement which formed part of social and territorial life. As a consequence, the Sydney Aborigines displaced by European settlement became increasingly dependent on European food sources, estates to live on, and employment.

The traditional food economy of the Sydney Aboriginal groups appears to have been substantially displaced by the 1840s, with many Aborigines being employed by whites on farms or selling their traditional food items for European goods (Hassell 1902; Jervis 1935, 1949). In a report to a Select Committee on the Aborigines in 1845, a local Campbelltown J. P. reported that:

> 'For the last five to ten years they [the Aborigines] have been gradually decreasing, from the number of about fifteen to twenty, until none can be said to belong to this police district, as a tribe. Their death may be attributed to natural causes' (Select Committee on the Aborigines 1845:33).

Despite the social impact of decreasing population and loss of traditional lands, some aspects of traditional life appear to have continued in Sydney. Macarthur describes a corroboree which took place on his property (Liston 1988:14) and Mathews documented ceremonies in the late 1800s. There is another mention of a ceremony taking place at Denbigh near Camden in the 1830s (Kohen 1985) and a corroboree involving over 400 individuals at the same place in the mid 1820s (Hassell 1903:3). It is likely that new family groups or mixed communities formed, taking up residence in remnant pockets of bushland on the outskirts of settlements and homesteads. Forced movement of people resulted in the loss of many aspects of Aboriginal culture and the emergence of new groups incorporating people from diverse areas. Reorganisation ensured the preservation of some of the core cultural practices and knowledge in Aboriginal communities (Hinkson 2001).

Contemporary Aboriginals of the Sydney region continue some traditional ceremonies, such as those conducted in the Bents Basin area (Keating 1996:1).

In parallel with the European take-up of the Cumberland Plain by the 1830s, Darug residency became disparate and limited to the estates of enlightened or tolerant land holders. This would often involve an employment relationship, with Darug working as farm labourers and domestic servants. Individuals and families began living within settlements and adopted aspects of European culture. There are a number of references from the Cumberland Plain which characterise this engagement.

Some Darug clans are known to have lived at an encampment on the 'Mamre Farm' estate, on South Creek at Orchard Hills, nine kilometres north of the airport site. This property was established in 1798 by the Reverend Samuel Marsden who was interested in creating a model farm where experimental crops and animal husbandry could be trialled. The estate eventually grew to over 1300 acres and was assigned a large contingent of convicts. An Aboriginal encampment was situated a few hundred yards from the homestead on the opposite side of the creek (Keating 1996:19, Thekingscandlesticks website). Marsden was an evangelist and motivated by a desire to civilise and convert the Aborigines. Some reports indicate that the Darug had always maintained a camp on or around the Mamre Estate, and that Marsden's first approach was to encourage them to work in exchange for food and clothing (WSCA website). However, his belief that the adoption of European material civilisation was a necessary first step towards conversion proved a source of disillusionment. He wrote that 'The natives have no reflection — they have no attachments, and they have no wants.' By the time Governor Macquarie founded the Native Institute in 1815, Marsden had apparently abandoned all hopes of success (Yarwood 2015).

In 1835, the Quaker missionary James Backhouse visited Mamre Farm and noted that '...the South Creek Natives live on Charles Marsden's property 'Mamre', often staying at the junction of South Creek and Eastern Creek. In comparison with some other tribes, the South Creek Natives may be considered as half-domesticated, and they often assist in the agricultural operations of the settlers.' He was also impressed by the fact that the wife of their Aboriginal guide - supplied by Marsden -

could read, having been 'educated in a school, formerly kept for the Natives, at Parramatta' (A History of Aboriginal Sydney website).

Backhouse added that ‘A few of the Natives...were, at one time, located upon a piece of the worst land in this part of the country, at a place, called Black Town. Here some of them raised grain, in spite of the sterility of the soil, at a time when they were unable to dispose of it.’ (Martin 1988:80).

Samuel Marsden died in 1838 and the Estate was taken up by his son Charles who continued the residential relationship with the local Darug (Keating 1996:19).

Emily MacLaurin who lived at Mamre, described a meeting place on South Creek at Mamre at a point where '...the Creek takes in a small stream from the west, the right bank of which reaches into the creek in a narrow finger'. It is thought that despite the influence of the Rev. Samuel Marsden, Darug ceremonies continued to be held at this spot for some time (WSCA website).

Mulgoa was also a recorded place of historical Darug settlement.

Allan Cunningham, explorer and botanist, wrote the following about the Mulgoa people, many of these men work upon the settlers’ farms at odd jobs throughout the year, and also at harvest of late ... A gentleman of Mulgoa...had, in 1826, 30 acres of wheat reaped by a party of them in 14 days as well as by Whites. They were always out before the Whites in the morning, and were fed and paid a regular price for their labour, the gentleman giving it as his opinion that the chief cause of dislike to work on the part of the Cumberland Blacks is their being cheated by the small convict settlers’ (Martin 1988:76-7).

The Macarthur's were known to have Aboriginal people living on their property at Camden. Macarthur's daughter is quoted as writing to a friend praising them and begging her friend to accept them (Liston 1988:14). In fact, in 1818, land was marked out on the Macarthur estate for Aborigines who wanted to live there under his protection (Liston 1988:14).

Cunningham notes at this time that

> ‘Toward the Hawkesbury and Cowpasture, the aborigines are not nearly so debased as around Sydney, and most of them will live in huts if they are built for them. Many of these too will work at harvest, and attend to other matters about the farm, having been brought up from infancy among the farming whites..." (Cunningham 1827:25).

According to Jack Hobbs, owner of the old Badgerys Homestead ‘Exeter Farm’ in the 1970s, the property was used by Aborigines for some time about the middle of the nineteenth century. The homestead, together with James Badgery’s land grant of 840 acres was situated on the northern side of Elizabeth Drive. There was also an Aboriginal campsite further south along South Creek (about three kilometres) on the Ciba Geigy property [245 Western Rd], (oral account recorded by Laila Haglund AHIMS site card 45-5-215 27 Jan 1978).

4.4 Previously identified cultural values

Consultation with Aboriginal stakeholders conducted since 1985 as part of environmental impact assessments for airport proposals at Badgerys Creek have documented a range of cultural values for the area.

4.4.1 1985 Draft EIS

The draft EIS prepared in 1985 for the proposed airport at Badgerys Creek included a section (9.4) titled 'Concerns of Aboriginal People’ (Kinhill 1985:209). The anthropological consultant for this project was referred to the Gandangara Local Aboriginal Land Council by the Western Metropolitan Regional Land Council as being the appropriate body with whom to liaise. She also canvassed other Aboriginal residents from around the area for their views on the project.

It was concluded that:

'Generally, there was considerable opposition to the concept of airport development in the area and fears were expressed about the changes to Aboriginal lifestyles which this would cause' (Kinhill 1985:211).

The 'changes to lifestyles' referred to were noise and air pollution, and the loss of the relative peace and quiet of the area. There was also much cynicism expressed regarding employment opportunities for Aboriginal people.

The area was regarded as having characteristics which would have made it of significance in the traditional life of Aboriginal people of the pre-colonial past and, as such it should be retained in as natural state as possible (Kinhill 1985:211).

In response to the 1984-5 investigation of a preferred airport site, the members of the Gandangara Local Aboriginal Land Council passed the following motion at a meeting in 26/11/1984:

- That the Gandangara Local Aboriginal Land Council strongly oppose the development of an airport at either Badgerys Creek or Wilton and that land council officers be instructed to lobby to prevent airport development in both these areas (Kinhill 1985:211).

In addition, a range of actions were recommended by the Land Council in the event that an airport at Badgerys Creek was constructed. These can be summarised by the following points:

- Contractors to be advised of the protected status of Aboriginal sites and all site discoveries be reported to the National Parks & Wildlife Service;
- All site mitigation work to be checked by the NPWS and the Land Council prior to commencement, and that this review process be acknowledged in construction contracts;
- If the Land Council is dissatisfied with actions which damage sites, the Land Council may invoke the Commonwealth *Aboriginal and Torres Strait (Interim) Heritage Protection Act 1984*;
- Appropriately trained Aboriginal Sites Officers to be employed in monitoring construction works;
- The Gandangara and Tharawal Local Aboriginal Land Councils to select an appropriate Dharawal language name for the airport;
- An appropriate commemorative tribute to the Aboriginal people of the area to be included in the airport design; and
- An Aboriginal curator of any display items associated with this tribute to be appointed.

4.4.2 1997 – 1999 EIS assessment

The following stakeholder organisations were consulted as part of the 1997 EIS assessment and subsequent supplementary assessments:

- Gandangara Local Aboriginal Land Council;
- Darug Tribal Aboriginal Corporation;
- Korewal Elouera Jerrungarugh Tribal Elders Aboriginal Corporation (KEJ TEAC); and
- Campbelltown City Council Aboriginal Advisory Committee.

In addition, the assessment also referenced two native title applications submitted by the KEJ TEAC. Table 4.1 lists details of these submissions, both of which are no longer active.

There have been no further Native Title claims or applications since these were rejected.

Table 4.1 Details of Native Title Submissions relevant to the airport site (National Title Tribunal website accessed July 2015).

Name	NNTT file no	Date filed	Application status
Illawarra (KEJ Tribal Elders)	NC1997/003	13/01/1997	Rejected
Gundu-ngura	NC1996/021	26/06/1996	Rejected

Members of the Gandangara Land Council's Culture and Heritage Section believed that any airport development in the southwest of Sydney would be the 'thin edge of the wedge' of development in the region and they argued against the development. It was commented upon that Pemmulwuy, a legendary Aboriginal activist of last century, probably visited the area in question [Badgerys Creek] in a recruitment drive and that his 'presence' can certainly be felt there.

Mr Gunther and Mr Thomas of the Land Council stressed that land is spiritual and has a value to Aboriginal people which is not reflected in the archaeology. The overall view communicated by a majority of Land Council members was in opposition to siting an airport at Badgerys Creek.

The Land Council wished to be involved in all further consultation relating to Aboriginal issues associated with airport development. In the event of airport approval, Council members wished to be involved in all archaeological salvage works and to monitor construction works. Consideration was also sought to facilitate employment opportunities for local kooris.

The Darug Tribal Aboriginal Corporation indicated that some of their members lived in the general Badgerys Creek region. Several family groups, such as the Botts from Mulgoa, were noted as being descendants of Darug ancestors such as Merri Merri (known as 'Chief' of the Mulgoa people), and for having a residential association with the general region, including Narellan, Hoxton Park and Liverpool. Colin Gale noted that he had shot and ferreted rabbits in the area up to the 1960s until it became too built up or fenced off (Letter from Colin Gale (DTAC) to Kerry Navin 17 Feb 1997).

Members of the Korewal Elouera Jerrungarugh Tribal Elders Aboriginal Corporation had previously submitted a Native Title claim over a large portion of the southern Sydney Basin which included all crown lands or lands held by the crown within the Badgerys Creek study area. The claim was on behalf of the 'Gundu-Ngura' people (NC96/21).

The claim submission stated that the 'Gundu-nguru people have always occupied this land' and that it contains 'much rock and cave art and Lore, and sacred sites and places...' (NC96/21). Proposed and existing developments, such as the proposed airport, were referred to as 'inappropriate activities' (NC97/3). A legally defined right of access and control of site management was requested. In discussions held with relevant members of the Elders Corporation, the basis for the submission of the Native Title claim was described in terms of descent from ancestors of known local tribal affiliation.

All Aboriginal stakeholders consulted for the 1997 EIS and subsequent assessments, expressed a strong view that sites and deposits associated with the archaeological record of Aboriginal occupation at Badgerys Creek were of high cultural value to Aboriginal people. In addition, the intangible cultural values of the landscape and its surviving biota were valued for their association with traditional culture and lore, and the sense of place and social identity derived from them. No sites or places of special cultural significance, unrelated to archaeological evidence, were identified during the assessment.

All stakeholder groups variously communicated a general opposition to the construction of a second airport in south-western Sydney.

5. Archaeological Context

This chapter provides an overview of the current understanding of the Aboriginal archaeology of the Sydney region, the Cumberland Plain, and in more detail, the Badgerys Creek area.

The information presented is based primarily on reviews conducted in 1997 for the EIS for the proposal for a second Sydney airport at Badgerys Creek or Holsworthy Military Area (NOHC 1997) and in 2014 by Australian Museum Consulting (AMC 2014) as part of an environmental survey of Commonwealth land at Badgerys Creek.

5.1 Sydney regional context

The Sydney region has been the subject of increasingly detailed archaeological survey and assessment since the passing of legislation protecting Aboriginal sites in 1974. The focus of this assessment has shifted in the last two decades to Western Sydney, and in particular to the new urban and industrial developments across the Cumberland Plain. This research has resulted in thousands of site recordings and a wide range of site types and features. The most prevalent recordings comprise surface occurrences of stone artefacts (ranging from single to hundreds of artefacts), shell middens, rock shelters containing occupation evidence (including deposits and rock art), grinding groove sites, and open context engraving sites. Rare site types include culturally modified trees, quarry and procurement sites, burials, stone arrangements, and traditional story or other ceremonial places.

Archaeological studies in the Sydney region have generated hundreds of reports and monographs and a number of academic theses. Studies generally fall into four categories - projects which have been carried out within a research-oriented academic framework, larger scale planning and management studies, archaeological surveys carried out by interested amateurs, and impact assessment studies which have been carried out by professionals within a commercial contracting framework. The latter mostly deal with specific localities subject to development proposals and constitute a large proportion of the archaeological research conducted to date.

Aboriginal occupation of the Sydney region dates back to the Late Pleistocene during the last glacial period, when sea levels were lower and the climate was colder and drier. To date, the earliest claimed evidence comes from two separate open context archaeological deposits. Nanson et al (1987) have argued that artefacts found in gravels of the Cranebrook Terrace (16 km to the NW of the airport site) are indicative of Aboriginal occupation over 40,000 years ago. There is, however, some doubt about the contextual integrity of these artefacts and this date is treated with caution by many reviewers (Nanson et al. 1987; Stockton 2009; Stockton & Holland 1974; Attenbrow 2010). More recently, excavations in a Pleistocene aged sand body on the Parramatta River (sites RTA-G1 and GG3), 25 km to the east of the airport site, have revealed an assemblage of silicified tuff artefacts dated to around 30,700 BP (Before Present) (JMCHM 2005b and 2005c, 2006).

The interpretation of artefacts within open context and fine grained sedimentary deposits, must always be treated with caution due to the potential for artefacts to move up and down the profile, and thus to be encountered in contexts which do not relate to their true age (e.g. Baker (1995:7)). For this reason, the Parramatta sand sheet sites are not yet considered to be definitive evidence for the early occupation of the Sydney region (Attenbrow 2004:335; 2010:20; Nanson et al. 1987; Williams et al. 2012:85).

The dating of artefacts recovered from deposits within enclosed rock shelter contexts is less likely to be affected by post depositional movement. For this reason, a basal occupation date from the Shaws Creek K2 rock shelter of 14,700 BP is the earliest and most widely accepted date for the Sydney region. This site is located near the western bank of the Nepean River, and 24 kilometres northwest of the airport site (Stockton and Holland 1974; Kohen et al. 1984; Stockton 2009a: 57-60).

Late Pleistocene occupation sites have also been identified elsewhere from the margins of the Sydney basin, and from rock shelter sites in adjoining areas. These include occupation between 15,000 and 11,000 BP from a levee deposit near Pitt Town adjacent to the Hawkesbury River

(Williams *et al.* 2012), a date of around 11,000 BP at Loggers Shelter in Mangrove Creek (Attenbrow 1981, 2004), a date of 12,200 BP from an open site hearth, Wombeyan 1, situated in a palaeosol on a colluvial fan at Wombeyan (NOHC 2003b), and occupation from 20,000 BP at Burrill Lake on the South Coast (Lampert 1971). A deflated Aboriginal hearth site located on a sand dune at Randwick provided, at the time, the earliest secure date (7820±50 BP Beta 87211) for an open site in the Sydney Basin (Austral/Godden Mackay 1997).

There are now thousands of sites in the Sydney region from which evidence of Aboriginal occupation has been dated using radiocarbon age determinations. This body of evidence reveals a steady increase in site use from around 6000 years ago, with almost 80 per cent of determinations occurring within the last 5000 years. The number of dated sites peaks in the second millennium. Twenty eight per cent of the Sydney region dates fall between 1000 and 2000 years BP (McDonald 1994).

The stone technologies used by Aborigines within the Sydney Basin have not remained static and a relatively consistent sequence of broad scale changes through time has allowed the development of model of technical change. This is known as the Eastern Regional Sequence and can be applied with various degrees of success and allowances for regional differences to sites throughout the eastern seaboard of Australia. Within the Sydney Basin the Sequence can be characterised using the following terminology and phases (based on McDonald 1994 and 2005):

The Pre-Bondian 30,000 - 8000 years PB.

In this phase, there was an apparent preference for utilising silicified tuff, often at great distances from the stone sources. This material was augmented with quartz and unheated silcrete (coarse-grained raw materials). Cores and tools varied widely in size. There were no backed artefacts, elouera or ground edge stone tools. Unifacial flaking was the predominant technique and bipolar flaking was rare. Artefacts from this period consisted mostly of large heavy artefacts including unifacial pebble tools, scrapers, core tools, denticulate saws, and hammerstones.

The Early Bondaian 8000 – 4000 years BP

Within this phase, characteristics of the pre Bondaian continued but tools on smaller blades were introduced and became predominant. There was a decline in silicified tuff as a preferred stone and more use was made of local raw materials (such as silcrete and chert), especially at sites occupied for the first time. Blades that were backed (one edge blunted by fine trimming) and ground edge implements were notable introductions. Bipolar flaking occurred widely although relatively rarely at individual sites. Unifacial and bifacial flaking were the dominant technique.

The Middle Bondaian 4000 – 1000 years BP

In this phase, utilised stone materials varied between and within sites over time. Edge ground artefacts were present in higher proportions as were quartz artefacts. The percentage of Bondi points (a type of backed blade) increased and remained greater than the percentage of bipolar artefacts. This was the main phase of backed artefact production. Asymmetric flaking with platform faceting was adopted. Cores and tools tended to be smaller, the use of bipolar flaking increased, ground stone artefacts appeared infrequently (at less than half of the dated sites) and elouera were rare.

The Late Bondaian 1000 years BP to European contact

In this phase, utilised stone material types continued to diversify, and in some localities the use of quartz either became predominant or markedly increased in proportion. Backed artefacts possibly declined, and became rare or absent particularly in coastal sites. Bipolar flaking became a little more common. Ground stone has been found in low frequencies at the small number of dated sites from this period, but was identified as a major tool type by Europeans at the time of contact. Elouera became a little more frequent. Bone and shell implements including fishhooks appeared in this phase, particularly in some coastal sites.

McDonald notes that the introduction of ground implements around 4000 BP and shell fishhooks in the last 1,000 years were major technological innovations (McDonald 1994:69). The significance and possible reasons for the technological changes in the Eastern Regional Sequence have been the

subject of considerable research and debate since their identification. Contemporary theories postulate various changes in social behaviour, group interactions, and population dynamics either as contributing causes or as consequences of these technology changes (e.g. Attenbrow 1987; Beaton 1985; Lourandos 1985; Walters 1988; McDonald 1994; Attenbrow 2010). McDonald, for example, interprets the introduction of the Bondaian in the Sydney Basin as a manifestation of social change brought about by population pressure promoted by sea level rise (1994:347).

5.2 The Cumberland Plain

Hundreds of Aboriginal sites, predominantly open artefact scatters (also referred to as open camp sites), have been recorded within the Cumberland Plain. The campsites vary greatly in size from small sparse scatters to large concentrations of artefacts, with the larger denser sites tending to occur in close proximity to stone source localities and permanent water sources. Stone materials used in artefact manufacture at the sites reflect this proximity. Sites adjacent to the Hawkesbury/Nepean River contain higher proportions of chert and other fine-grained rocks found in the river gravels, while sites further east and south contain higher proportions of silcrete. Other rare site types include scarred trees (68 recordings), raw material extraction/procurement sites, stratified deposits, and grinding groove sites (3 recordings) where there are exposures of Minchinbury sandstone interbedded within the Wianamatta shales and clays.

The picture of Aboriginal utilisation and occupation of the Cumberland Plain is constantly being revised and refined as archaeological methods improve and more archaeological data becomes available for the area. The archaeological data for the Plain is derived from a number of sources including impact assessment studies, archaeological planning and management studies and academic archaeological investigations.

Larger scale projects undertaken on the Cumberland Plain include:

- Doctoral research on the western Cumberland Plain (Kohen 1986);
- A major compilation and analysis of data for the northern Cumberland Plain (Smith 1989a);
- Investigations at Rouse Hill (eg McDonald and Rich 1993; JMCHM 2005a);
- Surveys at Badgerys Creek for the 1997 EIS assessment of the Second Sydney Airport (NOHC 1997); and
- Work at the Australian Defence Industry site at St Marys (JMCHM Pty Ltd 1997).

Several predictive models have been formulated to explain Aboriginal site location on the Cumberland Plain. Haglund (1980) developed a predictive model of site location based on early survey work in the Blacktown area. She predicted that sites would most likely be located near water courses such as creeks and soaks, and on high ground near water.

Kohen (1986:292) postulated that the availability of water was the most important factor influencing the distribution of sites across the landscape. Other criteria which appear to play a role in site location are proximity to a diversity of economic resources such as food and lithic materials and to a lesser extent, elevation.

In 1989, Smith was commissioned by the NPWS to conduct a baseline study of Cumberland Plain sites to assist in the long term management of Aboriginal sites on the Cumberland Plain (Smith 1989a). Prior to her study, 307 sites had been recorded on the Cumberland Plain. These comprised 297 open context artefact occurrences, four scarred trees, one carved tree, four grinding grooves and an Aboriginal mission site (the Blacktown Institute). Smith (1989a:2) added 79 open sites and 29 isolated finds from field surveys related to her study.

Smith's analysis supported the predictions made by Haglund and Kohen that sites would most commonly be found near water sources. She concluded that site location and site densities were influenced by the availability of water and raw materials, but not by other tested variables such as

topography, natural vegetation. Smith identified that site densities in the southern Cumberland Plain appeared to be lower overall to site densities on the northern Plain studies (1989a & 1989b:10).

The following is a summary of Smith's conclusions:

- Sites would occur in all areas of the Cumberland Plain, except where destroyed by European land-use, erosion processes and flooding;
- Sites would be located in all topographic units;
- Site densities may be expected to be 10 per cent higher in the northern section of the Plain because of the greater concentrations of stone resources in that area;
- Fifty percent of all sites would be found within 50 metres of a water source;
- Sites would tend to be more frequent around permanent water sources (apart from areas overlying the Londonderry Clay or Ricaby Creek Formation, and the Werrington Downs area); and
- Sites could be expected in relatively high frequencies on or near stone resources.

Smith's (1989b) following study of the Liverpool release areas tended to confirm this site location model in that almost 75 percent of sites were found in association with a permanent water source and over 60 percent of sites were within 50 metres of water. In this study, Smith concluded that sites in the Liverpool area were more likely to occur on creek flats than on any other topographical feature, and that the probability of sites occurring on creek flats increased near creek confluences.

The studies by both Kohen and Smith provided a strong foundation from which increasingly detailed and informed processes of archaeological model building and testing were conducted. The findings of the Kohen and Smith studies are now known to be limited by their reliance on surface-only evidence, and imbalances in survey coverage (eg. McDonald 1992a, Rich and McDonald 1995:14).

Kohen's later studies at Penrith confirmed the importance of fifth order creeks and rivers. He recorded over 50 sites in the Penrith area which included open artefact scatters, axe grinding grooves and rock shelters (Kohen 1997). He noted that sites occurring throughout the Penrith area "are particularly likely to occur adjacent to the rivers and creeks (Kohen 1997:7). The distribution of raw materials associated with the manufacture of stone tools suggests that chert and basalt were carried or traded east from the river gravels and that silcrete was traded or carried from sources near South Creek and Eastern Creek, west towards the Nepean flood plain".

Prior to 1993, relatively few open context sites had been excavated on the Cumberland Plain. There is now a substantial and increasing corpus of information from excavated contexts, revealing a substantial time depth and previously hidden richness in artefact density and diversity. Excavations at Plumpton Ridge, a major source of silcrete as a raw material, revealed evidence of extraction activity at least 2200 years ago (McDonald 1986). The stratified Power Street bridge site on Eastern Creek at Doonside yielded a date of 5,957±74 BP (NZA-3112) (McDonald 1993:21).

The more recently encountered Pleistocene aged date of 30,700 years BP for tuff artefacts within a Parramatta River sand sheet presents an argument for very early occupation of the Plain (JMCHM 2005b and 2005c, 2006).

Excavations on the Cumberland Plain have demonstrated that surface sites are generally an inaccurate representation of subsurface deposits (McDonald & Rich 1993, Rich & McDonald 1995).

The results of test excavations at Rouse Hill (McDonald & Rich 1993) have confirmed that sites occur widely across the landscape including areas such as hilltops and slopes, and near creeks. Larger sites with higher artefact densities are more likely to be located near permanent water. Excavations of a site at West Hoxton, southeast of Badgerys Creek, provided evidence of artefacts present up to 80 metres from a creek line, extending onto adjacent lower slopes (Rich & McDonald 1995).

In one of the largest test excavation programs in metropolitan Sydney to date, nineteen sites and fifteen potential archaeological deposits were systematically investigated in the context of the Rouse Hill Infrastructure Project (McDonald 1993, McDonald and Rich 1993, JMCHM 2005a). Over 7000 artefacts were retrieved from infrastructure project excavations and 87 percent of identified potential deposits were subsequently designated sites. Many of the sites and small surface scatters proved to be extensive, complex and relatively intact archaeological sites. The two potential deposits which were not found to be sites were located on hillslopes with thin topsoil development (McDonald & Rich 1993:93).

McDonald noted that:

> 'the range, complexity and high degree of intactness of the archaeological record were not expected either from the original surface recordings made nor from previous test excavations on the Cumberland Plain, which (in retrospect) were all of an extremely limited nature' (McDonald 1993:2).

Charcoal from two knapping floors located in sites OWR7 and RH/CD7 in the Rouse Hill development area have provided Early Bondaian dates of 4,060±90 BP (Beta 66450) and 4,690±80 BP (Beta 66453) respectively (McDonald & Rich 1993:101, 102).

The southwest section of the Rouse Hill Development Area was situated on shale geology and included the upper reaches of Caddies Creek and its tributary, Smalls Creek. This area provides a comparable topographic context to the airport site which is also on shale geology and contains the upper reaches of Badgerys Creek and Oaky Creek. The following findings from the Rouse Hill investigations are potentially applicable to similar upper catchment areas on the Cumberland Plain:

- most areas which were the subject of subsurface investigations contained sub-surface material;
- site patterning could be related to gross environmental factors, however the relationship between sites and the environment is complex - sites on permanent water are more complex than sites on ephemeral drainage lines. Major confluences are prime site locations;
- depositional environments e.g. alluvial terraces, contain the best potential for intact cultural material, although some hillslope zones may also have good potential;
- intact archaeological material may remain below the plough zone (i.e. top 25 centimetres of soil);
- minor gullies tend to have low density sites; and
- fewer sites were located on ridgetops possibly due to more disturbance in these areas.

The concluding analysis of the Rouse Hill investigations demonstrated the dynamic nature of stone tool technologies on the Cumberland Plain (JMCHM 2005a). McDonald reviewed previous project work within a theoretical framework to identify intra and inter-regional variation. Change in stone tool technology was identified over time and in relation to landscape (McDonald 2005a). Her report provided a framework to tentatively date sites through technological analyses and to identify cultural changes.

The Rouse Hill investigations further substantiated the finding that surface archaeological evidence on the Cumberland Plain may not accurately represent the subsurface resource. Of the excavations conducted, subsurface deposits were present even when there was no surface indication of a site. According to McDonald (2005a:5), “despite artefacts being rare or completely absent on the surface at each of the sites investigated, all six sites were found to contain intact archaeological deposit. Almost 500 square metres were excavated during this study and almost 35,000 artefacts retrieved.”

McDonald (2005a) considered that Aboriginal occupation was focussed on the major river systems and characterised by mobility between a small number of sites. As a result of various studies and the

application of stream order analysis, McDonald framed the following predictive statements regarding the density and complexity of archaeological sites relative to their associated fluvial contexts:

- Fourth and Fifth order streamlines (typically permanent creeks and small rivers) will be associated with archaeological evidence that is more complex and possibly stratified, reflecting more permanent and repeated occupation.
- Third order streamlines will be associated with evidence of more frequent occupation such as knapping floors. Higher artefact densities will be found in the lower reaches of tributary creeks.
- Second order streamlines will be associated with sparse archaeological evidence which is most likely to indicate occasional use and/or occupation.
- First order streamlines (with only intermittent water flow, typically in headwater contexts) will be associated with sparse archaeological evidence, which may be indistinguishable from, or may define, a background level of artefact incidence.

Comber undertook excavation at two sites at Penrith Lakes known as Camenzulis (2010b) and PL9 (2010a). At PL9, she retrieved more than 1,500 artefacts, including backed blades and an edge ground axe. Her work confirms McDonald's (2005) and Kohen's predictive model that sites are more likely to occur adjacent to the rivers and high order creeks.

The Penrith Lakes excavations further indicated that extensive subsurface archaeological deposits may remain in depositional environments despite disturbance from subsequent agricultural land use. Surveys (2006) prior to the excavations revealed a small number of artefacts amongst evidence of grazing, ploughing, cropping and a dam construction, and yet over 2,500 artefacts were recovered during excavation (Comber 2014).

5.3 The local district of the airport site

There have been a considerable number of archaeological investigations undertaken in the vicinity of the Commonwealth-owned land at Badgerys Creek. Australian Museum Consulting conducted a review of this work in 2014. A revision of their summary table is presented in Appendix 7. The location of previous surveys is presented in Figure 5.1. The review encompassed investigations, registered with the OEH AHIMS and from the localities of Badgerys Creek, Luddenham, Bringelly, Leppington, Erskine Park, Kemps Creek, West Hoxton and Orchard Hills.

5.4 Previously recorded Aboriginal sites in the local district around Badgerys Creek

A search of the NSW Aboriginal Heritage Information Management System (AHIMS), revealed 396 Aboriginal heritage recordings within an 18 x 16 km rectangular search area (accessed 18 June 2015). The search area was defined by a distance of 5 km from the northern, eastern and southern most points of the airport site, and a 4 km distance from the western boundary. The western margin was reduced in order to minimise the inclusion of topographies on Hawkesbury Sandstone.

A summary of the AHIMS search results, organised according to exclusive (primary feature) categories, is presented in Table 5.2. The search results are consistent with the broad trends for the whole of the Cumberland Plain. Open context artefact occurrences predominate and comprise 89 per cent of the search area record. The next highest category (6%) is potential archaeological deposits (where surface artefacts were not recorded). This low incidence is a consequence of former recording practice which emphasised surface find recordings and was limited to identifying high potential deposits. The remaining recording types comprise rare site types, such as modified trees (formerly known as scarred or carved trees) (n = 12, 3%), grinding grooves (n = 2, 0.5%) and single recordings of a burial, shell midden, stone arrangement, and resource gathering site.

Of particular importance to the district's Aboriginal cultural values is a late nineteenth century recording of a group of eight carved trees by R. J. Etheridge (AHIMS site no. 45-5-0234 [formerly 45-5-1234]) (Figure 5.2). These culturally modified trees almost certainly formed part of the traditional

burial place of one or more prominent Aboriginal persons. Their location was recorded as the 'Greendale Estate, Vermont, near Narellan, Camden district' (Etheridge 1918:49, Australian Museum records, accession nos: E.3608 – 3615, Bell 1982). The carved sections of the trees were presented to the Australian Museum in 1892 by a Mr A. Vickery, possibly a local resident at the time.

There are two possible locations of the Greendale Estate (Figure 5.2). One is a land grant of 1200 acres to D'Arcy Wentworth which extended from the southwest of Luddenham, between The Northern Road and the Nepean River. This grant is identified as 'Greendale' on a pre-1840s parish map but by the late nineteenth century is known as 'Elmshall Park'. A more likely location is an 1813 grant of 500 acres to Mary Birch, which is situated 2.5 km to the southwest of the airport site. This property is identified as 'Greendale' on late nineteenth century maps and borders a grant of 55 acres to Samuel Fowler which is the central point for the locality name Greendale. This record of nomenclature is closest in time to the recording of the trees. The Birch landholding was sold to Wentworth in 1819. By 1902, most of the Greendale area was owned by a John Colburn (Liverpool City Council 2013).

A less likely possibility is that the trees were located on the Vermont Estate. This was a large original land grant to W.C. Wentworth which extended east and south of the confluence of Bringelly Creek with the Nepean River (9 km southeast of the airport site) (Figure 5.2).

Only one of the grinding groove recordings from the AHIMS search relates to the shale based topography of the Cumberland Plain. This is site 45-5-0215, which is situated on the South Creek flood plain, within two kilometres of the airport site.

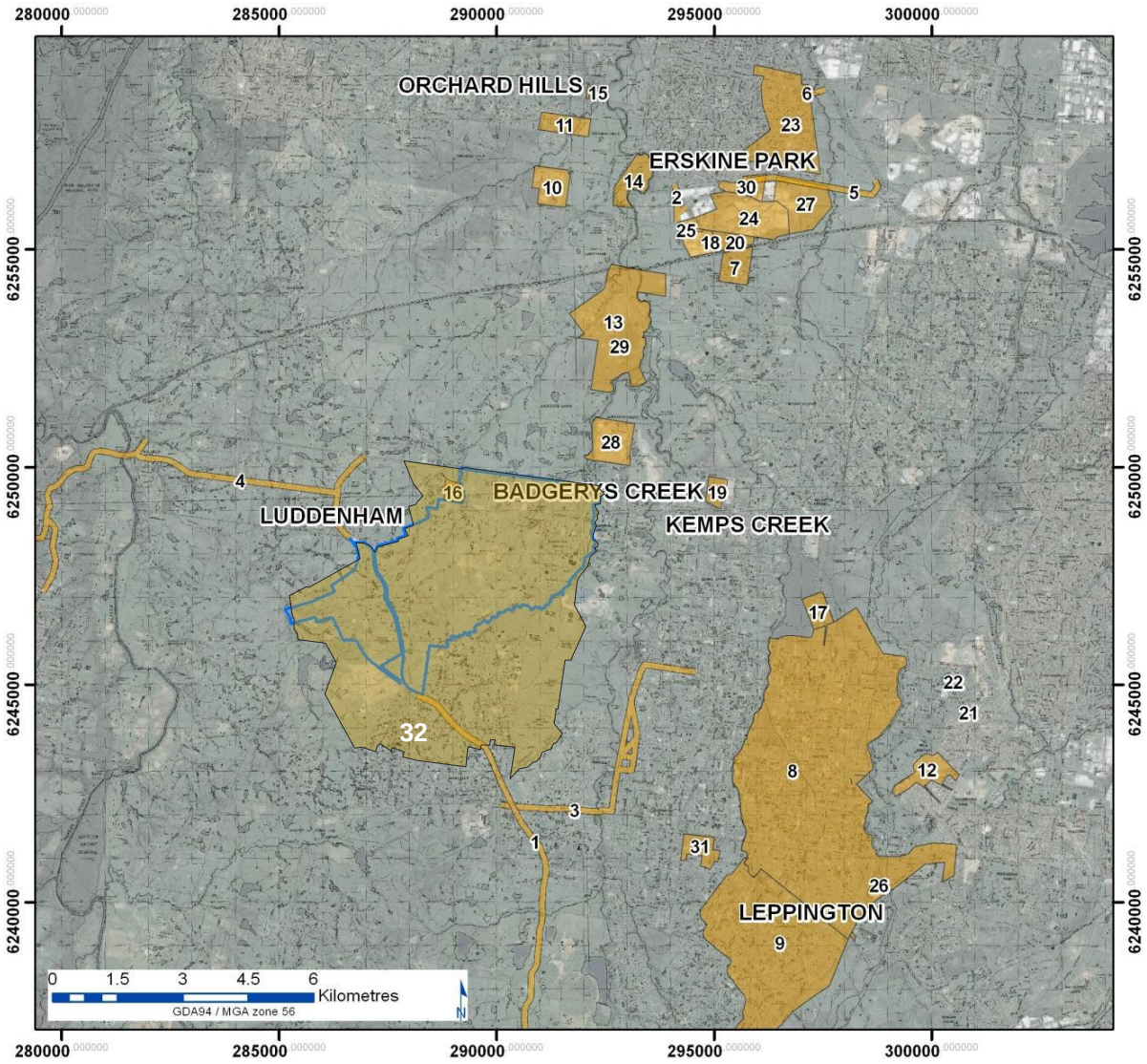
It is most probable that this site consists of an outcrop of Minchinbury sandstone, a rock type which is poorly mapped and exposed infrequently across the Plain, typically in narrow lenses and isolated outcrops. This is in contrast to the massively bedded Hawkesbury sandstone which dominates the landscape surrounding the Plain and across which grinding grooves are frequently recorded.

The South Creek site is one of only three previously recorded grinding groove sites recorded on Minchinbury sandstone within the shale topographies of the Cumberland Plain (search area = 1539 km^2). The other two are located in the northeastern margin of the Plain, north and east of Blacktown.

Table 5.2 Summary of AHIMS search results

Site type/ feature	Number of recordings	Percentage of recordings
Open context artefact occurrence	353	89.2
Potential archaeological deposit (with no recorded surface artefacts)	25	6.4
Modified tree	12	3.1
Grinding grooves	2	0.5
Burial	1	0.2
Shell (midden)	1	0.2
Stone arrangement	1	0.2
Resource Gathering	1	0.2
Total	**396**	**100**

AHIMS accessed 18 June 2015



Legend

Badgerys Creek Commonwealth Land

Previous investigations

Key

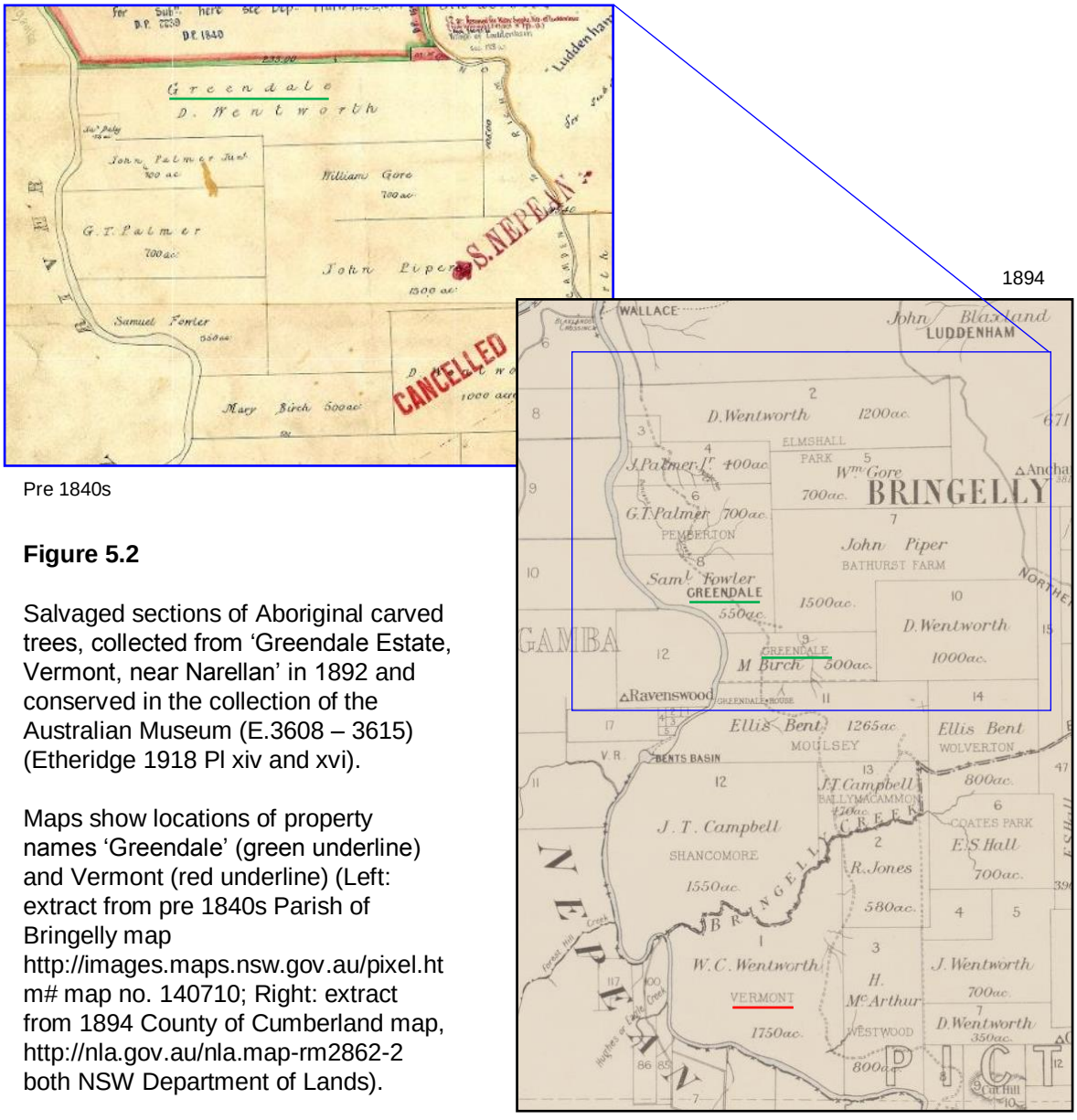
1, Artefact Heritage (2012)
2, Brayshaw (2005)
3, Brayshaw McDonald (1992)
4, HLA-Envirosciences (1995)
5, Navin Officer (2003)
6, Navin Officer (2005d)
7, AHMS (2005a 2005b)
8, AMBS (2012)
9, AMBS (2013)
10, Archaeological Surveys & Reports Pty Ltd (2009)
11, Brayshaw (1989)
12, Brayshaw McDonald (1995)
13, Dallas (1988a)
14, Dallas (1989)
15, Dallas (1998b)
16, Dean-Jones (1991)
17, Haglund (1979)
18, JMCHM (2000) McIntyre-Tamwoy (2003)
19, JMCHM (2001a)
20, JMCHM (2009)
21, Kayandel (2005)
22, Kayandel (2006)
23, Koettig (1981)
24, McIntyre (1984) Navin Officer (2005a 2005b)
25, Navin Officer (2005c)
26, Navin Officer (2006)
27, Navin Officer (2007)
28, Nicholson (1989) Kohen (1991)
29, Steele (1999 2001 2007)
30, Total Earth Care Pty Ltd (2007)
31, White (2001)
32, Navin Officer (1997)

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community. Topographic data © 2006 Department of Lands 1:25000 TopoView Topographic and Orthophoto Map mosaic

Australian museum CONSULTING

Figure 5.1 Previous archaeological investigations within the local district of the airport site (from AMC 2014, Figure 3.2).





Pre 1840s

Figure 5.2

Salvaged sections of Aboriginal carved trees, collected from 'Greendale Estate, Vermont, near Narellan' in 1892 and conserved in the collection of the Australian Museum (E.3608 – 3615) (Etheridge 1918 Pl xiv and xvi).

Maps show locations of property names 'Greendale' (green underline) and Vermont (red underline) (Left: extract from pre 1840s Parish of Bringelly map http://images.maps.nsw.gov.au/pixel.htm# map no. 140710; Right: extract from 1894 County of Cumberland map, http://nla.gov.au/nla.map-rm2862-2 both NSW Department of Lands).

5.5 Previous archaeological investigations within the airport site

The airport site has been the subject of four previous archaeological investigations.

5.5.1 1978 MANS Study

A preliminary study of possible second Sydney airport locations was carried out in 1978. This study, which is generally referred to as the MANS (Major Airport Needs of Sydney) study, included an archaeological assessment (Haglund 1978).

Records of the areas subject to archaeological survey for this study have not survived; however no sites were recorded within the current airport site. Haglund located three sites (two artefact scatters: sites 45-5-213 and 214, and the South Creek grinding groove (site 45-5-215) north of Elizabeth Drive.

5.5.2 1985 Second Sydney airport site selection program

Anutech Pty Ltd undertook an archaeological assessment of a proposed airport site at Badgerys Creek and its surrounds as part of the Second Sydney Airport Site Selection Program in 1984-5. Lance and Hughes (1984) compiled a predictive study and Lance (1984) subsequently conducted a sample survey of the 1985 Badgerys Creek study area. Lance structured his survey to 'concentrate on areas in which prehistoric archaeological sites were considered most likely to occur' (Lance 1984). A comprehensive survey of the selected sample areas was conducted for the 1985 EIS (Department of Aviation 1985). This involved around 70 hectares and represented 4 percent of the 1985 study area (Figure 5.3). It was noted that there was ‘relatively little’ ground surface exposure adjacent to the creeks due to vegetation coverage, and ‘limited’ exposure on hillslopes.

One artefact scatter was located (Site 45-5-517) in the 1985 survey. The site comprised five silcrete flakes and flaked pieces and was found in a ploughed and devegetated area adjacent to Badgerys Creek.

Lance argued that the uniformity of landforms within the 1985 airport site and the low density of sites reported in similar locations suggested that the paucity of sites was a real archaeological pattern rather than a function of poor ground surface visibility in the study area.

Lance concluded that the only sites likely to have survived in his study area were stone artefact scatters which would have already been disturbed by the extensive land use in the area. Consequently, such artefact scatters would have little scientific importance. A possible exception to this was considered to be sites which occurred along the banks of Badgerys Creek and in areas which had incurred only 'minor surface damage and disturbance' (Department of Aviation 1985:206-208).

The proposed airport site was assessed as having relatively low archaeological sensitivity and no further archaeological assessment was recommended.

5.5.3 1997 Draft Environmental impact statement

In 1997, an archaeological investigation of two alternative potential airport locations was conducted by Navin Officer Heritage Consultants for PPK Environment and Infrastructure, on behalf of the Department of Transport and Regional Development (NOHC 1997). The two investigation areas were Badgerys Creek and the Holsworthy Military Training Area. The Badgerys Creek study area comprised the composite footprint of the three airport options (Figure 5.4). The assessment was based on Aboriginal cultural values reported by Aboriginal stakeholders and an archaeological survey of surface archaeological features. Due to the nature of the subject archaeological resource, and in particular the high value rock shelter deposits of the Holsworthy area, a decision was made to minimise the permanent impact of the EIS investigation assessment by excluding subsurface testing from the assessment methodology.

Survey coverage

The field survey aimed to cover a representative sample of all landscape units, and achieved a net coverage of 36.8 per cent of the combined area of all three options (14.22 km^2 surveyed out of 33.82 km^2). An estimated 9 per cent of the surveyed area provided archaeologically useful ground surface exposures. Taking into account survey coverage, usable exposures and visibility variables, the effective net survey coverage was around 5 per cent of the total study area (NOHC 1997:p5-13). The 1997 EIS survey areas are illustrated in Figure 5.4.

Survey results

One hundred and ten Aboriginal site recordings were made during the 1997 EIS field survey program of the three option composite Badgerys Creek study areas. To this was added the previously recorded site by Lance (Site B2, 45-5-517) producing a total inventory of 111 recordings.

Table 5.3 presents a summary of the 1997 site inventory.

The airport Option A, as defined for the 1997 assessment, corresponds relatively closely with the current airport site. Ninety two percent of all recordings comprised surface artefact occurrences (44 involving single artefacts and 58 with more than two visible artefacts). The remaining recordings consisted of eight scarred trees and one open potential archaeological deposit.

Within Option A, there were 55 open artefact occurrences (30 involving single artefacts and 25 with more than two visible artefacts), and five scarred trees (of which only two occur within the current airport site).

Table 5.3 Summary of the site inventory which formed the basis of the 1997 Badgerys Creek EIS assessment (after NOHC 1997: Table 5.1)

Recording Attribute	Number Recorded	Option A	All Options	Outside of Option boundaries
total no. recordings	111	60	97	14
open artefact scatters	58	25	48	10
scarred trees	8	5	7	1
isolated finds	44	30	41	3
site or isolated find associated with a potential archaeological deposit	9	5	6	3
potential archaeological deposit only (recorded during field survey)	1	0	1	0

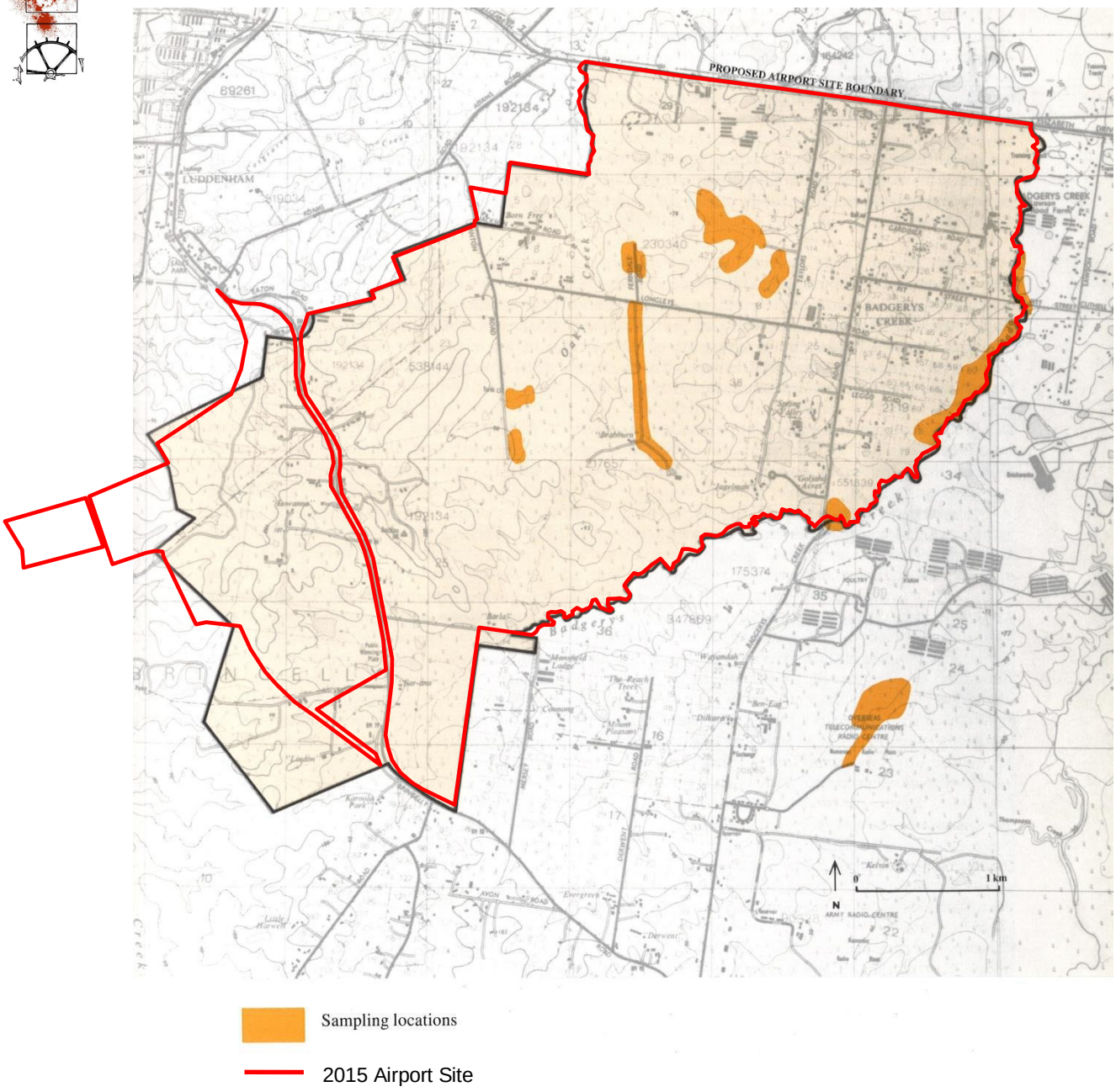


Figure 5.3 Areas of archaeological survey conducted in 1984-5 for the Second Sydney Airport Site Selection Program (Department of Aviation 1985:207). The 2015 airport site is indicated by a red boundary

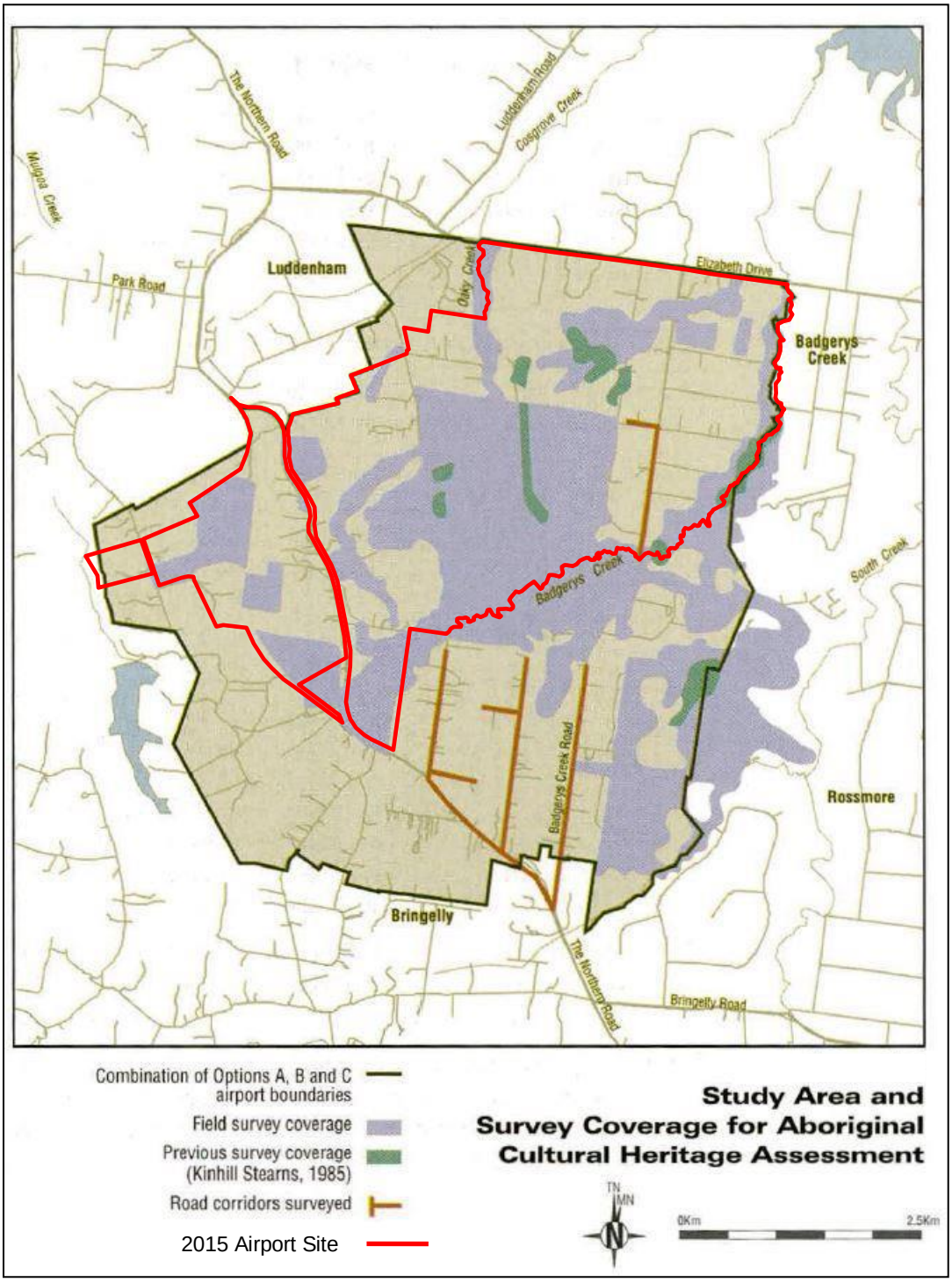


Figure 5.4 The archaeological survey areas conducted for the 1997 Second Sydney Airport EIS (after NOHC 1997: Figure 3-1). The 2015 airport site is indicated by a red boundary.

Artefact occurrences with more than two artefacts

Open artefact scatters, defined as surface artefact occurrences containing more than two surface artefacts, were the principal recording type within the 1997 Badgerys Creek study area. The surface characteristics of these sites were dominated by low artefact numbers and low artefact densities. The number of recorded artefacts ranged from 2 to 31, with 46 precent containing between 3 and 5 artefacts and 22 percent containing only 2 artefacts. Nineteen percent contained between five and 10 artefacts and 10 percent contained between 11 and 20 artefacts.

Average surface artefact densities per site were correspondingly low, with a maximum value of 1 artefact per square metre and a majority of sites recorded at less than 0.1 artefacts per square metre (55 percent), and between 0.1 and 0.5 (40 percent). Maximum recorded artefact densities per site were also low with a range of between one and six artefacts per square metre. The majority of sites had values of one (50 percent), or 2 (26 percent) artefacts per square metre.

It was considered that the low artefact frequencies, combined with relatively high degrees of ground surface visibility during the survey, provided generalised but reliable indication of the type and character of open artefact scatters within the Badgerys Creek study area. Most sites of this type were considered likely to contain only small numbers of artefacts and at low densities. Sites with larger numbers and greater densities were consistently found in valley floor and fluvial corridor contexts. This was consistent with surface site patterning identified elsewhere on the Cumberland plain.

It was noted, however, that subsurface testing programs in comparable Cumberland Plain contexts had indicated that artefact densities and the spatial extent of sites may be considerably higher below the surface, particularly within aggrading landscape contexts such as alluvial flats and basal valley slopes. It was conjectured that subsurface testing of open artefact scatters would identify higher artefact numbers and densities, particularly in contexts subject to consistent sedimentation, such as basal slopes and alluvial flats.

An assessment of the condition of each site was made based on the nature and extent of ground disturbance evident to the recorder. 76 per cent of open artefact scatters were rated to be in poor condition, with 21 percent rated as good, and only one classed as very good. None were considered to be in excellent condition. These ratings were considered to be a reliable indication of the condition of sub-surface artefactual material within the zone of ploughing and clearing disturbance. In contrast, it was noted that where sedimentary facies occur below this zone, mostly within valley floor and some basal slope contexts, the potential remained for artefactual material to remain unaffected by historic land-use impacts.

A set of field assessments into various aspects of the archaeological potential of an artefact occurrence were also conducted. These were: the potential to be larger than the recorded surface extent, the potential to contain more artefacts than those recorded, and the potential to contain undisturbed sub-surface (*in situ*) artefacts. The results of these assessments are presented in Table 5.4. A significant percentage of open artefact scatters were considered to have moderate or high potential to be larger in area and number of artefacts. This was related to the often limited extent of surface exposures in which artefacts were detected and the likelihood that the exposure boundaries are unrelated to the artefact distribution. In addition, the effects of ploughing and soil mobility were considered likely to have enlarged the artefact distribution. Just over half of the sites were assessed as having a moderate or high potential for *in situ* artefactual material. This assessment related predominantly to sites within fluvial corridor contexts.

Open artefact scatters in fluvial corridor contexts accounted for 53 percent of recordings of this type, despite fluvial corridors accounting for only 17 percent of the study area. Thirty one percent of sites occurred on alluvial flats or valley floor contexts within the corridor zone. Crests and ridgeline zones contained proportionately low artefact densities (12%), with highest percentages (7%) occurring on minor watersheds situated close to fluvial corridor zones.

Silcrete dominated the stone material types recorded at open artefact scatters, and was present in 86 per cent of sites, and accounted for more than 50 per cent of the recorded artefacts in 66 per cent of these locations. Other stone types rarely accounted for more than 50 per cent of recorded artefacts. Other important stone types were quartz, chert and tuff which were present in 41, 36 and

29 per cent of sites respectively. Quartzite, other volcanics, and rhyolite were recorded in a small number of sites.

Table 5.4 1997 assessments of archaeological potential for open artefact scatters in the Badgerys Creek study area

Type of potential	Low	Moderate	High	Not Recorded
to be larger	31%	41%	26%	2%
to contain more artefacts	29%	43%	26%	2%
to have in situ material	41%	33%	19%	7%

Isolated Finds

Isolated finds accounted for 69 percent of all Badgerys Creek recordings. The frequency of stone material types indicated a similar order of preference to open artefact scatters with silcrete dominating (48 percent), followed by chert (27 percent), quartz (14 percent) and tuff/mudstone (7 percent).

The condition of these single artefact occurrences also mirrored the ratings for open artefact scatters with 64 percent assessed as being poor, 25 percent as good, and two percent as very good. Nine percent were unassessed. This concurrence across recording categories was thought to be an indication of the homogeneity and widespread nature of the ground surface disturbance within the Badgerys Creek study area.

The assessed archaeological potential of isolated find localities was consistently lower than for open artefact scatters. The majority of locations had low potential, with only eleven percent assessed as having high potential for *in situ* artefactual material. These lower values were a reflection of the larger number of isolated finds recorded in shallow soil contexts, such as crests and upper slopes.

Although higher proportions of isolated finds were recorded from crest and watershed contexts compared to artefact scatters (approximately twice artefact scatter values), the relative sequence in landform occurrence was relatively similar. Highest frequencies occurred in secondary and minor fluvial corridors with 74 per cent of these recorded on alluvial flats. Seven per cent of isolated finds were recorded from major watershed ridgeline contexts (compared to three per cent of artefact scatters), suggesting that Aboriginal occupation of these topographies was more likely to result in the discard of isolated artefacts than in lower elevation and better watered contexts.

Artefact Traits

There were 102 recorded surface artefact occurrences, with a combined assemblage of 373 artefacts. Flakes were the most commonly recorded artefact type, and were noted in 73 percent of all artefact occurrences. This was followed by flaked pieces with 57 per cent, and cores with 17 percent. The high percentage of flaked pieces was interpreted to be indicative of the high degree of post depositional damage to artefacts from farming and other mechanical land-use impacts. Eighteen percent of sites contained artefacts with some form of secondary flaking, and six per cent included artefacts with use wear. Backed artefacts or microliths were noted in seven percent of occurrences. Bipolar reduction techniques were noted in only two percent of occurrences, and were probably under-represented in the sample due to difficulties in distinguishing artefactual quartz in highly disturbed surface contexts. This low frequency may also be a reflection of the predominance of silcrete working compared to quartz. Single platform cores were noted from 10 percent of locations, with multiplatform cores noted from eight percent.

Pebble cortex, mostly alluvial kin origin, was noted on artefacts from 25 percent of occurrences, providing a strong indication that pebble and gravel beds were a major source of stone used for

flaking. Pebble cortex was noted on both silcrete and quartz primary flakes. Hammerstones were noted from one site only, and manuports from three.

Greater diversity in technological traits was evident from sites in fluvial corridor contexts, and particularly when adjacent to more permanent streamlines. Taken at face value, this breakdown of the distribution of artefactual traits suggested that the majority of artefact occurrences were indicative of non-intensive lithic working such as could be expected from small and low intensity occupation sites away from major camp sites or base camps. The latter are more likely to be situated adjacent to the larger stream beds and it is in these contexts that indications of more intensive stone use, such as utilised tools and cores are concentrated. It was concluded that although this pattern was supported by research conducted elsewhere on the Cumberland plain, further research and sub-surface sampling would be required to substantiate the trends within the Badgerys Creek study area.

Modified Trees

Eight scarred trees (also referred to by the more inclusive term of modified trees), were recorded from the Badgerys Creek study area. Five of these were interpreted as possibly of Aboriginal origin, two as probable, and only one as most likely to be an Aboriginal scar. The surety of an Aboriginal origin for the two recordings situated within the current airport site (B8 and B40) was assessed as possible. Seven of the trees occurred on rough barked Eucalypt species and one on a smooth barked Eucalypt.

The small number of recordings and the generally low degree of certainty regarding a possible Aboriginal origin, was not an unexpected result. This was because of the low survival rate of old-growth endemic trees and the high incidence of historic sources of scarring. Possible alternative causes of scarring included bird and domestic animal damage, disease, and impact from farming machinery and fencing. Two recordings were on dead trees, and a further two on trees in poor or very poor condition. Three trees were classed as being in good condition and only one was classed as excellent. The generally poor condition of the recorded trees was characteristic of the surviving older growth trees throughout the study area. These had been heavily impacted by land clearance, fire and agricultural practices. Most scarred trees were recorded from alluvial flats and valley floor contexts within fluvial corridor zones. It was thought that this pattern was more likely to reflect trends in non-Aboriginal tree clearance than any pattern in Aboriginal bark exploitation.

Potential Archaeological Deposits

The identification of potential archaeological deposits (PAD's) was based on the mapping of landforms which complied with predictive site location criteria, and the trends identified from the surface survey. Individual and site specific PADs were not systematically recorded during the field survey program.

The results of the surface survey indicated that core areas of archaeological potential were consistently situated on basal slope, locally elevated, and level or low gradient areas within, and immediately adjacent to, valley floor topographies and in close association (up to 100 m) with water sources. Wherever ground surface exposures into pre-historic sediments existed within these contexts, artefacts were consistently recorded. In addition, alluvial and colluvial sedimentation within the fluvial corridor zone provide the only significant areas in which subsurface artefactual material may remain undisturbed below a plough zone depth of approximately 20 centimetres. Zones and sites with archaeological potential identified as a result of the 1997 assessment are mapped in Figure 5.5.

Potentially exploited natural resources

Apart from the scarred trees, no other forms of site specific natural resource exploitation were noted from Badgerys creek. A local surface concentration of ochreous sandstone nodules with apparently high concentrations of iron oxide was noted along a section of Oaky Creek. No evidence for Aboriginal quarrying or exploitation of the nodules could be identified, however it remains possible that these nodules were used by Aborigines as a source of ochre. The source did not display outstanding quality, and any past exploitation was probably opportunistic and local in character.

Non-artefactual forms of silcrete in the form of relatively small flaked and rounded surface gravels were noted from many locations within the northern and north eastern portions of the 1997 EIS study area. Large scale sources of silcretes on the Cumberland Plain are associated with relict alluvial gravel beds of Tertiary age, however, no such sources are known from the study area (personal communication Tessa Corkill February 1997). The natural gravels encountered in the study area were interpreted as a remnant surface scatter from a now eroded source. If was conjectured that the dominance of silcrete in the Badgerys Creek artefactual assemblage was at least partly indicative of local Aboriginal exploitation of these surface gravels.

Aboriginal cultural and intangible values

All Aboriginal stakeholders consulted for the 1997 EIS assessment and subsequent supplements, expressed a strong view that sites and deposits associated with the archaeological record of Aboriginal occupation at Badgerys Creek were of high cultural value to Aboriginal people. In addition, the intangible cultural values of the landscape and its surviving biota were valued for their association with traditional culture and lore, and the sense of place and social identity derived from them. No sites or places of special cultural significance, unrelated to archaeological evidence, were identified during the assessment.

All stakeholder groups variously communicated a general opposition to the construction of a second airport in south western Sydney.

Conclusions

It was concluded that the results of the 1997 EIS investigation were fully consistent with previous findings for the Cumberland plain. Based on a comparison with the corpus of previous results, the known and predicted archaeological resource within the Badgerys Creek study did not stand out as having unique or outstanding features. Nor could the study area be reliably considered to represent a significant potential to include unique or outstanding features to any greater extent than comparable topographies elsewhere within the Cumberland plain.

The following points summarised the concurrence between the results of the 1997 investigation and previous conclusions:

- sites and varying artefact densities occur in all topographic zones;
- site density was found to be higher in topographies associated with permanent water sources;
- alluvial flats were a zone of high site density and appeared to have been a focus of Aboriginal occupation;
- basal slopes adjacent to valley floor contexts were also found to have relatively high site densities;
- sites in association with permanent water (secondary or higher order fluvial corridors), tended to be larger, and have higher artefact densities and greater technical complexity, than those associated with lesser order drainage lines;
- in line with the results of the Rouse Hill investigations (JMCHM 2005a), all of the fluvial corridor zones were identified as zones of archaeological potential relative to adjacent topographies. These zones were considered likely to contain larger and more complex sites, as well as the least disturbed sub-surface deposits below the plough zone;
- ridgetops in general contained fewer sites; and
- minor gullies (ie drainage lines outside of fluvial corridors), tended to have low site densities.

It was argued that the Badgerys Creek study area consisted mostly of an upper portion of the greater South Creek catchment, but did not include any section of this major Cumberland Plain stream line, or its associated flats and basal slopes. As such, the study area was comparable to many other

similar upper catchment Cumberland plain topographies. It was observed that the extent of previous land surface disturbance, particularly from vegetation clearance, agricultural development, and recent residential developments in no way distinguished the Badgerys Creek area as a zone of better than average archaeological potential. The fluvial corridor and valley floor of South Creek, situated one kilometre to the east of the current airport site, was considered likely to contain larger sites, deeper sedimentary contexts and to provide a greater archaeological potential than comparable fluvial corridors within the study area.

The assessment concluded that the level of potential development impact associated with any of the Badgerys Creek airport options could be placed within a local scale and context. The Holsworthy airport options were, by contrast, placed within a regional, and national context. The loss of cultural heritage significance represented by the Holsworthy options would not normally be contemplated except in cases where no other viable alternatives existed.

Management and mitigation

The 1997 EIS investigation identified a range of Aboriginal heritage management measures in the event that airport development at Badgerys Creek proceeded. These included:

- surface survey of remaining unsurveyed areas within direct impact areas;
- conduct of a program of subsurface testing in areas of defined archaeological potential;
- salvage excavations to be conducted in a range of locations, according to the priorities and criteria identified in the preceding testing program;
- salvage of Aboriginal scarred trees after appropriate field recording, if appropriate;
- regular monitoring of indirect impacts on sites;
- environmental protection to be reviewed and, if necessary, redesigned to mitigate indirect impacts on sites;
- development of conservation and management plans for *in situ* site conservation;
- subsequent curation and care of salvaged materials; and
- monitoring of ground surface disturbance during construction activities (NOHC 1997:20-11-20 13).

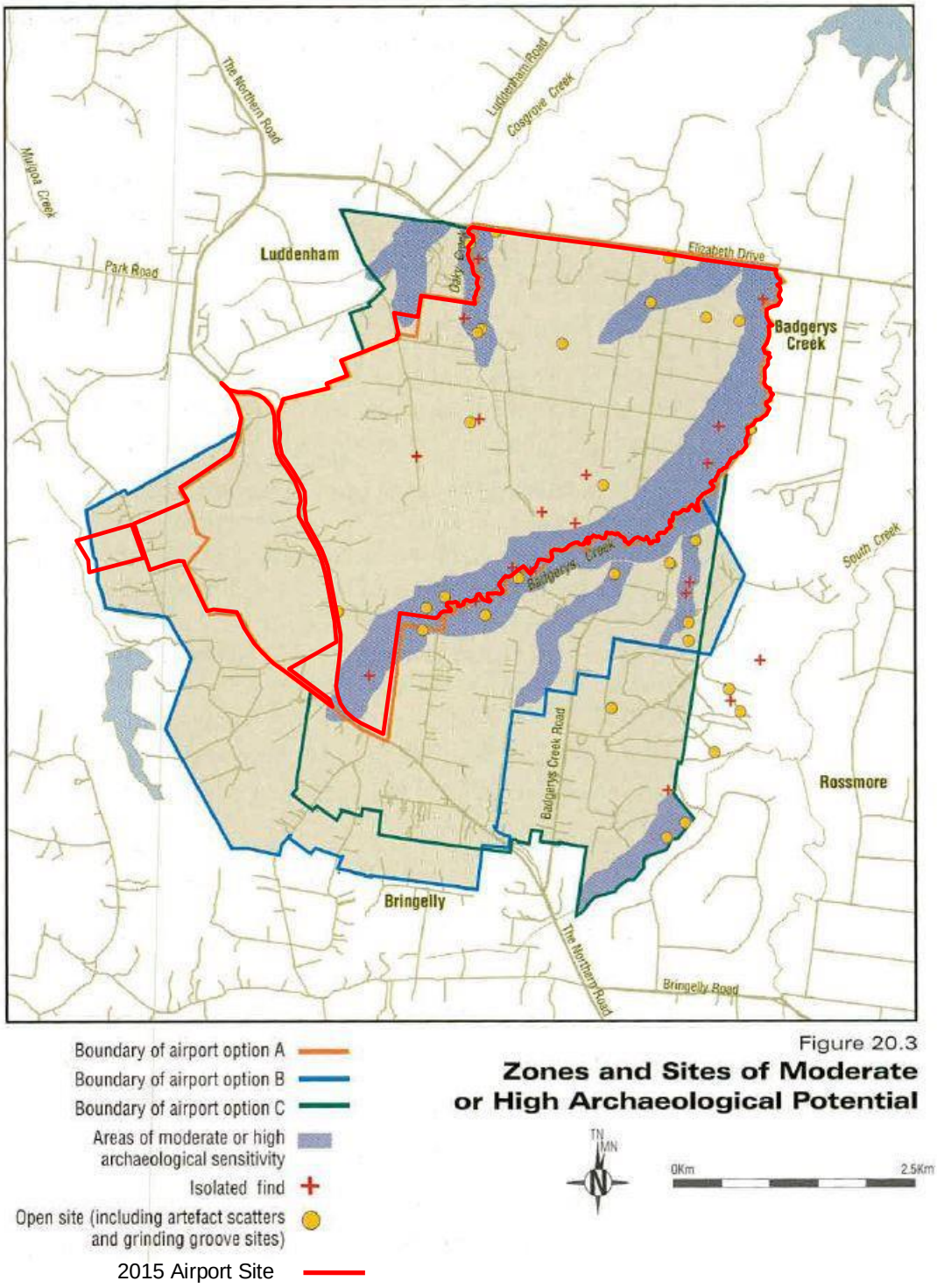


Figure 5.5 Zones and sites identified in the 1997 EIS assessment with predicted subsurface Aboriginal archaeological potential

5.5.4 1997 EIS Auditors report

The Draft EIS was the subject of an Auditor's report in 1997 (SMEC 1998). This review presented criticisms of a number of areas of the assessment including the logic employed, data (or lack thereof), interpretation (especially the work of others), presentation, the sampling strategy used in executing the field survey strategy, and the fact that no test excavations were carried out.

The Auditor's assessment was that the scientific (or archaeological) significance of the known and unknown cultural heritage resources in the Badgerys Creek area might well prove to be higher than that presented in the draft EIS. Despite this reservation, the Auditor concurred with inferences made in the Draft EIS that the scientific significance of the known and projected cultural heritage resources at Badgerys Creek is low. The Auditor also commented that a cultural heritage management plan would need to be prepared if the airport proposal was to proceed.

5.5.5 1999 Supplement to the 1997 EIS

A supplement to the 1997 EIS was completed in 1999. One additional field site was added to the EIS database. The supplement addressed comments submitted during the Draft exhibition period and criticisms presented in the Auditors report.

The supplement included an assessment of the cumulative impacts of an airport development on the existing Aboriginal cultural resource in the Badgerys Creek region. This analysis suggested that the development of any of the airport options would result in a significant impact on the archaeological resource of the Cumberland Plan. It noted however, that only a very small proportion of the Cumberland Plain had been subject to comprehensive field survey, and that this limited the ability to quantify this impact.

5.5.6 1999 Supplement auditor's report

The Auditor's Report on the Supplement to the Draft EIS (SMEC 1999) noted the EIS recommendation that once a preferred option was selected, a detailed and comprehensive program of subsurface testing and salvage would be conducted within the selected site. The Auditor suggested that the possibility that this testing may reveal items of greater significance than what had been identified on site to date should be considered.

The Auditor noted that the Supplement identified that all of the airport options would impact on sites that are valued by the local Aboriginal community for their cultural significance.

5.5.7 1999 Environment Australia assessment report

In 1999, at the end of the EIS process (which had commenced in 1997) Environment Australia conducted a review of the Draft EIS, supplement, final EIS and audit findings.

The following points were made in relation to the assessment of Aboriginal heritage:

- A higher priority could have been given to more detailed supporting anthropological and historical studies to assist in addressing issues relating to Aboriginal cultural significance more effectively.
- More detailed studies into contemporary Aboriginal heritage values, as opposed to archaeological values, would have helped to clarify the nature of the cultural heritage significance of the proposed airport site.
- Further work into contemporary Aboriginal heritage values should be done prior to construction of the airport as part of any conservation management plan.
- Information relating to the implications of native title claims for the airport development had not been provided.

- The survey methodology appears to have been adequate and in accordance with accepted methodological standards in NSW NPWS guidelines.

- The decision not to undertake subsurface testing for the EIS was appropriate as it could have resulted in unnecessary damage to cultural heritage sites and was in accordance with current best practice in the conservation of cultural heritage.

- A conclusion in Technical Paper 11 (Aboriginal Cultural Heritage) that 'below the plough zone and within the deeper sedimentary deposits of the lower Badgerys Creek fluvial corridor, the potential for significant archaeological deposits within a regional content cannot be wholly discounted' was not included in the main Draft EIS report.

- A regional survey of the archaeological and contemporary Aboriginal cultural heritage resources of the Cumberland Plain would assist in identifying the Aboriginal cultural heritage values of the Cumberland Plain and would allow a more accurate assessment of individual sites and suites of sites.

- The suggestion that regional trade-offs may assist in mitigating cumulative impacts induced by the airport development was not taken up in the environmental management measures proposed in the Supplement. The possibility of pursuing such initiatives could be explored in the context of regional environmental planning, in consultation with the local Aboriginal community.

It was concluded that the impact of the airport on the Aboriginal cultural heritage significance of the site, and potentially of the region, would be significant. Almost all of the archaeological resource in the airport site would be destroyed, and contemporary Aboriginal cultural heritage values would be damaged. It was recommended that a cultural heritage conservation management plan should be developed in consultation with the local Aboriginal community to guide the process of site documentation, destruction and management. To offset the loss of the cultural heritage of the site and region, consideration should be given to promoting measures which would identify and mitigate the effects of the airport on the regional resource (Environment Australia 1999: 19-10 – 19-11).

5.5.8 2014 AMC Environmental survey

In 2014 Australian Museum Consulting, on behalf of SMEC, undertook the Aboriginal heritage component of an environmental survey program which aimed to update existing baseline environmental information on the Commonwealth owned land at Badgerys Creek.

The following tasks were undertaken:

- A search and review of relevant OEH (AHIMS) database information.

- A review of relevant previous archaeological reports specific to the area.

- A review of relevant contextual environmental information and previous land use history.

- Field inspection of 21 of previously recorded Aboriginal heritage sites situated within areas of previously identified moderate and high archaeological potential with the aim of establishing their current status and condition.

- Preparation of a report describing the results of the assessment, identified information gaps and requirements for further investigations to support any future assessments.

Of the 21 Aboriginal heritage sites within areas of moderate and high archaeological potential, only seven sites could be re-found and verified. These were the two possible scarred tree sites and five stone artefact occurrences. It was reported that impacts described by the 1996 assessment have continued to affect the condition and visibility of the sites, and the majority of sites have either been actively impacted by water or stock movements, or are now overgrown and obscured by vegetation. These impacts have either obscured the previously recorded artefacts, or removed them from the immediate location of the original site recording.

The following observations were made regarding the reinspected sites:

- The two scarred trees of possible Aboriginal origin (B40 AHIMS site 45-5-2630 and B8, 45-5-2634), were found to be heavily impacted by ongoing rotting of the heartwood caused by previous damage and stock impacts respectively.

- No artefacts were visible at the following fifteen sites:

B4	AHIMS site no.	45-5-2638
B7	AHIMS site no.	45-5-2635
B41	AHIMS site no.	45-5-2768
B44	AHIMS site no.	45-5-2632
B46	AHIMS site no.	45-5-2699
B54	AHIMS site no.	45-5-2790
B55	AHIMS site no.	45-5-2693
B59	AHIMS site no.	45-5-2690
B74	AHIMS site no.	45-5-2685
B76	AHIMS site no.	45-5-2683
B81	AHIMS site no.	45-5-2679
B82	AHIMS site no.	45-5-2764
B86	AHIMS site no.	45-5-2781
B88	AHIMS site no.	45-5-2665
B94	AHIMS site no.	45-5-2789

  Reasons for the lack of visible artefacts at these locations were noted to be obscuring vegetation, displacement by stock trampling, removal by erosion agencies, and subsequent deposition of sediment. Difficulty in re-finding artefacts at seven of these locations was expected due to the original recording consisting of single artefacts.

- Three artefacts were recorded at site B45 (AHIMS site 45-5-2633), a site associated with an agricultural dam and originally recorded as comprising 12 artefacts. It was considered likely that impacts from water erosion had removed surface artefacts from the vicinity of the site.

- One artefact was recorded 120 metres from site B5 (AHIMS site 45-5-2637), and attributed to the original site recording which consisted of an isolated artefact (this recording has been allocated a new site designation, B136, for this study). The area of the find had been heavily impacted by ploughing and erosion.

- One artefact was recorded at site B95 (AHIMS site 45-5-2762), a site associated with a dam that was originally recorded as comprising six artefacts. The site was almost completely obscured by pasture grass.

- Only one site contained more visible artefacts than originally recorded. This was at site B80 (AHIMS site 45-5-2678) which was originally recorded as a scatter of 11 artefacts exposed within two small salt pan erosion areas. The AMC reinspection recorded 64 artefacts within extensive exposures caused by ongoing stock impacts and water erosion.

Following the AMC review of archaeological investigations which post-date the 1997 EIS assessment, it was concluded that refinements in the understanding of the nature of Aboriginal cultural heritage across the region now suggest that the Commonwealth lands at Badgerys Creek have greater potential to contain subsurface archaeological deposits than previously indicated. In addition, landforms with potential to contain such deposits are likely to be larger than those accounted for by the 1997 predictive model.

Cumberland Plain studies have provided further evidence substantiating the observation that the presence or absence of surface archaeological materials is not a wholly reliable indicator of the distribution of in situ archaeological deposits. Given that all of the Badgerys Creek recordings relate

to ground surface exposures, created by erosional and human land-use disturbance, it was considered likely that substantial archaeological deposits remain present within landforms that have not experienced significant disturbance.

Current archaeological knowledge now provides a basis for challenging the 1997 EIS site location model which suggested that most Aboriginal heritage sites would be located within 50 m of water resources (NOHC 1997:59). Some instances are now known of Aboriginal heritage sites with dense subsurface archaeological deposits located up to 300 metres from water sources. This has important implications for future heritage significance and impact assessment, and for the development of appropriate heritage impact mitigation measures and research methodologies.

The AMC 2014 baseline assessment presented three recommendations:

- *Aboriginal community consultation should be carried out to ensure the appropriate involvement of Aboriginal stakeholders in the assessment and decision making regarding their heritage. Consultation should comply with the Australian Heritage Commission's Ask First: A guide to respecting Indigenous heritage places and values (Australian Heritage Commission 2002), and address the NSW Office of Environment and Heritage's* Aboriginal cultural heritage consultation requirements for proponents *2010 (DECCW 2010b), as appropriate.*

- *Full archaeological survey of the Commonwealth owned land at Badgerys Creek should be undertaken in consultation and engagement with Aboriginal community stakeholders. The survey and assessment should seek to assess a representative sample of all landforms within the area, and should comply with the requirements of the NSW Office of Environment and Heritage's Code of Practice for Archaeological investigation of Aboriginal Objects in New South Wales (DECCW, 2010)*

- *A program of archaeological test and salvage excavations should be carried out throughout impact areas resulting from future development or land use activities on the Commonwealth owned land at Badgerys Creek, in consultation and engagement with Aboriginal community stakeholders. The scope and methodology of the excavation should respond to the results of the archaeological survey and assessment, and should seek to recover and analyse an appropriate representative sample of the Aboriginal archaeological resource of the area.*

5.6 Current predictive regional model

The development of a predictive model of the location and content of Aboriginal archaeological sites on the Cumberland Plain has been a continuous process and involved constant evaluation against the results of increasingly sophisticated sampling and survey methodologies.

The following is a compilation of key trends and predictive statements derived from the corpus of previous investigations reviewed in the previous sections:

- Surface and subsurface stone artefacts occur at variable areal incidences in all landforms types.

- Site frequency together with artefact density and diversity are strongly related to landscape variables which determine access to fresh water and to other exploitable resources. This relationship is likely to be complex and to include multiple behavioural and environmental variables.

- Low surface artefact incidences may not accurately reflect the composition or density of subsurface archaeological deposits. Some areas with few or no surface artefacts have been found to contain archaeological deposits with relatively higher artefact densities and areal incidence.

- Intact archaeological material may remain below the plough zone (i.e. top 25 centimetres of soil).

- At a micro-topographic level, artefact distributions will most likely be situated on locally elevated, well drained ground with relatively level or low gradients.
- Micro-topographic contexts which are both low-lying and poorly drained, or comprise high gradient slopes are likely to contain no, or very low, artefact densities.
- Surface and subsurface artefact occurrences are mostly situated in relative proximity to permanent water sources such as creeks and rivers and wetland basins on alluvial flats. The majority of sites are located within 100 metres of a fresh water source.
- Sites in association with permanent water (secondary or higher order fluvial corridors), tend to be larger, have higher artefact densities and greater technical complexity, than those associated with lesser order drainage lines.
- Sites or potential archaeological deposits in the vicinity of lower order and ephemeral drainage lines are most likely to include archaeological deposits with low-to-moderate artefact densities.
- Regional trends indicate that Aboriginal sites are most frequently located in close proximity to permanent water courses on creek banks, alluvial flats and lower hillslopes (basal slopes), or on high ground such as ridges and knolls, and within range of food resources and the raw materials for manufacturing tools.
- Complex sites (defined as sites with more artefact types and more archaeological features in intricate arrangement) are usually located close to permanent water sources. These sites are probably indicative of intensive use by larger groups, or repeated use by smaller groups over a longer period of time.
- Stream order may provide a predictive framework for the incidence and nature of associated archaeological deposits (McDonald 2005a).
    - Fourth and Fifth order streamlines are likely to be associated with more complex and possibly stratified archaeological evidence which reflects more permanent and repeated occupation.
    - Third order streamlines are likely to be associated with evidence of frequent occupation such as knapping floors. Higher artefact densities will be found in the lower reaches of tributary creeks.
    - Second order streamlines are likely to be associated with sparse archaeological evidence, probably related to occasional use and/or occupation.
    - First order streamlines are likely to be associated with sparse archaeological evidence, and this may be indistinguishable from, or may define, a background level of artefact incidence.
- Creek junctions could provide foci for site activity and the size of the confluence (based on stream order) could influence the size and complexity of sites (McDonald and Rich 1993; JMCHM 1997, 2005a).
- High value potential archaeological deposits are most likely to be located on aggrading landforms within valley floor contexts and fringing basal slopes, on locally elevated and well-drained ground.
- Despite a general trend for relatively elevated landforms such as ridge and spurline crests to contain low site densities and artefact incidences, sites with large numbers of artefacts may still be present on ridge tops and hill crests.
- Sites situated in alluvial and aggrading sedimentary or colluvial contexts retain the potential to include high value stratified archaeological deposits.

- Artefact assemblages generally comprise a small proportion of formal tool types with the majority of assemblages dominated by unretouched flakes and debitage.

- Excavations conducted along higher order stream lines (particularly South Creek and Ropes Creek), have detected extensive archaeological deposits, thought to be the result of repeated occupation events, within c.150 metres of the stream banks (e.g. Brayshaw McDonald Pty Ltd 1995; Total Earth Care Pty Ltd 2007).

- Silcrete is the dominant raw material evident at most surface and subsurface artefact distributions, followed by tuff/chert. Substantial sources of silcrete, mostly associated with Tertiary gravel deposits, are located in the north western Cumberland Plain at places such as St Marys, Plumpton Ridge, Marsden Park, Schofields, Riverstone, Deans Park, Llandilo and Ropes Creek. However, a low areal incidence of surface silcrete gravels occurs across large areas of the Cumberland Plain and may have served as a low-key source of workable stone for knapping. Silcrete cobbles and amorphous naturally fractured gravels have been noted during surveys and excavations at Luddenham and Erskine Park (e.g. Dallas 1988a; Brayshaw 2005; NOHC 2005c; Steele 2007).

- Single trees and stands of remnant older growth vegetation retain the potential for evidence of Aboriginal modification (mostly scars resulting from the removal of bark). The large scale nature of historical vegetation clearance across the Cumberland Plain means that old-growth remnants are now rare.

- Grinding grooves (shallow linear grooves produced during the manufacture of ground edges on stone artefacts such as axes (hatchets)) are a rare site type on the Cumberland Plain and may occur wherever Minchinbury sandstone is exposed on the surface.

Australian Museum Consulting (2014) note that archaeological investigations continue to identify individual site characteristics which run contrary to these predictive statements. An example is the excavations conducted by ENSR Australia Pty Ltd at the Oran Park and Turner Road Land Release Precincts in 2009, approximately 12 km south of the airport site. It was concluded that:

> The archaeological landscape revealed by this investigation suggests that archaeological models derived from other regions or other areas should not be applied uncritically. There was no evidence for greater complexity (defined as intricacy) associated with confluences. There was no evidence of greater densities of archaeological material associated with higher order watercourses. Instead it appears that archaeological deposit in the south west [Cumberland Plain] is of relatively low density with occasional clusters in association with all areas of reliable water regardless of stream order. Future assessments in south west Sydney would benefit from paying greater attention to the investigation of areas within 300 metres of all reliable watercourses (i.e. more than the conventional 50 metres vicinity of watercourses) (ENSR 2009:66, cited in AMC 2014: 29, quoted in AMC 2014:29).

5.7 Previously recorded sites within the airport site

There are 51 previously recorded Aboriginal sites within the airport site. All of these are documented in the AHIMS register. Of these, one recording pre-dates and one post-dates, the 1997 EIS survey and assessment (B3, AHIMS site no. 45-5-2586 and B136). Due to a data error, the AHIMS register places an external site recording within the airport site (EG6, AHIMS site no. 45-5-2562). This recording has been excluded from this assessment.

There are no recorded sites or places on the Commonwealth or National Heritage Lists. These lists were established under the *Environment Protection and Biodiversity Conservation Act 1999* and are administered by the Commonwealth Department of the Environment.

Data relating to all previously identified Aboriginal sites within the airport site is presented in Table 5.6. The general location of sites is shown in Figure 5.6.

Table 5.6 Summary of previously recorded Aboriginal heritage sites located within Commonwealth owned land at Badgerys Creek (refer to Appendix 2 for map grid references)

Site No.	OEH Site No.	Site type	No. surface stone artefacts (1996)	No. surface stone artefacts (AMC 2014)	Type of ground surface exposure	Max dimensions of surface artefact distribution (1996) (m)	Dimensions of ground surface exposure(s) (1996) (m)	Arch'l subsurface potential (NOHC1997)
B3	45-5-2586	sao	1		stock track		0.3m wide	high
B4	45-5-2638	sao	1	nil	erosion gully platform		2.6 x 3.9	low
B5	45-5-2637	sao	1	1	creek ford		20 x 7	low
B7	45-5-2635	sao	1	nil	stock track and creek bank		1 x 1	moderate
B15	45-5-2705	sao	1		suburban road verge		4 x 4	low
B24	45-5-2642	sao	1		track from dam wall			not recorded
B25	45-5-2643	sao	1		grassed ploughed area (vineyard)			low
B31	45-5-2617	sao	1		dirt track		3 x 3	low
B32	45-5-2618	sao	1				10 x 2	not recorded
B39	45-5-2629	sao	1		ploughed zone between vines		100 x 2	low
B40	45-5-2630	modified tree						possible
B41	45-5-2768	sao	1	nil	BMX bike jump		2.5 x 2.5	moderate
B42	45-5-2631	sao	1		building (construction) site		6 x 2	low
B43	45-5-2783	sao	5		salt scald	30 x 30	10 x 5	high
B44	45-5-2632	sao	3	nil	erosion gully and horse track	150 x 25	150 x 25	moderate
B45	45-5-2633	sao	12	3	scald at gate and dam bank	120 x 30	18 x 4 7 x 4	moderate
B46	45-5-2699	sao	13	1	channel and erosion scour and agricultural dam wall	60 x 50	25 x 5 40 x 5 15 x 20	high
B54	45-5-2790	sao	2	nil	eroded gully margin	11 x 1	15 x 3	low
B55	45-5-2693	sao	2	nil	gateway and ant nest scald	23 x 2	4 x 3	low
B59	45-5-2690	sao	1	nil	road margin		16 x 15	not recorded
B66	45-5-2659	sao	16		scald	12 x 4	25 x 4	low



Site No.	OEH Site No.	Site type	No. surface stone artefacts (1996)	No. surface stone artefacts (AMC 2014)	Type of ground surface exposure	Max dimensions of surface artefact distribution (1996) (m)	Dimensions of ground surface exposure(s) (1996) (m)	Arch'l subsurface potential (NOHC1997)
B67	45-5-2658	sao	1		trampled and eroded soil exposure		2 x 6	moderate
B68	45-5-2623	sao	1		stock trail		200 x 30	high
B69	45-5-2771	sao	1		graded embankment for agricultural dam		10 x 5	not recorded
B70	45-5-2770	sao	5		drainage line scald and stock yards	7 x 3	16 x 8	moderate
B71	45-5-2687	sao	1		stock treadage		20 x 3	not recorded
B74	45-5-2685	sao	1	nil	recently ploughed field		100 x 200	moderate
B75	45-5-2682	sao	1		agricultural dam wall		25 x 6	moderate
B76	45-5-2683	sao	1	nil	side of bitumen road		100 x 5	low
B77	45-5-2681	sao	9		dry creek bed	10 x 2	11 x 5	high
B78	45-5-2680	sao	1		creek bed	10 x 15	10 x 15	high
B79	45-5-2663	sao	1		road cutting		50 x 10	low
B80	45-5-2678	sao	11	64	erosion scald above agricultural dam and creek bed	100 x 30	20 x 6 4 x 2	moderate
B81	45-5-2679	sao	1	nil	creek bed and banks		17 x 30	high
B82	45-5-2764	sao	1	nil	agricultural dam wall		40 x 5	low
B84	45-5-2782	sao	7		scald around dead tree	1.7 x 1.5	30 x 15	moderate
B86	45-5-2781	sao	5	nil	erosion scar	30 x 20	30 x 20	low
B87	45-5-2763	sao	5		graded vehicle track	20 x 4	20 x 4	high
B88	45-5-2665	sao	2	nil	excavated trench below dam	20 x 5	20 x 5	low
B90	45-5-2667	sao	2		vehicle track	10 x 0.5	2.5m wide	moderate
B91	45-5-2671	sao	2		ploughed marked garden	6 x 1	300 x 200	low
B92	45-5-2670	sao	4		disused vehicle track	25 x 3	3m wide	high

Site No.	OEH Site No.	Site type	No. surface stone artefacts (1996)	No. surface stone artefacts (AMC 2014)	Type of ground surface exposure	Max dimensions of surface artefact distribution (1996) (m)	Dimensions of ground surface exposure(s) (1996) (m)	Arch'l subsurface potential (NOHC1997)
B93	45-5-2668	sao	1		agricultural dam wall		20 x 1.5	low
B94	45-5-2789	sao	1	nil	salt scald/clay pan		2 x 1	high
B95	45-5-2762	sao	8	1	agricultural dam wall and margin		100 x 7	moderate
B101	45-5-2673	sao	1		gate exposure		2.5 x 1.5	indeterminate
B102	45-5-2656	sao	19		sheet wash areas in old horse training paddock	13.5 x 3.5	19 x 5	high
B103	45-5-2814	sao	1		gate exposure		7 x 2	low
B104	45-5-2813	sao	1		horse training track and adjacent spoil		100 x 10	low
B112	45-5-2788	sao	3		stock scar	10 x 1	20 x 1	moderate
B136		sao		1	vehicle track		20 x 7	

sao = surface artefact occurrence

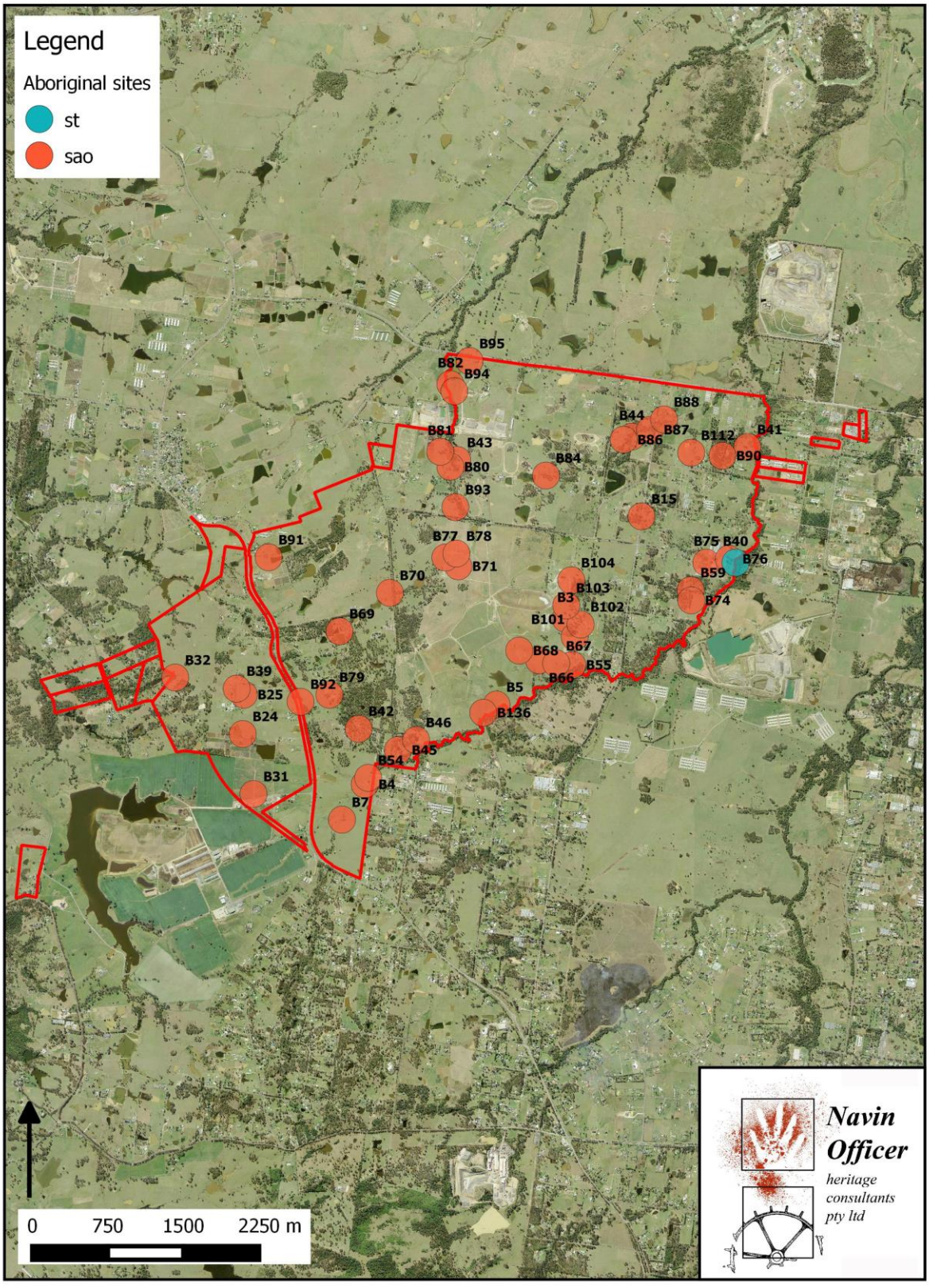


Figure 5.6 General locations of previously recorded Aboriginal sites within the airport site (sao = surface artefact occurrence, st = scarred tree). *Only generalised site locations are shown for this unrestricted access version of the report.*

6. Results of Archaeological Investigation

6.1 Survey and Test Excavation Locations

Survey

A number of previously recorded sites were inspected as part of reconnaissance coverage across the airport site, and a small number of surface artefact occurrences were recorded during the systematic inspection of potential test excavation locations. These recordings and inspections are presented in section 6.2.1.

Test Excavation

Archaeological test excavations were conducted at 13 of the 38 pre-selected potential test locations.

Four of these locations were paired to make a total of eleven test locations.

Test locations are shown in Figure 6.1.

Ten test pits (each 1 x 0.5 m, and totalling 5 m^2) were conducted at each test location (TL), with the exception of 26/27 where 14 pits were conducted. The extra pits at TL26/27 were a response to the extensive fill encountered at this location.

6.2 Site Recordings

Twenty-three new recordings of Aboriginal sites were made as a consequence of this assessment. These comprised:

- nine recordings with surface artefacts only (B113 – B120 and B122); and
- fourteen recordings where subsurface artefacts were confirmed through test excavation (B121, B123 - B135).

Within the latter category, one site also included surface artefacts (B121 at TL9).

One previously recorded site was subject to test excavation which confirmed the presence of subsurface artefacts (B88, AHIMS no. 45-5-2665, at TL26/27).

Five of the test locations revealed subsurface artefact occurrences which were recorded as two separate sites, due to micro-topographic divisions and/or a distance of greater than 100 metres (refer to Section 6.2.2).

Map grid references for these recordings are provided in Appendix 2.

A summary of all site recordings, based on surface and subsurface evidence, is provided in Table 6.2.

The location of all site recordings made as a result of this assessment are shown in Figure 6.2.

The location of all site recordings, including the 1997 EIS recordings, are shown in Figure 6.19.

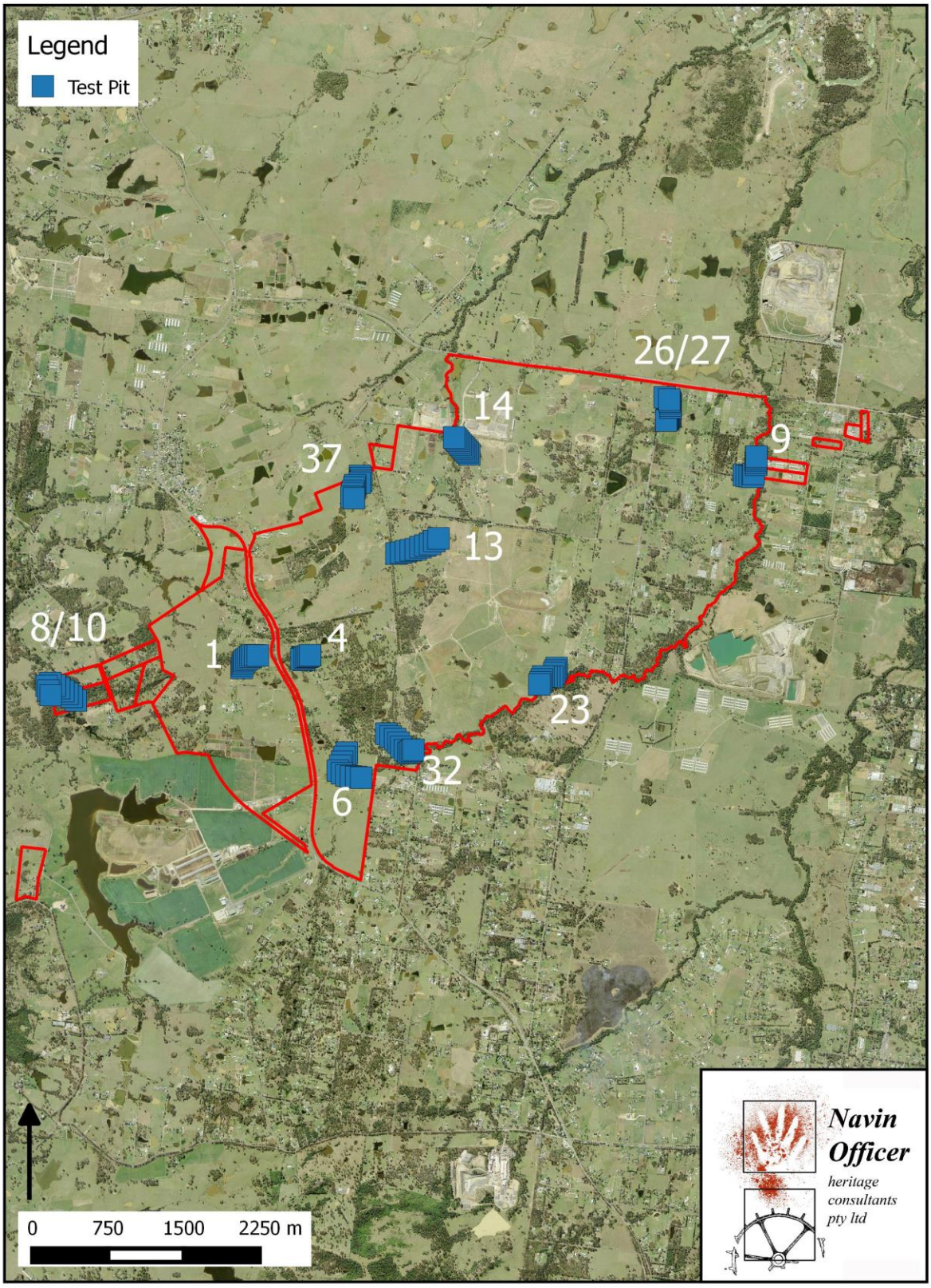


Figure 6.1 Approximate test excavation locations (large numbers) and pit locations (blue squares). Refer to Appendix 5 for large scale mapping. *Only generalised locations are shown for this unrestricted access version of the report.*

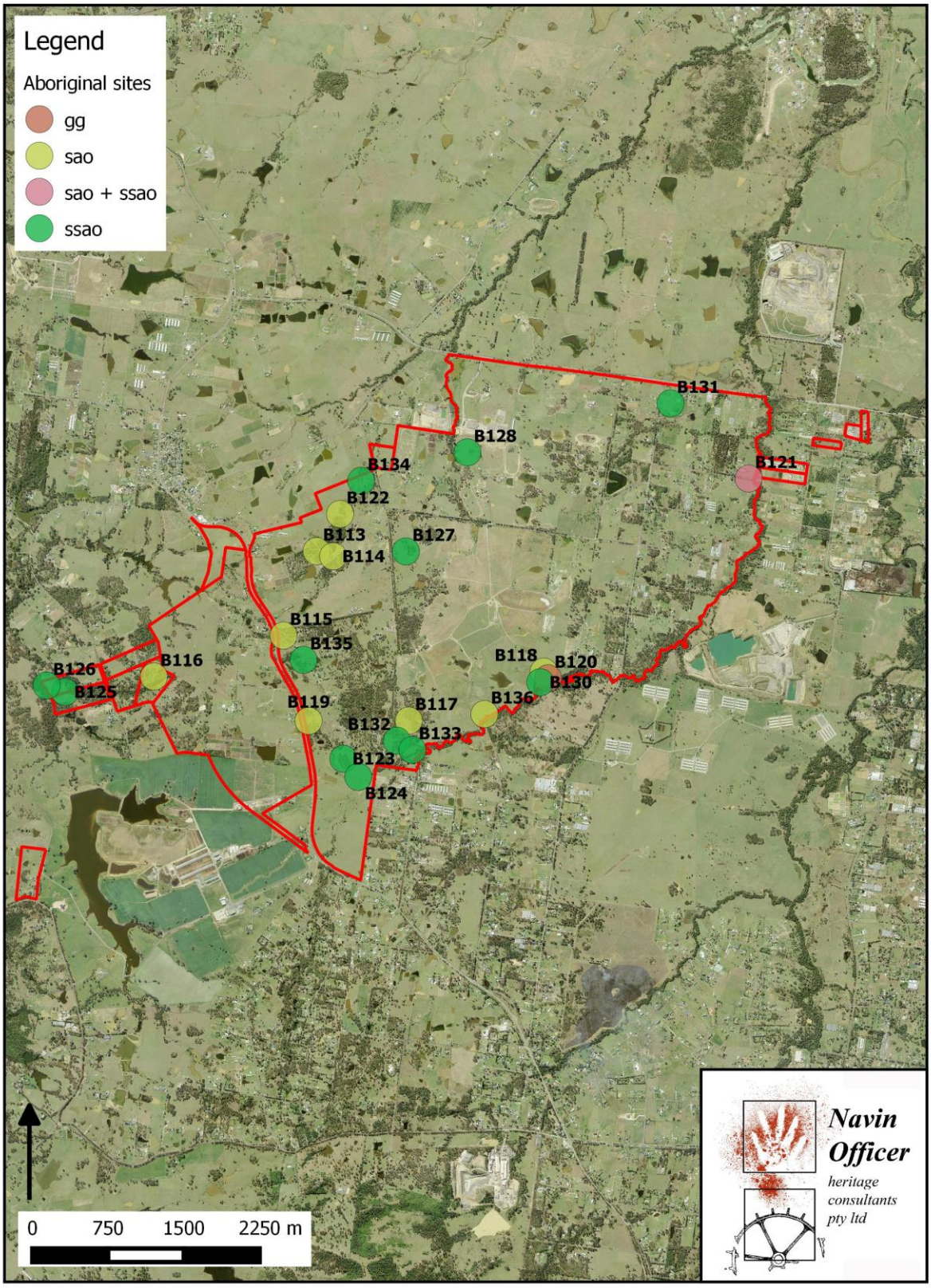


Figure 6.2 General location of sites recorded as a result of surface survey and subsurface investigation undertaken for this assessment (gg = grinding grooves, sao = surface artefact occurrence, ssao = sub-surface artefact occurrence). *Only generalised site locations are shown for this unrestricted access version of the report.*

6.2.1 Surface recordings

Site Re-inspections

B8 – Possible Aboriginal scarred tree (AHIMS site no. 45-5-2634)

The AHIMS site location for this recording (*GDA 288225.6245690)* was inspected by Australian Museum Consulting (AMC) in 2014 (AMC 2014). Although no trees were found to be present in the registered location, an isolated paddock tree was noted 35 m to the southeast which displayed extensive scarring. The tree is a Grey Box (*Eucalyptus macrocarpa*) standing approximately 18 m high, and is approximately two metres in girth at approximately 1.5 m high (Figure 6.3).

AMC noted that it was no longer possible to identify the scar as being cultural in origin. Bark had been removed from the tree to a height of approximately 1.6 m around 80 per cent of the trunk, probably as a result of impact with cattle, and it is no longer possible to identify the shape of the originally recorded scar (AMC 2014:53).

This tree was also inspected for the current assessment and the AMC interpretation that the evidence for Aboriginal scarring was now indeterminate was confirmed. Further research, including reference to the original B8 field recording (Figure 6.4), indicated that the tree under review could not be the subject of the original recording and that the original recorded map reference was in error.

Following correction of the original map reference, it can be confirmed that the B8 scarred tree is located outside of the airport site (*map grid reference removed from this version*). This site has therefore not been included in the assessment of the airport site.



Figure 6.3 The scarred tree situated 35 m southeast of the erroneous map grid reference for site B8 (scale: 10 cm intervals) (AMC 2014:Figure 5.17, p.53)



Figure 6.4 Image of the B8 scarred tree taken in December 1996; scale is just over 10 cm long (NOHC archive)

B40 – Possible Aboriginal scarred tree (AHIMS site no. 45-5-2630)

This tree was re-inspected by AMC in 2014 (AMC 2014:45). It is located on alluvial flats, at the eastern end of Longleys Road, on the break-of-slope of the western bank of Badgerys Creek, approximately 5 m east of the creek line. It occurs within a remnant margin of riparian vegetation.

AMC noted that the tree is approximately 10 metres east of a property fence line. It stands approximately 20 metres high, and its trunk was approximately 3.4 m in girth at approximately 1.5 m high. The tree is a Forest Redgum (*Eucalyptus tereticornis*) species.

The original recording of this tree in 1996 indicated that it was in very poor condition with a partially hollow and unstable trunk, a missing crown, and evidence of stock damage and insect attack. The original scar surface was partially missing and termite activity was noted (NOHC 1997, AHIMS site card attachment).

The scar was originally recorded with the following traits (NOHC 1997):

Aspect:	west
Length (excl. regrowth):	3.0 metres
Length (incl. regrowth):	3.3 metres
Width (excl. regrowth):	60 centimetres
Width (include. regrowth):	80 centimetres
Regrowth (max. width):	15 centimetres
Regrowth (max. depth):	17 centimetres
Height above ground:	base of inside scar 0 centimetres base of regrowth 0 centimetres

AMC noted that when the current condition of the tree was compared with the 1996 EIS survey photograph (Figure 6.5), it was clear that significant damage had occurred to that portion of the heartwood in the area of the scar. The site was located within a fenced margin of riparian vegetation adjacent to the creek bank and was not considered easily accessible, or exposed to stock activity.



Figure 6.5 Photo of the B40 scarred tree taken in 1996 (NOHC archive)



Figure 6.6 View of B40 scarred tree looking southeast in 2014 (AMC 2014:Figure 5.2, p.45).



Figure 6.7 View of unoccluded section of scar on B40, looking southeast (AMC 2014:Figure 5.3, p.45).

B136 – surface artefact occurrence

This recording of a single surface artefact was made by AMC in 2014 and ascribed to previously recorded site B5 (AHIMS site no. 45-5-2637). Following a refinement of the 1997 map grid reference for B5, based on original recording data, it has been determined that the AMC find is located more than 100 metres from the original B5 recording. As a consequence, this is considered to be a new recording of a separate site and has been designated as B136.

The site was described by AMC as an isolated silcrete artefact, on a waning lower slope, located within a vehicle track adjacent to a corner post of the property boundary, approximately 30-40 metres west of Badgerys Creek.

At the time of the recording the adjacent paddock was being ploughed, and the artefact location had been impacted by heavy vehicle access (Figure 6.8).

Based on the basal slope context of this find, in relative proximity to Badgerys Creek, this site is considered to have moderate subsurface archaeological potential away from exposures and eroded surfaces.

Artefact description:

1. red silcrete flake, 29 x 20 x 8 mm



Figure 6.8 General location of artefact find (by scale) at site B136, looking west (AMC 2014:Figure 5.25, p.59)

New Recordings

B113 – surface artefact occurrence

This recording consists of an open context artefact occurrence of at least 20 surface artefacts exposed along an eroded vehicle track and dam wall. The artefacts are situated on a low gradient minor (first order) spurline, and low rise, situated between and just upstream of the confluence of two second order streamlines (tributaries of Cosgroves Creek). This site is situated in a basal slope valley context (Figure 6.9).

This site is located at potential test location 34. The artefacts were located over an area of approximately 150 x 30 m. Subsurface archaeological potential away from exposures and eroded surfaces is assessed to be high.

Artefacts:

1. grey brown banded chert flake, 36 x 26 x 9 mm
2. brown banded chert flaked piece, 26 x 19 x 8 mm
3. red silcrete flake, 20 x 12 x 3 mm
4. grey brown silcrete flake, 20 x 9 x 7 mm
5. quartz flaked piece, 11 x 6 x 4 mm
6. possible axe, material may be sandstone, 116 x 87 x 30 mm



Figure 6.9 General view of eroded track at site B113 looking northeast (upslope)

B114 – surface artefact occurrence

This recording consists of an open context artefact occurrence of at least ten surface artefacts exposed along an eroded track and creek edge. The artefacts are situated on low gradient slopes adjacent to, and the western banks of, a secondary order streamline (a tributary of Cosgroves Creek). This site is situated in a basal slope valley context.

This site is located at potential test location 33. The artefacts were located over an area of approximately 110 x 20 m.

Subsurface archaeological potential away from exposures and eroded surfaces is assessed to be high.

Artefacts:

1. cream chert flake retouch, 12 x 11 x 4 mm
2. red silcrete flake, 10 x 13 x 2 mm
3. pink silcrete broken flake, 20 x 15 x 3 mm

B115 – surface artefact occurrence

This recording consists of an open context artefact occurrence of at least 20 artefacts exposed within a disturbed area in a former church yard. The church building has been demolished and the graves relocated. These past actions may have been the source of disturbance which have caused the artefacts to be exposed on the current ground surface. An alternative, though less likely possibility, is that the artefacts were imported onto the site in fill used to back fill graves following recovery of grave material.

The artefacts are situated on the crest of a prominent fourth order ridgeline, where it intersects with a major watershed fifth order ridgeline (Figure 6.10). The ridge has formed from a basaltic dyke.

The site is located at potential test location three. The artefacts were located over an area of approximately 5 x 5 m. Subsurface archaeological potential away from exposures and disturbed ground is assessed to be high.

Artefacts:

1. quartz flake, 17 x 5 x 6 mm
2. quartz flake, 12 x 8 x 5 mm
3. quartz flake, 15 x 10 x 4 mm
4. quartz flake, 12 x 8 x 4 mm
5. quartz flake, 10 x 9 x 2 mm
6. quartz flake, 9 x 10 x 1 mm



Figure 6.10 General view of location of site B115 looking south

B116 – surface artefact occurrence

This recording consists of an open context artefact occurrence of at least two artefacts exposed on an eroded vehicle track which steeply traverses low to moderately-graded mid slopes on the side of a spurline. The site is situated upslope of a dam which impounds a second order streamline (tributary of Duncans Creek).

The site is located adjacent to and downslope of potential test location seven. The two noted artefacts were located approximately five metres apart. Subsurface archaeological potential away from exposures and eroded surfaces is assessed to be low.

Artefacts:

1. quartz flake, 17 x 13 x 5 mm
2. cream chert broken flake, 20 x 10 x 3 mm



Figure 6.11 General view of location of site B116 looking north (upslope)

B117 - surface artefact occurrence

This recording consists of an open context artefact scatter of at least three surface artefacts exposed in erosion scalds along a low gradient crest of a (first order) minor spurline. The exposures are situated along the edge of a group of trees. The spurline crest faces south and descends to a narrow portion of the Badgerys Creek valley floor. This site is situated in a mid-slope valley context (Figure 6.12).

The site is located within potential test location 15. The artefacts were located approximately eight metres apart. Subsurface archaeological potential away from exposures and eroded surfaces is assessed to be high.

Artefacts:

1. black basalt flake, 26 x 15 x 7 mm
2. basalt hammerstone, 36 x 27 x 12 mm
3. red silcrete flake, 18 x 13 x 6 mm



Figure 6.12 General view of location of site B117 looking north (upslope)

B118 – surface artefact occurrence

This recording consists of an open context artefact occurrence of at least two surface artefacts exposed on a recently ploughed track on the southern edge of a ploughed field (Figure 6.13). This site is situated just above the break-of-slope of a broad crest of a third order ridgeline. It is approximately 150 metres north of Badgerys Creek.

This site is situated to the west of potential location 23. The artefacts were located approximately one metre apart. Subsurface archaeological potential is assessed to be moderate, although repeated ploughing of this landform may have significantly disturbed the vertical context of subsurface artefacts.

Artefacts:

1. quartz flake 25 x 17 x 5 mm
2. quartz flake 27 x 15 x 6 mm

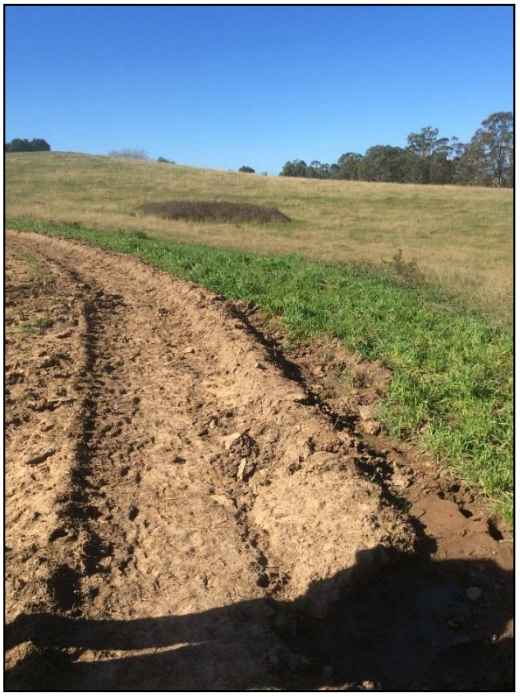


Figure 6.13 General view of B118 looking northeast

B119 - surface artefact occurrence

This recording consists of an open context artefact occurrence of at least two artefacts exposed in a scoured area on the eastern side of a gate situated between a house paddock and the paddock behind (to the east). The site is located approximately 50 metres east of The Northern Road. The artefacts are situated on a minor (first order) spurline located between, and just upstream of, the confluence of a third and a second order streamline (tributaries of Badgerys Creek).

This site is situated in a basal slope valley context. Subsurface archaeological potential away from exposures and eroded surfaces is assessed to be moderate to high.

Artefact:

1. yellow chert flake, 35 x 27 x 10 mm

B120 – Grinding grooves

This recording consists of at least four Aboriginal grinding groves located on a series of small sandstone outcrops situated on, and just below, the break-of-slope of a mid-valley context ridge-side bench. The bench is relatively narrow (around 40 metres wide), faces south, and extends for approximately 400 metres along the middle portion of a third order ridgeline which rises 26 m above the creek. The bench is situated 14 m above and 100 metres to the north of Badgerys Creek (Figure 6.14).

The grinding grooves are located on a discontinuous and low surface outcrop of Minchinbury sandstone which is mostly exposed on the steep slope immediately downslope of the bench. There are at least four grooves of definite Aboriginal origin and two others of probable Aboriginal origin.

The grooves are located on three separate sandstone outcrops, two with one definite groove each and the (western most) third with two definite and two probable grooves (Figures 6.15, 6.16 and 6.17). The three sandstone outcrops form part of an east-west aligned group of low, near ground level outcrops, and extend across a distance of 33 m.

This site is located in test location 23. A number of test pits were situated on the level ground of the ridge-side bench in relative proximity to the grinding grooves. No subsurface artefacts were detected on the bench. One stone artefact was detected at this test location, and this was situated on basal slopes 4.5 m above Badgerys Creek (site B130).



Figure 6.14 General view of site B120 grinding groove site, looking west. Note alignment of low sandstone exposures (left) along break-of-slope.



Figure 6.15 The eastern most B120 sandstone exposure with grinding groove (left of scale)



Figure 6.16 the middle B120 sandstone exposure with grinding groove (right of scale)



Figure 6.17 The western most B120 sandstone outcrop with at least two definite and two probable grinding grooves

B121 – surface and subsurface artefact occurrence

This recording consists of an open context artefact occurrence of at least two surface artefacts. The site is located on alluvial flats adjacent to Badgerys Creek, in a valley floor context. The artefacts, which were approximately five metres apart, were visible in erosion scalds in a road reserve at the eastern end of Pitt Street (Figure 6.18). The exposures are adjacent to a gate on the northern side of the easement.

The surface artefacts are located at the southern end of test location nine.

Artefacts:

1. red silcrete flake, 26 x 15 x 7 mm
2. red silcrete flake, 12 x 8 x 5 mm



Figure 6.18 General view of the location of site B121 (test location 9), looking east from test pit one towards Badgerys Creek (in distance)

B122 - surface artefact occurrence

This recording consists of an open context artefact occurrence of a single surface artefact exposed on the wall of an agricultural dam which impounds a third order streamline (tributary of Cosgroves Creek).

This site is situated in a valley floor context, and in relative proximity to the natural course of the creek line. The subsurface archaeological potential away from the disturbed ground of the dam wall and impoundment is assessed to be moderate to high.

The site is located between potential test locations 36 and 37.

Artefact:

1. red silcrete flake, 20 x 16 x 7 mm

6.2.2 Subsurface recordings

Aboriginal artefacts were recovered from ten of the eleven test locations; the exception was TL1.

Thirty-nine (34%) of the 114 test pits contained Aboriginal artefacts.

Three test locations included only one test pit with artefacts (TL4, 13, and 23), and three included more than five test pits with artefacts (TL6, 9 and 26/27).

Ninety-one Aboriginal artefacts were recovered from 39 test pits.

The highest number of artefacts from a test location was 36.

The highest number of artefacts from a single test pit was seven from pit 9, TL9.

A summary of test location and test pit artefact numbers is provided in Table 6.1.

Some test locations with recovered artefacts have been recorded as more than one site recording, due to landform and distance variables. These divisions are presented in Table 6.2.

Table 6.1 Summary of artefact recovery data from test locations and test pits

test locn	pit	no. of artefacts	spit(s)	total pit depth (cm)	areal incidence of artefacts by pit (artefacts per m^2)	broad scale landform	fine scale landform
1	1	0	1	10	0	major watershed ridgeline	crest
	2	0	1	5	0	major watershed ridgeline	crest
	3	0	1	10	0	major watershed ridgeline	crest
	4	0	1	10	0	major watershed ridgeline	crest
	5	0	1	5	0	major watershed ridgeline	crest
	6	0	1	10	0	major watershed ridgeline	crest
	7	0	1	6	0	major watershed ridgeline	crest
	8	0	1	10	0	major watershed ridgeline	crest
	9	0	1	10	0	major watershed ridgeline	upper slope
	10	0	1	7	0	major watershed ridgeline	upper slope
total	*0 of 10*	*0*					
4	1	0	1	10	0	secondary watershed ridgeline	crest
	2	0	1	10	0	secondary watershed ridgeline	crest
	3	0	1	10	0	secondary watershed ridgeline	crest
	4	0	3	30	0	secondary watershed ridgeline	crest
	5	1	2	23	2	secondary watershed ridgeline	crest
	6	0	1	10	0	secondary watershed ridgeline	crest
	7	0	1	10	0	secondary watershed ridgeline	crest
	8	0	1	10	0	secondary watershed ridgeline	crest
	9	0	1	10	0	secondary watershed ridgeline	crest
	10	0	1	10	0	secondary watershed ridgeline	crest
total 4	*1 of 10*	*1*					
6	1	1	2	20	2	mid slope	minor spur crest
	2	3	2	15	6	mid slope	minor spur crest
	3	2	2	17	2	basal slope	slope
	4	1	3	30	2	basal slope	slope
	5	0	3	25	0	valley floor	alluvial flats
	6	0	3	25	0	valley floor	alluvial flats
	7	0	3	25	0	valley floor	alluvial flats
	8	0	3	25	0	valley floor	alluvial flats
	9	2	3	25	4	valley floor	alluvial flats
	10	1	4	35	2	valley floor	alluvial flats
total 6	*6 of 10*	*10*					
8/10	1	0	2	14	0	mid slope	minor spur crest
	2	0	2	20	0	mid slope	minor spur crest
	3	1	2	16	2	mid slope	minor spur crest
	4	1	1	20	2	mid slope	minor spur crest
	5	0	2	16	0	mid slope	minor spur crest
	6	0	4	40	0	basal slope	minor spur crest
	7	1	5	50	2	valley floor	alluvial flats

test locn	pit	no. of artefacts	spit(s)	total pit depth (cm)	areal incidence of artefacts by pit (artefacts per m^2)	broad scale landform	fine scale landform
	8	0	3	27	0	valley floor	alluvial flats
	9	1	4	35	2	valley floor	alluvial flats
	10	0	5	50	0	valley floor	alluvial flats
total	*4 of 10*	*4*					
9	1	0	4	35	0	basal slope	slope
	2	1	3	30	2	basal slope	slope
	3	6	2	20	12	valley floor	alluvial flats
	4	6	5	50	12	valley floor	alluvial flats
	5	4	5	45	8	valley floor	alluvial flats
	6	1	4	35	2	valley floor	alluvial flats
	7	3	4	37	6	valley floor	alluvial flats
	8	5	3	30	10	valley floor	alluvial flats
	9	7	4	35	14	valley floor	alluvial flats
	10	3	4	34	6	valley floor	alluvial flats
total 9	*9 of 10*	*36*					
13	1	0	2	25	0	secondary spurline crest	knoll
	2	0	1	10	0	secondary spurline crest	crest
	3	1	1	10	2	secondary spurline crest	crest
	4	0	1	10	0	secondary spurline crest	crest
	5	0	2	30	0	secondary spurline crest	shoulder
	6	0	1	10	0	secondary spurline crest	shoulder
	7	0	1	4	0	secondary spurline crest	shoulder
	8	0	2	20	0	secondary spurline crest	shoulder
	9	0	2	18	0	secondary spurline crest	shoulder
	10	0	2	15	0	secondary spurline crest	shoulder
total 13	*1 of 10*	*1*					
14	1	4	2	29	8	mid slope	minor spur crest
	2	0	3	25	0	basal slope	minor spur crest
	3	2	3	30	4	basal slope	minor spur crest
	4	0	2	20	0	basal slope	minor spur crest
	5	0	2	20	0	basal slope	minor spur crest
	6	0	3	25	0	valley floor	elevated rise
	7	0	3	25	0	valley floor	elevated rise
	8	2	3	30	4	valley floor	elevated rise
	9	0	2	20	0	valley floor	elevated rise
	10	0	4	40	0	valley floor	elevated rise
total 14	*3 of 10*	*8*					
23	1	0	2	15	0	upper slope	break-of-slope
	2	0	1	12	0	upper slope	slope
	3	0	2	20	0	upper slope	slope
	4	0	3	30	0	mid slope	bench
	5	0	2	20	0	mid slope	minor spur crest
	6	0	2	20	0	mid slope	minor spur crest
	7	0	3	25	0	mid slope	minor spur crest
	8	0	4	40	0	mid slope	fan
	9	1	4	40	2	basal slope	fan
	10	0	4	40	0	basal slope	fan
total 23	*1 of 10*	*1*					

test locn	pit	no. of artefacts	spit(s)	total pit depth (cm)	areal incidence of artefacts by pit (artefacts per m^2)	broad scale landform	fine scale landform
26/27	1	0	3	30	0	floor	alluvial flats
	2	4	3	30	8	valley floor	alluvial flats
	3	0	2	20	0	floor	alluvial flats
	4	0	3	30	0	floor	alluvial flats
	5	3	3	34	6	valley floor	alluvial flats
	6	5	2	20	10	valley floor	alluvial flats
	7	3	2	20	6	valley floor	alluvial flats
	8	1	2	20	2	valley floor	alluvial flats
	9	0	3	30	0	basal slope	slope
	11	1	2	20	2	upper slope	slope
total 26/27	*6 of 14*	*17*					
32	1	0	2	20	0	mid slope	minor spur crest
	2	0	2	20	0	mid slope	minor spur crest
	3	1	2	15	2	basal slope	minor spur crest
	4	1	2	25	2	basal slope	minor spur crest
	5	0	3	25	0	basal slope	minor spur crest
	6	0	2	20	0	valley floor	alluvial flats
	7	0	3	28	0	valley floor	alluvial terrace
	8	0	1	10	0	valley floor	alluvial terrace
	9	2	1	15	4	valley floor	alluvial terrace
	10	3	2	26	6	valley floor	alluvial terrace
total 32	*4 of 10*	*7*					
37	1	1	6	60	2	valley floor	elevated rise/terrace
	2	2	4	40	4	valley floor	elevated rise/terrace
	3	0	4	40	0	valley floor	elevated rise/terrace
	4	2	4	35	4	valley floor	elevated rise/terrace
	5	1	4	37	2	valley floor	elevated rise/terrace
	6	0	5	50	0	valley floor	elevated rise/terrace
	7	0	3	30	0	valley floor	elevated rise/terrace
	8	0	4	35	0	valley floor	elevated rise/terrace
	9	0	3	30	0	valley floor	elevated rise/terrace
	10	0	3	33	0	basal slope	minor spur crest
total 37	*4 of 10*	*6*					

Table 6.2 Summary of Aboriginal heritage sites recorded in the airport site as part of this assessment (refer to Appendix 2 for map grid references)

Site No.	Site type	No. surface stone artefacts (2015)	Subsurface Site Pit no.	Type of ground surface exposure	Dimensions of ground surface exposure (2015)
B113	sao	20		eroded track and dam wall	150 x 30
B114	sao	10		eroded track, creek edge	110 x 20
B115	sao	20		erosion and disturbance	5 x 5
B116	sao	2		track	
B117	sao	2		erosion scald	
B118	sao	2		edge of ploughed field	
B119	sao	2		gate exposure	
B120	gg	at least 4 grooves		sandstone outcrop	
B121	sao +ssao	3	TL9 pits 2-10	track/gate exposure	
B122	sao	1		dam wall	
B123	ssao		TL6 pits1-4		
B124	ssao		TL6 pits 9&10		
B125	ssao		TL8/10 pits 3&4		
B126	ssao		TL8/10 pits 7&9		
B127	ssao		TL13 pit 3		
B128	ssao		TL14 pits 1&3		
B129	ssao		TL14 pit 8		
B130	ssao		TL23 pit 9		
B131	ssao		TL26/27 pit 11		
B132	ssao		TL32 pits 3&4		
B133	ssao		TL32 pits 9&10		
B134	ssao		TL37 pits 1,2,4 & 5		
B135	ssao		TL4 pit 5		

sao – surface artefact occurrence

ssao – sub-surface artefact occurrence

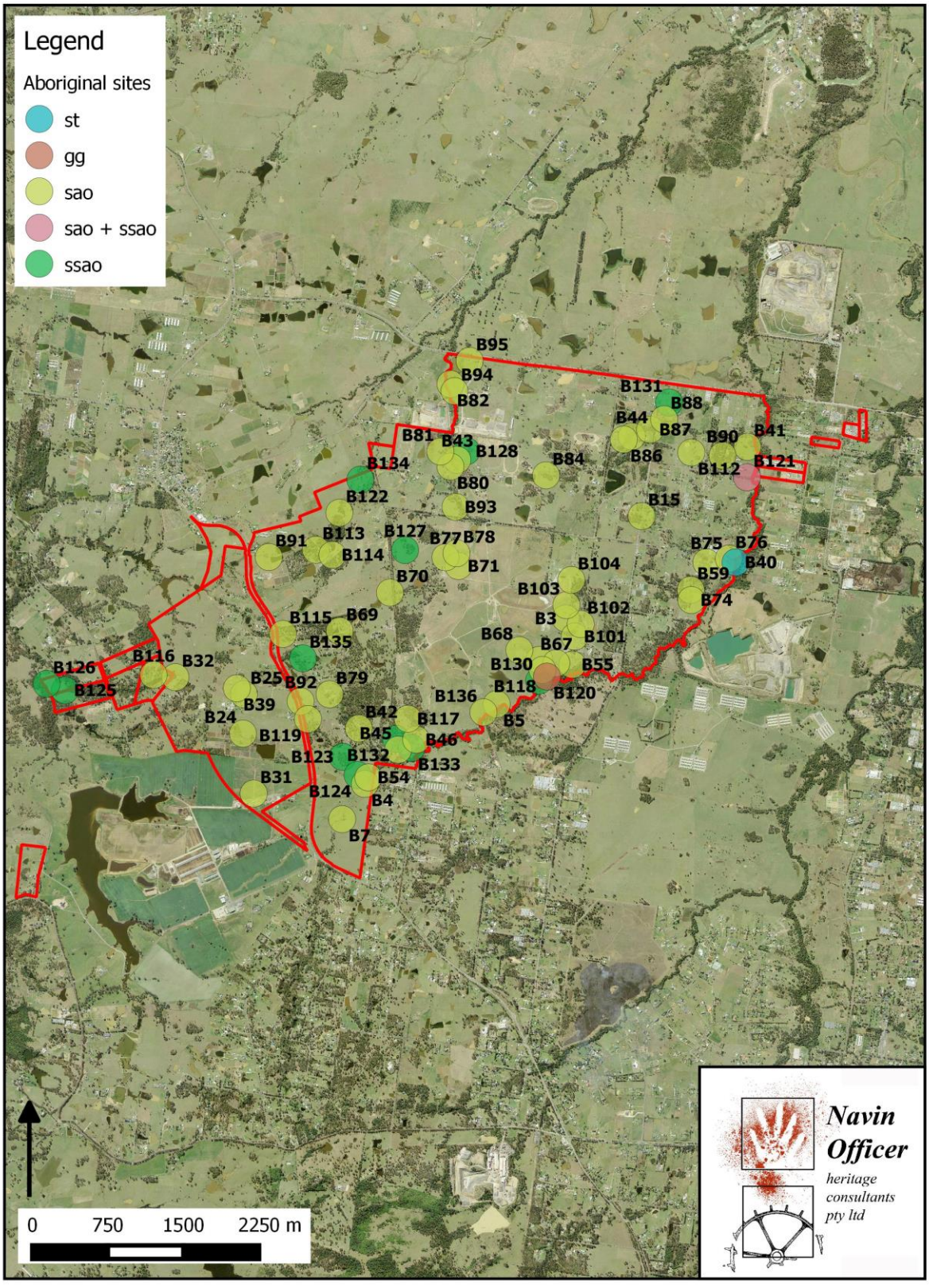


Figure 6.19 General location of all Aboriginal sites recorded to date in the airport site (gg = grinding grooves, sao = surface artefact occurrence, ssao = sub-surface artefact occurrence). *Only generalised site locations are shown for this unrestricted access version of the report.*

6.3 Analysis

6.3.1 Overview of the artefact assemblage, by test location

In this section, artefacts from each excavated test location (shortened to 'location' throughout this report) are pooled together, so that each location is treated as a single data set. This enables the assemblages recovered from the different excavated locations to be compared.

The sample of artefacts recovered from the study location is dominated by unretouched flakes, with retouched flakes, cores and flaked pieces also present (Table 6.3). No ground artefacts were recovered from test excavations. The ratio of retouched flakes to unretouched flakes is quite high relative to typical stone artefact assemblages in south east Australia, with 11 retouched flakes and 76 unretouched flakes. Retouched flakes make up 12 per cent of the total assemblage. As a point of comparison, a number of excavated sites documented in the Mangrove Creek catchment all contained assemblages in which retouched flakes made up less than one per cent (Attenbrow 2004, table 4.7).

The assemblage is distributed unevenly between the different locations, with a small number of the locations yielding high numbers of artefacts. The majority of locations yielded fewer than ten artefacts each. The notably rich locations were location nine (36 artefacts) and location 26/27 (17 artefacts). The same number of test pits (ten) were excavated in each of the locations, and so the number of artefacts recovered from each location is proportional to the average density of artefacts in that location. Comparing the total number of artefacts recovered from the different locations, in other words, is equivalent to comparing the average density of artefacts between the different locations. For example, location 14 has twice the density of artefacts as location 8/10 (8 artefacts and 4 artefacts in total, respectively).

The uneven distribution of artefacts between the different locations is clear when the total count of artefacts is plotted according to location (Figure 6.20). Plotting the locations in descending order of their artefact counts, reveals that the distribution of artefacts across the separate locations resembles a very strongly skewed normal distribution, or a Poisson distribution. The distribution of artefact counts between locations is consistent with what would be expected from a random sampling of a population that is sparsely and unevenly distributed. In such situations, the expected pattern of sample sizes is for the majority of samples to contain relatively low counts, with a small number of samples containing much higher counts. The distribution of sample sizes between the different test locations, therefore, is consistent with the distribution that would be expected when sampling a random and representative sample of a population of artefacts that is unevenly distributed across the landscape.

The sample of retouched flakes consists mainly of backed artefacts (Table 6.4). Backed artefacts are a common type of retouched flake in south east Australia, and it is not unusual for a stone artefact assemblage to have a high proportion of backed artefacts in its set of retouched flakes (Attenbrow 2010).

Backed artefacts are a distinctive artefact type, within which the artefacts display considerable internal homogeneity in their shape and patterns of retouch present, and which are distinctively different in shape and retouch patterns from other artefacts found in Australian sites. They are found across the continent, with the exception of the northern tip of West Australia, the northern half of the Northern Territory, and Cape York (Smith and Cundy 1985).

Similar artefacts are found in the Indian subcontinent, the Middle East, Europe and southern Africa, but it has not been established that backed artefacts in these regions have any relationship to the appearance of backed artefacts in Australia – at this stage it is generally thought that Aboriginal populations invented backed artefact technology independently of other prehistoric populations (Hiscock 2008).

Table 6.3 All stone artefacts recovered, by location and technological type

location	unretouched flake	retouched flake	core	flaked piece	row total
4	0	0	0	1	1
6	7	3	0	0	10
8/10	4	0	0	0	4
9	29	4	2	1	36
13	1	0	0	0	1
14	5	3	0	0	8
23	1	0	0	0	1
26/27	16	1	0	0	17
32	7	0	0	0	7
37	6	0	0	0	6
column total	76	11	2	2	**91**

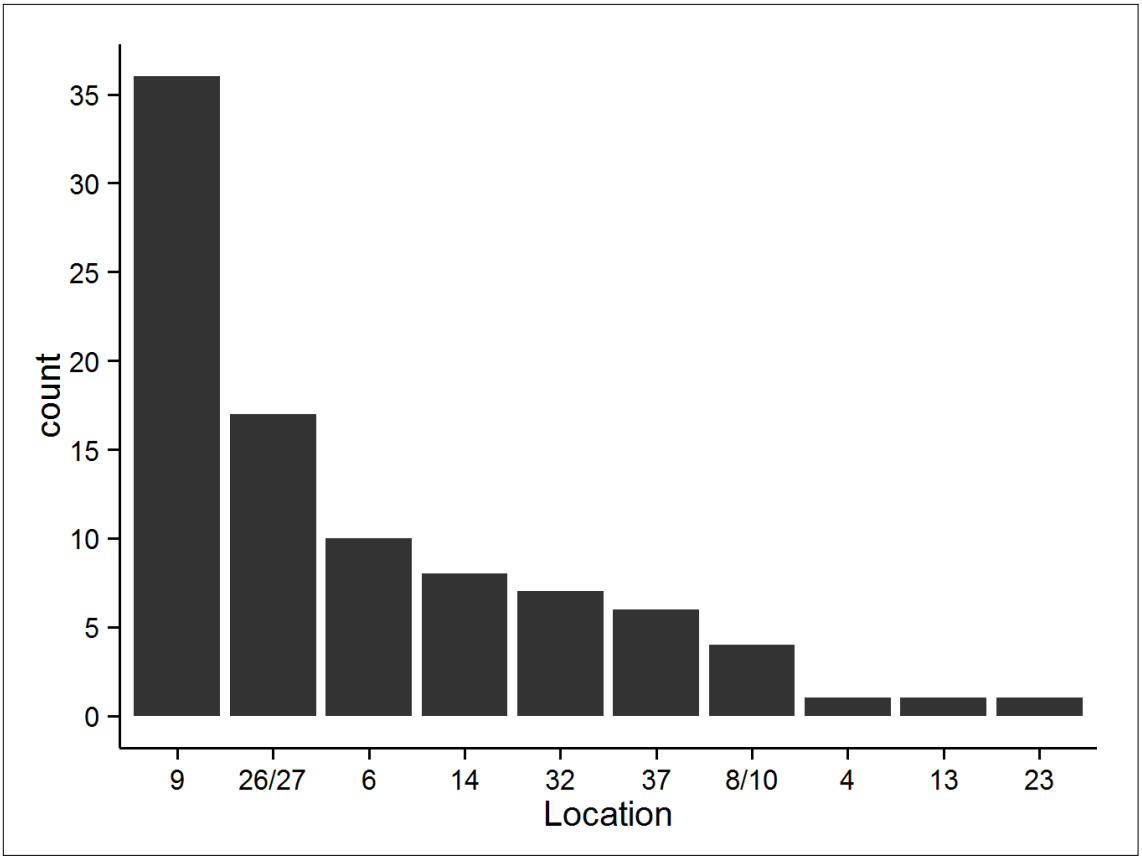


Figure 6.20 Count of stone artefacts by location

The backed artefacts recovered from the test excavations are subdivided into several different shapes: triangles, a crescent and trapezes are all present in the total assemblage (Figures 6.23 – 6.28). One backed artefact of indeterminate shape was recovered. Two woakwines were recovered: woakwines are backed artefacts on which the backing retouch is restricted to one end of the artefact.

One burin was recovered from location 14. A burin is a retouched flake with retouch scars that run along the margin (Noone 1938). The retouch scars can be initiated from existing surfaces on the flake, from break surfaces or from surfaces prepared through previous retouch (Barton et al. 1996; Tomáŝková 2005). Although there has been a long history of assuming that burins were functional tools, used for engraving purposes (e.g. Stafford 1977), it has been demonstrated that in many contexts they served to produce flakes that could be recruited as tools, and had no functional use themselves (Barton et al. 1996; Cochrane et al. 2013; Hiscock 1993).

The burin recovered from location 14 has retouch scars travelling along one of its lateral margins, initiated from a break at the distal end of the flake (Figure 6.22). Several of these scars are step-terminated, and it is possible that the occurrence of these step terminations caused the reduction of the artefact to be ceased. Step terminations create a problem for flake removal, in that they make it likely that further flakes struck from the same platform will also step or hinge terminate (Macgregor 2005).

The remainder of the retouched flakes are flakes with amorphous retouch. Amorphous retouch refers to retouch that has not functioned to shape the artefact to conform to any implement type that is generally recognised by archaeologists. The two retouched flakes that fell into this category were both broken flake fragments. One was possibly a fragment of a backed artefact: the size and angle of retouch scars is consistent with retouch found on backed artefacts, but the artefact is too incomplete to be sure that it can be classified as a backed artefact.

Table 6.4 Retouched flakes recovered, by location and retouched artefact type

location	backed triangle	backed woakwine	backed crescent	backed indeterminate	backed trapeze	burin	retouched flake (other)	row total
6	1	0	0	0	1	0	1	3
9	0	2	1	1	0	0	0	4
14	1	0	0	0	0	1	1	3
26/27	0	0	0	0	1	0	0	1
column total	2	2	1	1	2	1	2	**11**

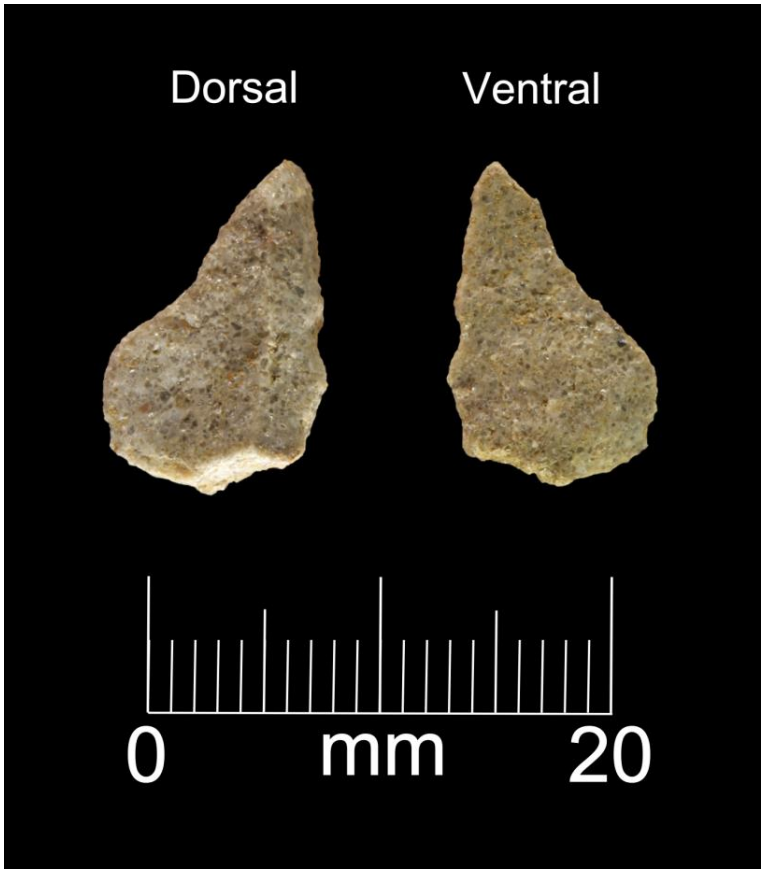


Figure 6.21 Silcrete retouched flake,
possibly a broken backed artefact, from Location 1

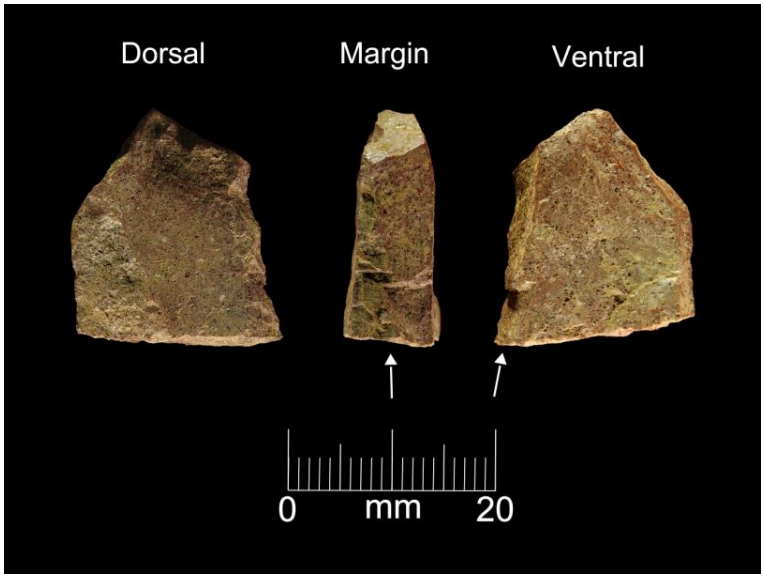


Figure 6.22 Silcrete burin from Location 14.
Arrows show burin flake scars

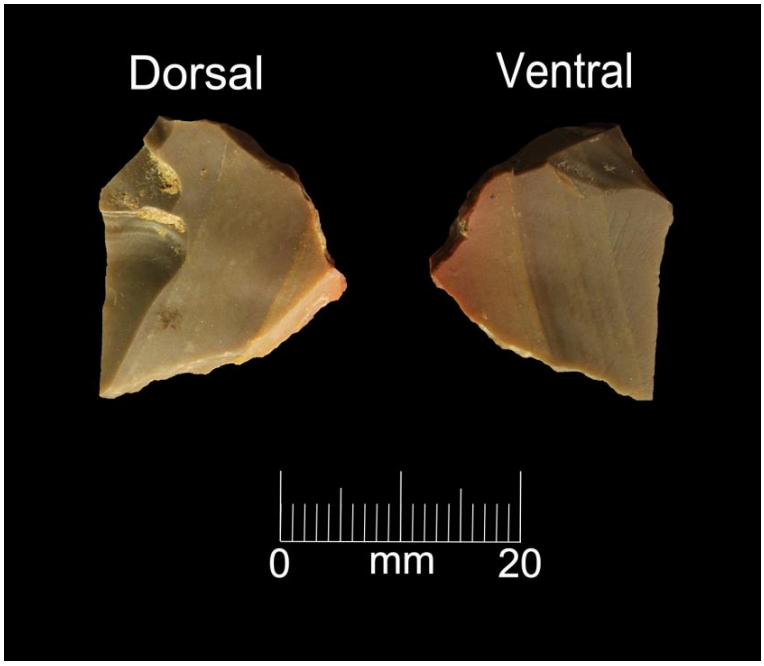


Figure 6.23 FGS backed triangle from location 14

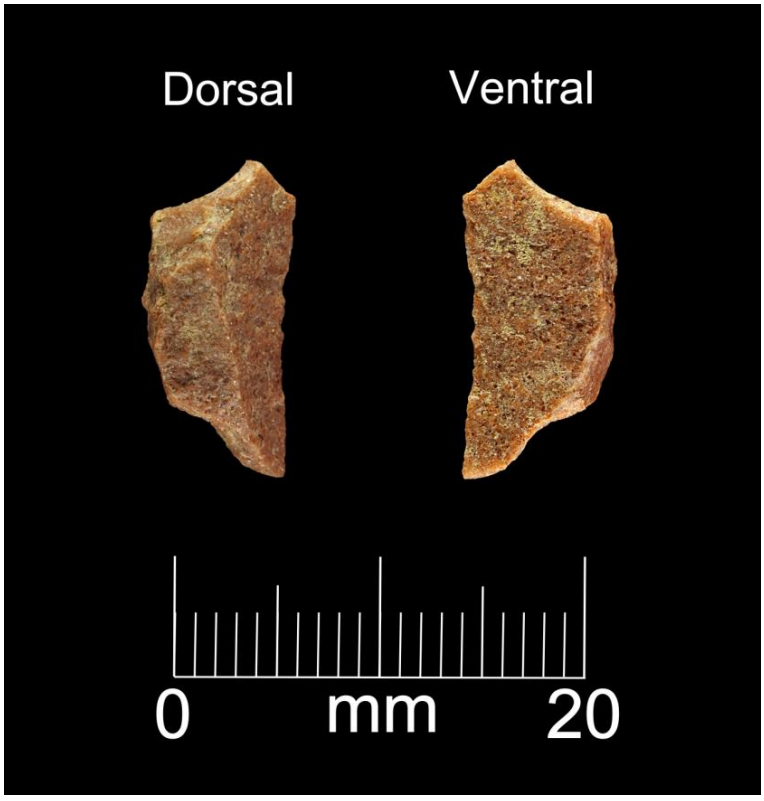


Figure 6.24 Silcrete backed trapeze from location 26/27

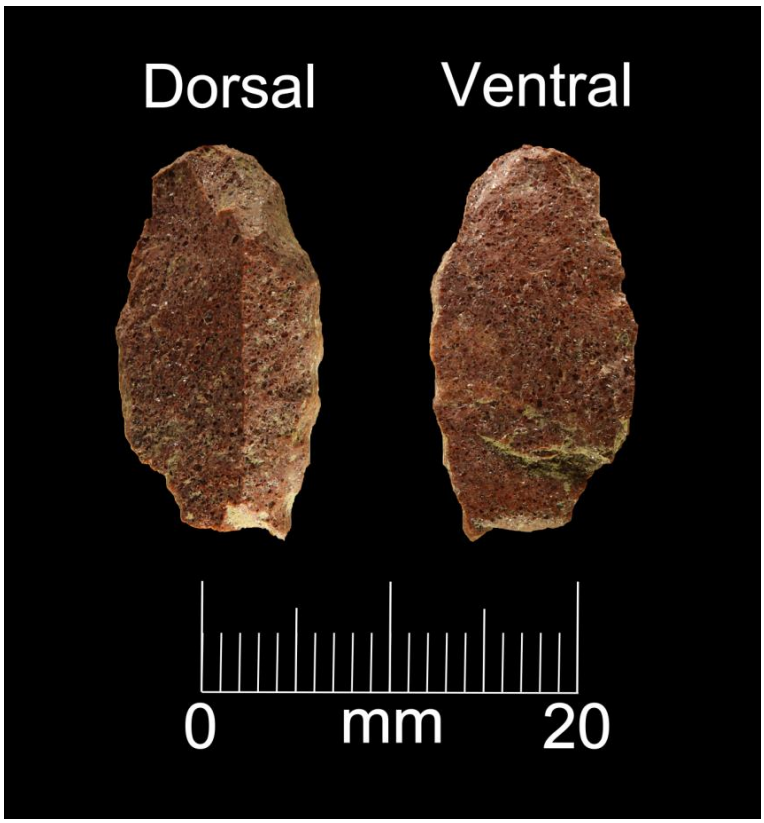


Figure 6.25 Silcrete broken backed artefact, indeterminate shape, from location 9



Figure 6.26 Silcrete backed woakwine from location 9

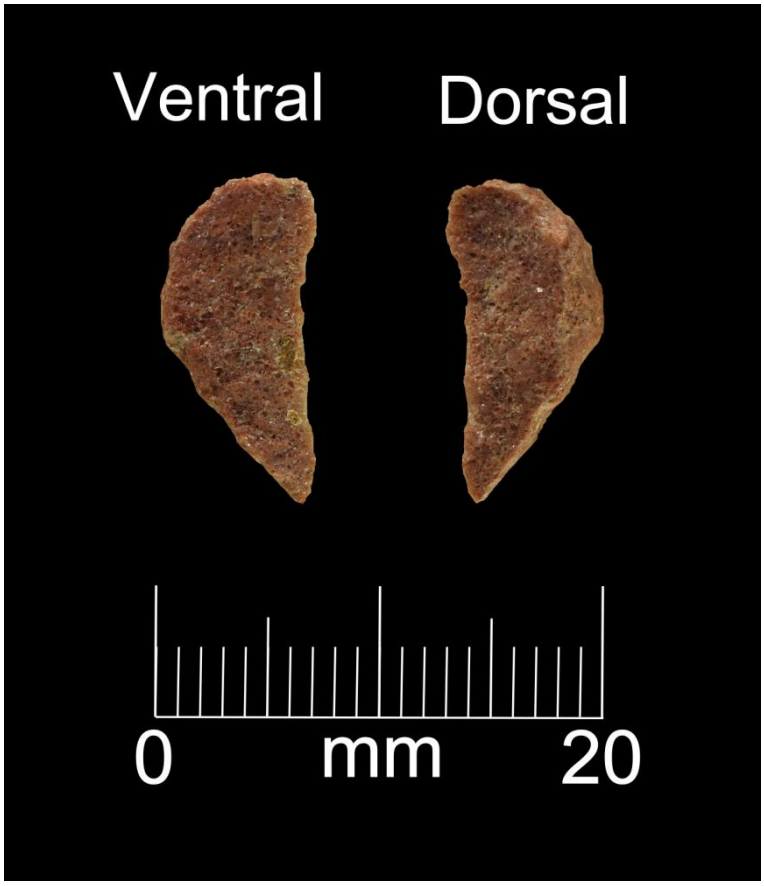


Figure 6.27 Silcrete backed crescent from location 9

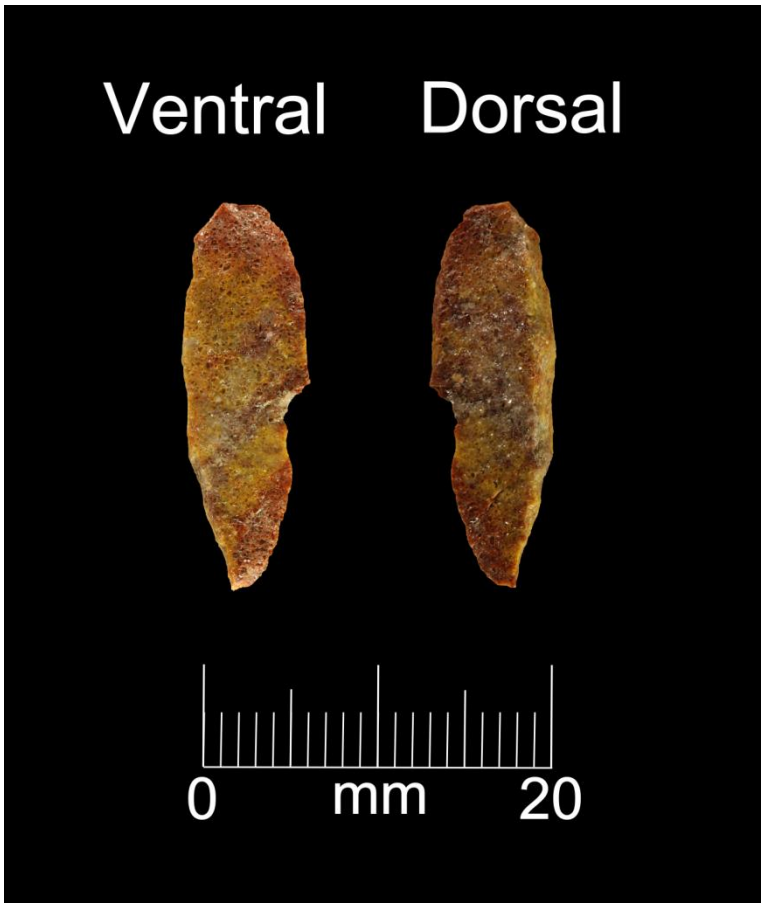


Figure 6.28 Silcrete backed woakwine from location 9

Four different raw material types were identified within the stone artefacts recovered:

- silcrete;
- vein quartz;
- igneous; and
- fine grained siliceous (FGS).

FGS is a category that encompasses all artefacts made of material in which no grain structure can be identified.

Silcrete is the material from which the majority of the assemblage of artefacts is made (Table 6.5). Silcrete artefacts make up the highest proportion of the assemblage from almost all of the individual locations.

Fine grained siliceous materials are the next most common material. FGS artefacts could be chert; fine grained sedimentary rock such as mudstone or redeposited volcanic ash; tuff; or fine grained metamorphics.

Quartz and igneous materials are present, with a small number of artefacts being made from these materials.

The proportion of materials is generally equivalent across the locations, with no statistically significant association between individual locations and the proportion of different materials recovered (Fisher's exact test, p=0.104).

Table 6.5 All stone artefacts recovered, by location and material

location	silcrete	FGS	quartz, vein	igneous	row total
4	0	1	0	0	**1**
6	4	4	2	0	10
8/10	2	1	1	0	4
9	28	8	0	0	36
13	0	1	0	0	1
14	4	4	0	0	8
23	1	0	0	0	1
26/27	15	1	0	1	17
32	6	1	0	0	7
37	4	2	0	0	6
column total	64	23	3	1	**91**

6.3.2 Overview of assemblage characteristics

In this section, artefacts recovered from all test pits and all locations are pooled together and examined as a single data set. This provides an overview of the complete sample of artefacts recovered during the test excavation program. The pooled data set is large enough to allow statistical testing of relationships that might exist between different artefact characteristics within the combined assemblage.

No detectable association exists between the material and technological type of stone artefacts (Fisher's exact test, p=0.365). The data provide no reason to conclude that the any material was used with higher frequencies in the production of some artefact types and not others. In other words, there is no evidence from the data that different artefact types are preferentially produced from different materials (Table 6.6).

Table 6.6 All stone artefacts recovered, by material and technological type

material	unretouched flake	retouched flake	core	flaked piece	row total
silcrete	54	9	1	0	64
FGS	18	2	1	2	23
quartz, vein	3	0	0	0	3
igneous	1	0	0	0	1
column total	76	11	2	2	**91**

No detectable association exists between breakage and material type (Fisher's exact test, p=0.68). The data do not indicate that different types of artefact have suffered different extents of damage (Table 6.7). More than half of the flakes (both unretouched and retouched) are broken fragments. Breakage of artefacts can occur during production, during use (if the artefact was used as a functional tool) or following discard. The proportion of broken artefacts in the assemblage could be indicative of a high frequency of breakage in any or all of these contexts.

The ratio of broken to complete artefacts is not unusual relative to other archaeological sites in south east Australia. The study location falls within the range of breakage frequencies commonly observed on open sites. The data do not indicate that the artefact assemblage from the study area is unusually undamaged and intact, or that the artefacts have suffered unusually high frequencies of artefact breakage.

Table 6.7 All artefacts recovered - by completeness and technological type

completeness	unretouched flake	retouched flake	core	flaked piece	row total
complete	28	6	2	2	38
proximal fragment	7	3	-	-	10
medial fragment	4	1	-	-	5
distal fragment	24	1	-	-	25
marginal fragment	5	0	-	-	5
LCS left	4	0	-	-	4
LCS right	4	0	-	-	4
column total	76	11	2	2	**91**

Examining flakes alone, the proportions of complete and broken artefacts are similar between material types (Table 6.8). There is no detectable association between material type and completeness category (Fisher's exact test, p=0.819). The data do not indicate that artefacts made of different materials have suffered different extents of damage.

Table 6.8 Flakes - by material and completeness

material	complete	proximal fragment	medial fragment	distal fragment	marginal fragment	LCS left	LSC right	row total
silcrete	25	7	3	18	3	3	4	63
FGS	6	3	2	7	1	1	0	20
quartz, vein	2	0	0	0	1	0	0	3
igneous	1	0	0	0	0	0	0	1
column total	34	10	5	25	5	4	4	**87**

The amount of cortex on the dorsal surfaces of flakes in an assemblage is indicative of the stage in the reduction process in which the flakes were produced (Marwick 2008). Assemblages of flakes produced early in the process of core reduction will have high proportions of their dorsal surfaces covered by cortex, while assemblages produced later in the core reduction process will have no cortex. The proportion of dorsal cortex on flakes was characterised using several categories recording both the amount and location of cortex on the dorsal surface (following Marwick 2008). In addition to this variable, the percentage of the dorsal surface covered in cortex was estimated for each flake, to the nearest ten percent.

Tertiary flakes make up the great majority of the assemblage of flakes, with cortex being vanishingly rare across all material types (Table 6.9). No detectable association exists between material and cortex distribution (Fisher's exact test, p=0.16). There is a significant association between material and dorsal cortex percentage (Kruskal-Wallis chi-squared=11.14, d.f.=3, p=0.011) however this is caused by the single igneous flake, which has a high percentage of dorsal cortex (Table 6.10). When this flake is removed, there is no significant association between material type and cortex percentage (Kruskal-Wallis chi-squared=0.615, d.f.=2, p=0.735). With the exception of the single igneous flake, therefore, the different materials show similar proportions of dorsal cortex on flake surfaces, with tertiary flakes being the dominant proportion of the sample of flakes of each material type.

The single igneous flake recovered from the test excavations indicates that igneous flakes in the study area were produced at an earlier stage in the reduction process than flakes made from other material types. The very small sample size of only one igneous flake, however, means that very little confidence can be placed in this inference. A larger sample of flakes would be required before robust inferences could be made on the differences in dorsal cortex on igneous flakes relative to flakes made from other materials.

The high frequency of tertiary flakes, and the generally low proportions of dorsal cortex on secondary flakes, is consistent with an assemblage produced in a situation where accessing sources of stone was costly. An assemblage of flakes produced under circumstances where obtaining replacement nodules of stone involves a cost (in terms of time or energy expended), would be expected to have a low frequency of cortex, as the nodules that people have to hand would be more intensively flaked and reduced. This could be the case if the study area is located at a substantial distance from the nearest sources of stone.

Table 6.9 Flakes recovered - by material and dorsal cortex distribution

material	tertiary	distal only	patch right	crescent left	primary	row total
silcrete	57	3	1	1	1	63
FGS	19	0	0	0	1	20
quartz, vein	3	0	0	0	0	3
igneous	0	0	1	0	0	1
column total	79	3	2	1	2	**87**

Table 6.10 Flakes - by material and dorsal cortex percentage

material	0	10	20	30	40	50	60	70	80	90	100	row total
silcrete	57	1	2	2	0	0	0	0	0	0	1	63
FGS	19	0	0	0	0	0	0	0	0	0	1	20
quartz, vein	3	0	0	0	0	0	0	0	0	0	0	3
igneous	0	0	0	0	0	0	1	0	0	0	0	1
column total	79	1	2	2	0	0	1	0	0	0	2	**87**

Flake platforms are mostly simple, single surfaces (Table 6.11). Multiple-surface and facetted platforms are quite frequent also. This could be indicative that the flakes in the assemblage have been produced from small, heavily reduced cores. Small, heavily reduced cores are more likely to have densely clustered surfaces, and striking flakes with multiple surfaces preserved on their platforms will be more common as a result of this.

Facetting platforms is generally employed as a strategy of reducing the risk of problems occurring during flake production (Whittaker 1994). The high frequency of facetted platforms in the assemblage could be indicative of a situation in which Aboriginal people were employing risk-reduction strategies in order to maximise the reduction potential of the stone they had available. This is consistent with the data on dorsal cortex, being indicative of a situation in which obtaining replacement stone was costly for Aboriginal groups occupying the study area.

The frequency of platform types is generally similar across the different materials, with no significant association between material and platform type (Fisher's exact test, p=0.664). The data do not indicate that different platform types were being employed with differing frequencies in the flaking of different materials.

Table 6.11 Flakes - by material and platform type

material	single	shattered	multiple	facetted	focalised	cortical	none	row total
silcrete	19	6	5	3	1	1	28	**63**
FGS	5	1	1	2	1	0	10	**20**
quartz, vein	1	1	0	0	0	0	1	**3**
igneous	0	1	0	0	0	0	0	**1**
column total	**25**	**9**	**6**	**5**	**2**	**1**	**39**	**87**

The assemblage is composed of small flakes, with the largest flake being only 23.38 millimetres long, and the median flake length being 12.28 millimetres (Table 6.12). Other dimensional variables exhibit ranges that are similarly restricted in their upper limit. The small size of flakes is consistent with the inference that the assemblage consists of flakes that were struck from small, and most likely heavily reduced cores.

The presence of small flakes indicates that knapping was carried out within the study location. The assemblage contains flakes with length lower than 10 millimetres, which is generally accepted as evidence of in-situ knapping (flake production) having taken place on location. Knapping usually produces a large number of small flakes relative to a small number of big flakes (Ahler 1989; Andrefsky 2007). The presence of small flakes also indicates that the assemblage was produced by knapping that occurred on-location, as small flakes are unlikely to have been transported into locations from elsewhere.

Generally, the presence of flakes under 10 millimetres is seen as indicating that knapping was carried out on location, as these flakes are unlikely to have been functional as tools and consequently are unlikely to be objects that would be transported from place to place (Dibble and McPherron 2006; Nadel 2001). Small flakes will not be found (or will be uncommon) on locations where knapping was not carried out, or was not a major component of the activities being carried out at that location. An example of this situation would be locations where large tools have been selectively gathered in a particular location and cached for future use (Hiscock 1988).

Locations with specific prehistoric uses, relating to resource-gathering (for example camps of hunting groups or carcass processing locations) could also have assemblages with size distributions skewed towards large artefacts, due to the absence of non-functional flakes (Andrefsky 2005).

Table 6.12 Descriptive statistics for dimensional variables of complete flakes

	valid n	minimum	25th percentile	median	75th percentile	maximum
length	34	4.25	8.14	12.28	15.76	23.38
width	34	4.22	6.61	7.22	11.06	22.58
thickness	34	0.67	1.68	2.78	3.73	10.25
platform width	27	2.37	4.04	5.29	8.46	19.67
platform thickness	24	0.48	1.11	1.75	3.04	8.36

The only apparent difference between flakes made from the different material is that the quartz flakes seem to be smaller than those made of other materials. A boxplot of the distributions of flake length illustrates this apparent size difference between materials (Figure 6.29). The single igneous flake is the largest flake in the assemblage, but the fact that this sample is only a single flake means that it is difficult to draw conclusions with any confidence as to whether igneous rock was being flaked in different ways to other materials. Statistically, there is no significant difference in any of the dimensional variables between flakes made from the different materials (Table 6.13: all p-values are greater than 0.1). This means that the apparent difference in distributions of flake size could be the result of random sampling effects. The data cannot be used to infer that any differences exist in the population of flakes within the study area.

The samples of artefacts made from the three most common materials (Silcrete, FGS and vein quartz) all contain flakes that are less than 10 millimetres in length. This indicates that all three materials were being knapped in-situ on the locations in the study location. This is consistent with an interpretation that these locations were associated with activities involving artefact production or maintenance.

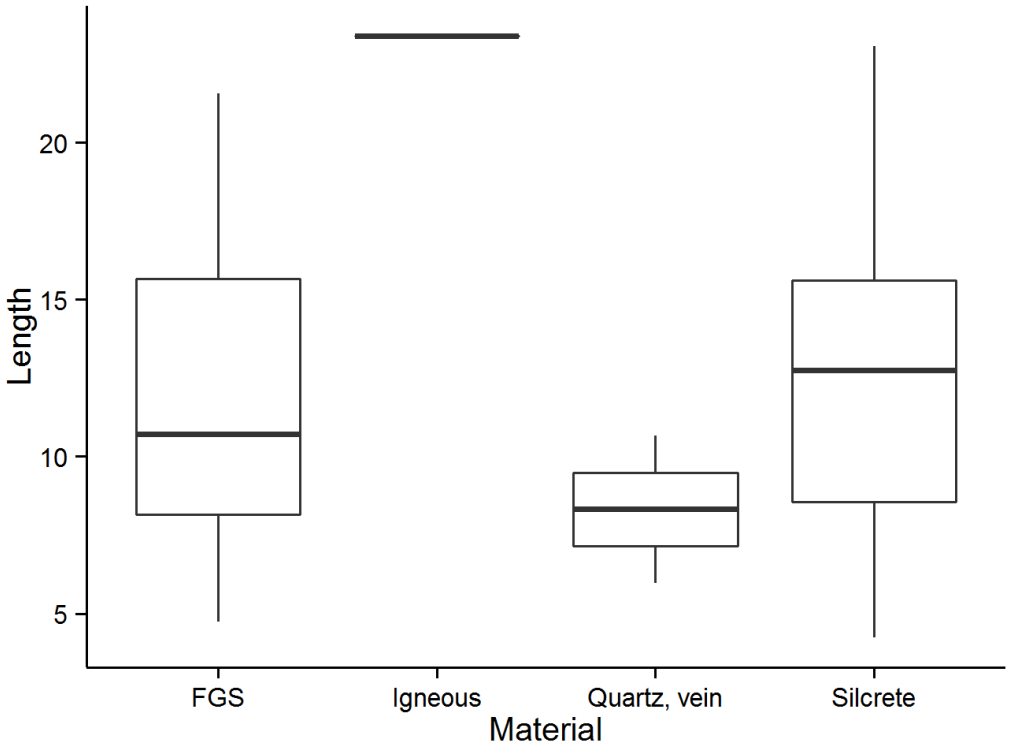


Figure 6.29 Boxplot of flake length by material type (complete flakes only)

Table 6.13 Kruskal-Wallis tests for differences in dimensional variables between all material types (complete flakes only)

	Kruskal-Wallis chi-squared	df	p-value
length	10.89	7.00	0.143
width	7.15	7.00	0.413
thickness	10.80	7.00	0.148
platform width	5.55	6.00	0.476
platform thickness	6.68	6.00	0.351

Flakes in the assemblage exhibit a wide range of variation in their shape. The relationship between flake length and flake width (referred to as a flake's 'elongation') quantifies the general shape of flakes in plan view. Plotting the length and width of flakes as a scatterplot illustrates that the elongation of flakes in the assemblage is highly variable, with some flakes being wider than they are long, and other flakes more than twice as long as they are wide (Figure 6.30).

There is a positive relationship between the two variables (shown by the linear trend-line fitted to the data). This relationship is not a statistically significant correlation, however (Spearman's rho=0.314, p=0.07). This means that it cannot be confidently inferred that flake length increases with increasing flake width in the overall population of flakes within the study area – the apparent relationship between the two variables could be the result of random chance. The individual data points are widely scattered above and below the trend-line.

Elongation of flakes is indicative of the types of core the flakes were produced from, and is also indicative of the degree to which the flake production process was standardised. Cores that are repeatedly flaked in the same orientation, and which develop worked surfaces with parallel dorsal ridges, tend to produce highly elongate flakes (Crabtree 1968). Cores that are frequently rotated between flake removals, or which are not elongate in shape, will produce flakes that are not elongate (Brantingham and Kuhn 2001; Shimelmitz et al. 2011).

The variability in flake elongation exhibited in the assemblage indicates that patterns of core reduction in the study area were similarly variable. The presence of both elongate and non-elongate flakes, and the wide range in elongation values, indicates that there was substantial variability in the morphology of core surfaces from which flakes were struck. The data indicate that patterns of core reduction were not standardised, and the production of flakes was not geared toward the production of flakes of any particular shape.

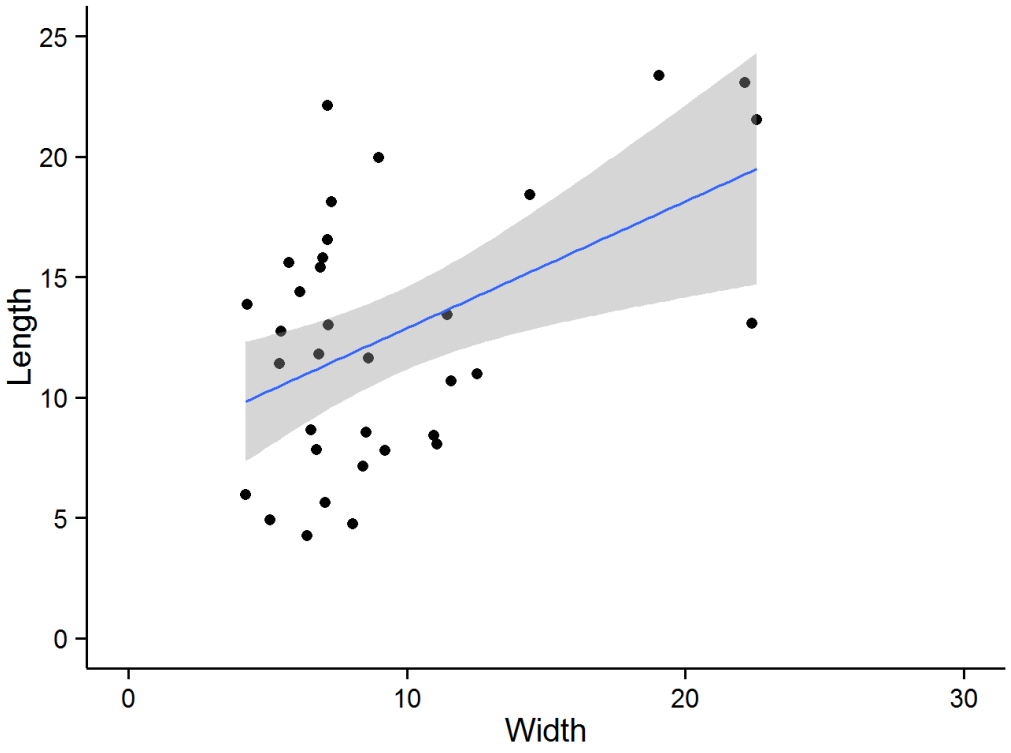


Figure 6.30 Scatterplot of flake length vs flake width (complete flakes only)

The relationship between a flake's platform width and its quarter width (the width of the flake, as measured one quarter along its length) shows how pronounced the expansion of the flake's margins are. Flakes struck from cores with flat or shallowly curved surfaces have margins which expand outwards in plan view, meaning that the width of the flake increases relative to the width of its platform, along the flake's length (Speth 1972, 1975). In contrast, flakes struck from cores with steeply curved or ridged surfaces have margins which do not expand as greatly – these flakes tend to have margins that are parallel to one another, meaning that the width of the flake doesn't increase along its length (Inizan et al. 1999).

The sample of complete flakes recovered from the test excavations exhibits substantial variability in terms of the degree to which their margins expand. All but one of the flakes has expanding margins (in that their quarter width is greater than their platform width) but the degree to which the flakes' quarter widths are greater than their platform widths is highly variable. Figure 6.31 plots each flake's quarter width against its platform width to illustrate this. Two lines have been drawn on the graph: the black line shows the values where quarter width and platform width are the same. Flakes lying below this line have contracting margins, in that their quarter width is less than their platform width. Flakes lying on the line have parallel margins, with their quarter width and platform width being equal. Flakes lying above the black line have expanding margins: their quarter width is greater than their platform width. The red line shows the values where quarter width is twice the platform width. Flakes lying on or above the red line have margins that expand dramatically, to the extent that the width of the flake doubles over one quarter of its length.

Most of the flakes in the assemblage fall above the black line, but below the red line. Three flakes fall above the red line, and one flake falls below the black line. The flakes between the two lines are scattered more or less evenly between the two lines, with no evident clustering of data points around either line. The data from this sample indicates that flakes in the study location are not standardised in terms of the degree to which their margins expand, which indicates that they were struck from cores which were variable in terms of the shapes of their worked surfaces. The data show no indication that flake production on the airport site was focused on the production of flakes of any particular shape, which is consistent with the data on flake elongation discussed above.

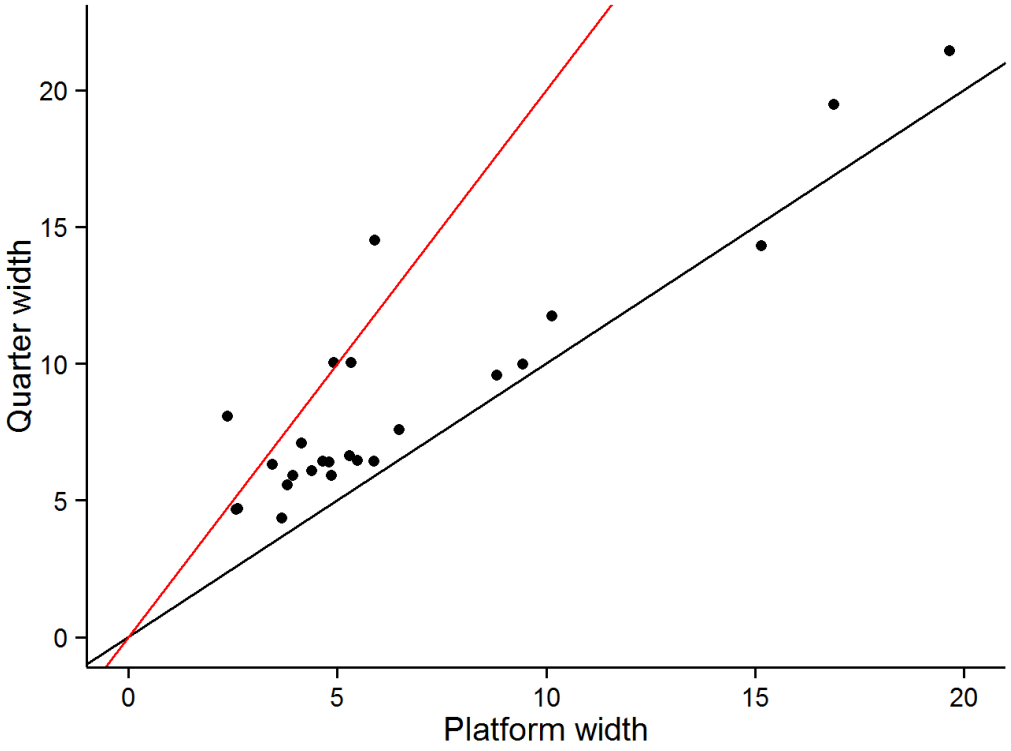


Figure 6.31 Scatterplot of flake quarter width vs platform width (complete flakes only). Drawn lines mark arbitrary thresholds

Both methods of examining flake shape – elongation, and comparing platform width with quarter width – indicate that patterns of flake production being employed by the groups occupying the study area were not standardised. The data do not provide any evidence for flake production systems being organised with the aim of producing standardised and regular flakes of any particular shape or morphology.

6.3.3 Analysis of assemblage variation across landforms

The relationship that people feel to the landscape and their appreciation for landform, functionally and spiritually, is documented as existing in the present, and is assumed to have operated, possibly in similar ways, in the past (Kiernan 2015). Terrain unit analyses are employed here to investigate the distribution and variation of archaeological materials relative to the landforms in which they are found. This analyses deal exclusively with lithic technologies (stone tools), noting where European heritage items or non-artefactual stone was recovered in order to describe the extent of subsurface disturbance and its natural or cultural origin.

This section of the report will provide a general introduction to the broader Badgerys Creek landscape and then discuss each of the terrain units within the project location that yielded subsurface artefacts testing program, finishing with a summary of the results of the terrain unit analysis.

Landform categories and sample size

The landscape has been subdivided according to several different landform variables. Each of these variables was categorical, meaning that a given location of ground would be classified as one of a number of mutually exclusive categories within each variable.

The number of test pits excavated from the different categories of each landform was not always equal between categories. This is because test pits were preferentially placed on landforms considered to have the potential to contain subsurface archaeological material. The primary aim when designing the placement of test pits in the landscape was not to sample the different landform categories equally. Instead, this aim was secondary to the aim of targeting locations of high archaeological potential.

The landform variables utilised in this study, as well as the categories which each landform was subdivided into and the number of test pits excavated within each of these landform categories, are summarised in Table 6.14.

A total of 114 test pits were excavated, each of which was assigned to one of the categories within each of the nine landform variables.

In addition to these categorical variables, the elevation of each excavated pit was recorded, both in absolute terms (elevation above the Australian sea level datum) and in relative terms (elevation above the nearest drainage greater than 1st order).

Table 6.14 Summary of the landform categories sampled, and the number of test pits excavated (n) within each category

landform variable	categories												
broad scale	valley floor (n=45)	basal slope (n=17)	mid slope (n=15)	upper slope (n=5)	minor spurline crest (n=1)	secondary spurline crest (n=11)	2nd watershed ridgeline (n=10)	major watershed ridgeline (n=10)					
fine scale landform category	alluvial flats (n=26)	alluvial terrace (n=4)	bench (n=1)	break-of-slope (n=1)	crest (n=21)	elevated rise/terrace (n=9)	fan (n=3)	knoll (n=1)	minor spur crest (n=22)	saddle (n=2)	shoulder (n=6)	slope (n=10)	upper slope (n=10)
watershed spurline order	1 (n=27)	2 (n=13)	3 (n=4)	4 (n=10)	5 (n=10)								
slope category	flat (n=71)	low (n=29)	low to moderate (n=9)	moderate (n=5)									
within 100 m of 1st order drainage	no (n=43)	yes (n=71)											
highest drainage line order within 100m	1 (n=28)	2 (n=11)	3 (n=26)	4 (n=10)	5 (n=30)								
order of closest drainage line	1 (n=47)	2 (n=15)	3 (n=12)	4 (n=21)	5 (n=19)								
overall valley context	lower (n=68)	middle (n=26)	upper (n=20)										
aspect	e (n=5)	ne (n=4)	nw (n=9)	o (n=71)	s (n=10)	se (n=2)	sw (n=10	w (n=3)					

6.3.4 Assemblage density relative to landform

The consistent dimensions of the excavated test pits, each of which was 1 m x 0.5 m, means that the number of artefacts recovered from each pit provides data on the areal density of artefacts within the landform in question. Areal density is the number of artefacts found on a location of ground, regardless of the depth at which the artefacts were found. The depth at which artefacts were recovered is ignored in this analysis, as all artefacts were recovered from shallow depths, and the depth from which individual artefacts were recovered was not interpreted as being indicative of the age of the artefacts (see Appendix 1).

A statistically significant difference exists between the number of artefacts recovered from excavated pits according to the broad scale landform category the pits were located in (Kruskal-Wallis chi-squared=21.89, d.f.=7, p=0.003).

For each broad scale landform category, the majority of excavated pits yielded no artefacts, with a small number of pits yielding one or more artefacts (Figure 6.32).

The valley floor landform contained the most archaeologically productive pits, with the richest pit yielding seven artefacts.

Mid slope and basal slope landforms were the landforms with the next highest densities, with all other landforms yielding a maximum of one artefact per pit.

When the valley floor category is removed from the data, all other landforms show no statistically significant difference in their distributions of artefacts recovered per pit (Kruskal-Wallis chi-squared=10.01, d.f.=6, p=0.124). In other words, the data do not provide any evidence to conclude that the other landforms are different in terms of their areal density of artefacts. The statistically significant difference detected in comparing all landforms with one another is due to the pits excavated on the valley floor being archaeologically richer than the pits excavated on other landforms.

A statistically significant difference exists between the number of artefacts recovered from pits across the different fine-scale landform categories (Kruskal-Wallis chi-squared=29.5, d.f.=13, p=0.006). Within each landform category, the majority of excavated pits yielded zero artefacts, causing each landform category to have a very low median number of artefacts recovered per pit (Table 6.15). Only two categories, alluvial flats and alluvial terraces, have a median value one artefact per pit, with all other categories having a median value of zero artefacts per pit.

The distribution of artefacts recovered per pit is highly skewed for most landform categories: in most categories, there were a small number of pits that yielded a much greater number of artefacts than the median or mean for that landform. The distribution of artefacts recovered from pits within each landform can be seen in more detail by tabulating the number of excavated pits relative to the number of artefacts recovered (Table 6.16). In this table, each column designates the number of artefacts recovered from a pit, and the values in the table are a count of the number of pits excavated that yielded that number of artefacts.

The frequency table indicates that alluvial flats were substantially more productive than other landform categories, with more than half of the pits within this landform yielding artefacts (in other landforms, at least half of the pits were sterile). Repeating a statistical test for difference between landforms, after removing the alluvial flats pits, reveals that other landforms are not statistically different in terms of their distribution of the number of artefacts recovered per pit (Kruskal-Wallis chi-squared=13.74, d.f.=12, p=0.318). This means that the data do not provide any evidence to indicate that the other landforms are different from one another, in terms of the areal density of artefacts.

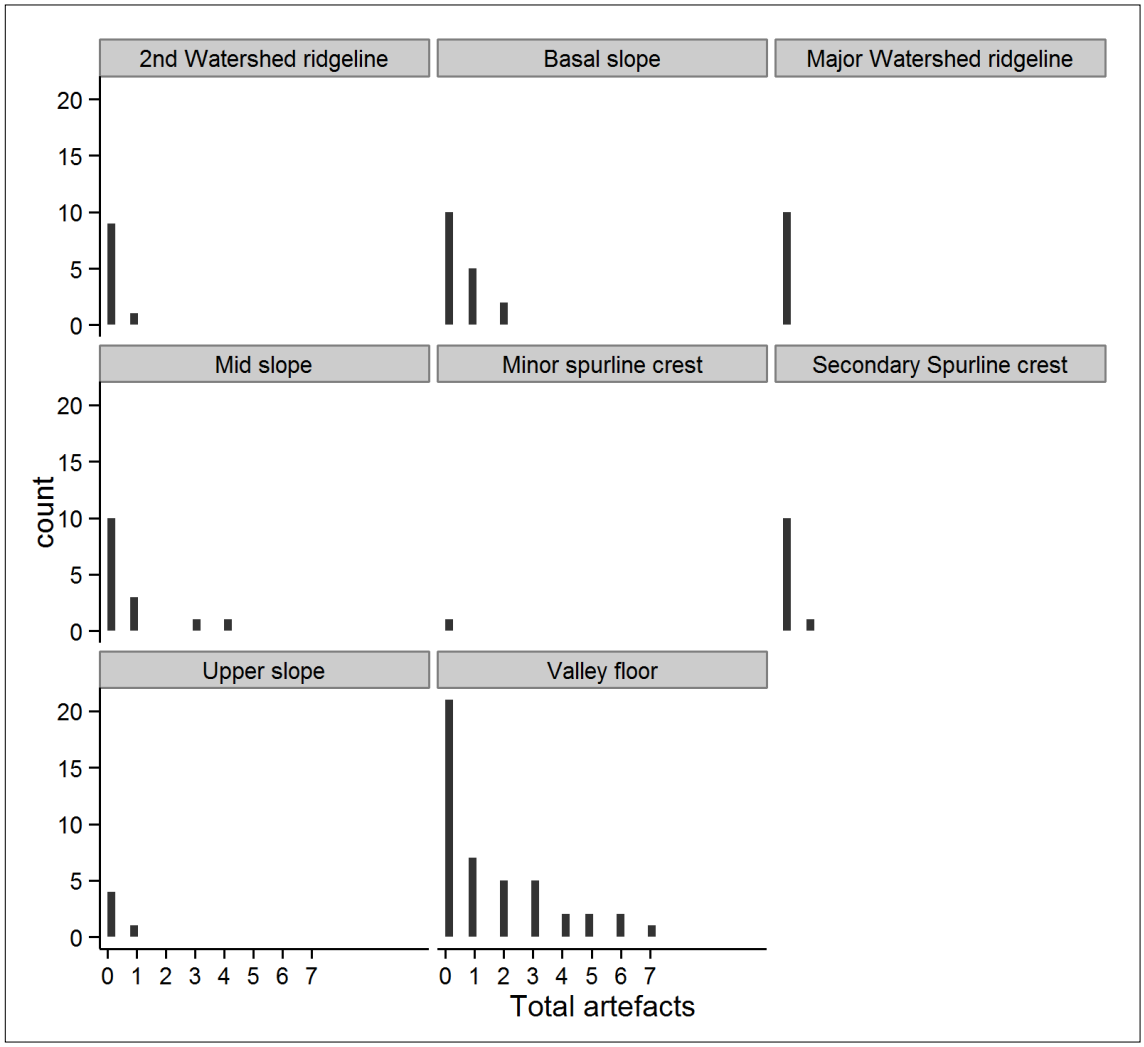


Figure 6.32 Boxplots of the frequency of total artefacts recovered per pit, broken down by broad scale landform category

Table 6.15 Descriptive statistics of the number of artefacts recovered per pit, by fine scale landform category.

fine scale landform category	valid n	minimum	median	mean	maximum
alluvial flats	26	0.00	1.00	2.1538	7.00
alluvial terrace	4	0.00	1.00	1.2500	3.00
elevated rise/terrace	9	0.00	0.00	0.6667	2.00
minor spur crest	22	0.00	0.00	0.6364	4.00
slope	10	0.00	0.00	0.5000	2.00
elevated rise	6	0.00	0.00	0.3333	2.00
fan	3	0.00	0.00	0.3333	1.00
crest	21	0.00	0.00	0.0952	1.00
bench	1	0.00	0.00	0.0000	0.00
break-of-slope	1	0.00	0.00	0.0000	0.00
knoll	1	0.00	0.00	0.0000	0.00

fine scale landform category	valid n	minimum	median	mean	maximum
saddle	2	0.00	0.00	0.0000	0.00
shoulder	6	0.00	0.00	0.0000	0.00
upper slope	2	0.00	0.00	0.0000	0.00

Table 6.16 Frequency table of the number of pits excavated in each fine scale landscape category, by the total number of artefacts recovered per pit

fine scale landform category	0	1	2	3	4	5	6	7	row total
alluvial flats	9	5	1	4	2	2	2	1	26
alluvial terrace	2	0	1	1	0	0	0	0	4
bench	1	0	0	0	0	0	0	0	1
break-of-slope	1	0	0	0	0	0	0	0	1
crest	19	2	0	0	0	0	0	0	21
elevated rise	5	0	1	0	0	0	0	0	6
elevated rise/terrace	5	2	2	0	0	0	0	0	9
fan	2	1	0	0	0	0	0	0	3
knoll	1	0	0	0	0	0	0	0	1
minor spur crest	14	5	1	1	1	0	0	0	22
saddle	2	0	0	0	0	0	0	0	2
shoulder	6	0	0	0	0	0	0	0	6
slope	6	3	1	0	0	0	0	0	10
upper slope	2	0	0	0	0	0	0	0	2
column total	75	18	7	6	3	2	2	1	**114**

The landscape was divided into three categories of 'overall valley context': lower, middle and upper. These three categories exhibit a statistically significant difference in the distribution of artefacts recovered per pit (Kruskal-Wallis chi-squared=17.34, d.f.=2, p<0.001).

Plotting the frequency of pits according to the total number of artefacts recovered per pit shows clearly why this significant difference exists: pits excavated in lower valley contexts were substantially richer, and more frequently yielded artefacts, than pits excavated in middle and upper valley contexts (Figure 6.33).

When lower valley context pits are removed from the data, the other two landforms exhibit no statistically significant difference in the number of artefacts recovered per pit (Kruskal-Wallis chi-squared=2.07, d.f.=1, p=0.15). The significant difference in the total data set is due to the greater richness of pits excavated in lower valley contexts.

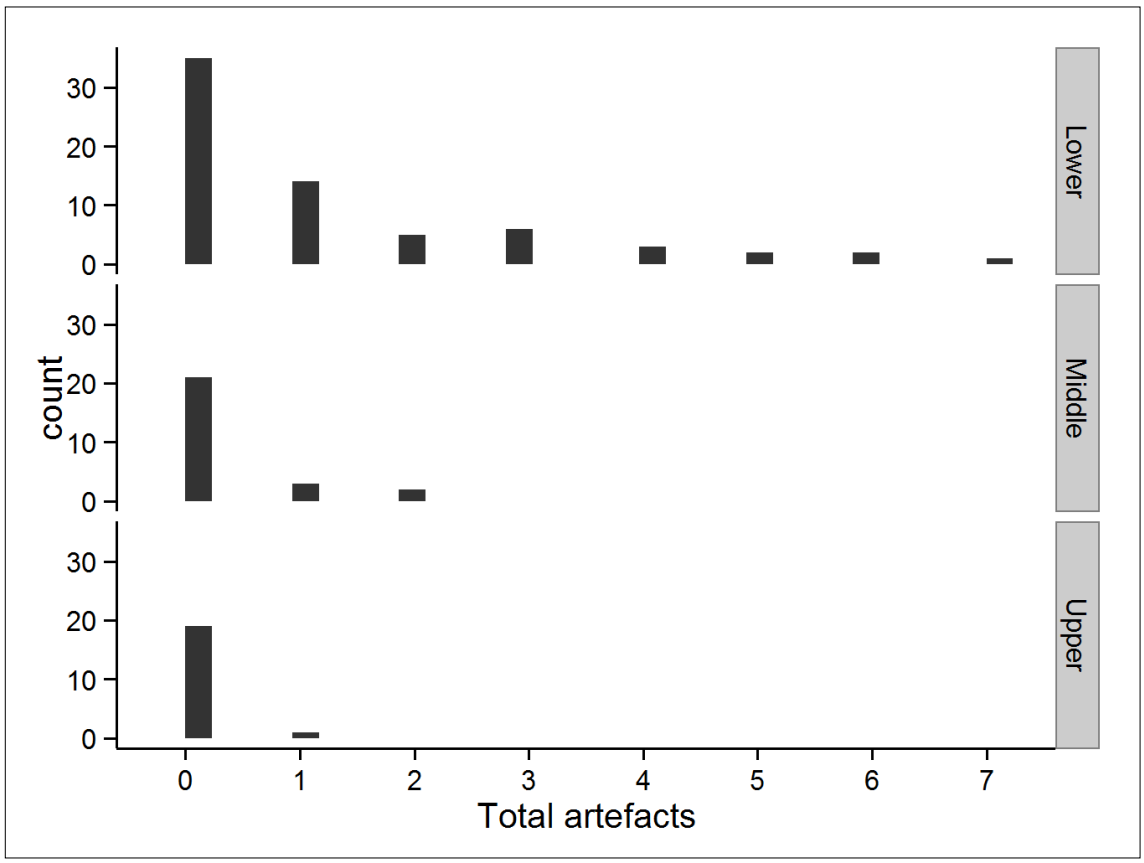


Figure 6.33 Frequency of pits excavated, by overall valley context and total number of artefacts recovered

A number of different landscape variables were designed to investigate the effect that proximity to drainage lines, and the size of drainage lines, has on the archaeological richness of the landscape.

For each of the excavated locations, the order of the closest drainage line was identified, using the established methods of designating drainage line orders: 1st order drainages being the smallest, with each confluence of drainage lines increasing the order of the downstream drainage line by one.

For each of the excavated locations, the highest drainage order within 100 metres was also identified. These variables, which categorise each excavated pit according to the proximity and size of the drainage lines in the surrounding landscape, provide data on the accessibility of water to Aboriginal groups occupying that particular region of the study location.

The numbers of artefacts recovered per pit was significantly different according to the order of the closest drainage line (Kruskal-Wallis chi-squared=24.92, d.f.=4, $p<0.001$).

A plot of the frequency of pits excavated by the number of artefacts recovered per pit shows that greater numbers of artefacts were more frequently recovered from pits near to higher order drainage lines (Figure 6.34). Pits excavated near lower order drainage lines were more frequently sterile.

The positive correlation between the order of the nearest drainage line and the number of artefacts recovered per pit is statistically significant (Spearmans rho=0.446, $p<0.001$).

The data indicate that proximity to a high order drainage line has a strong influence on the areal density of artefacts across the study location.

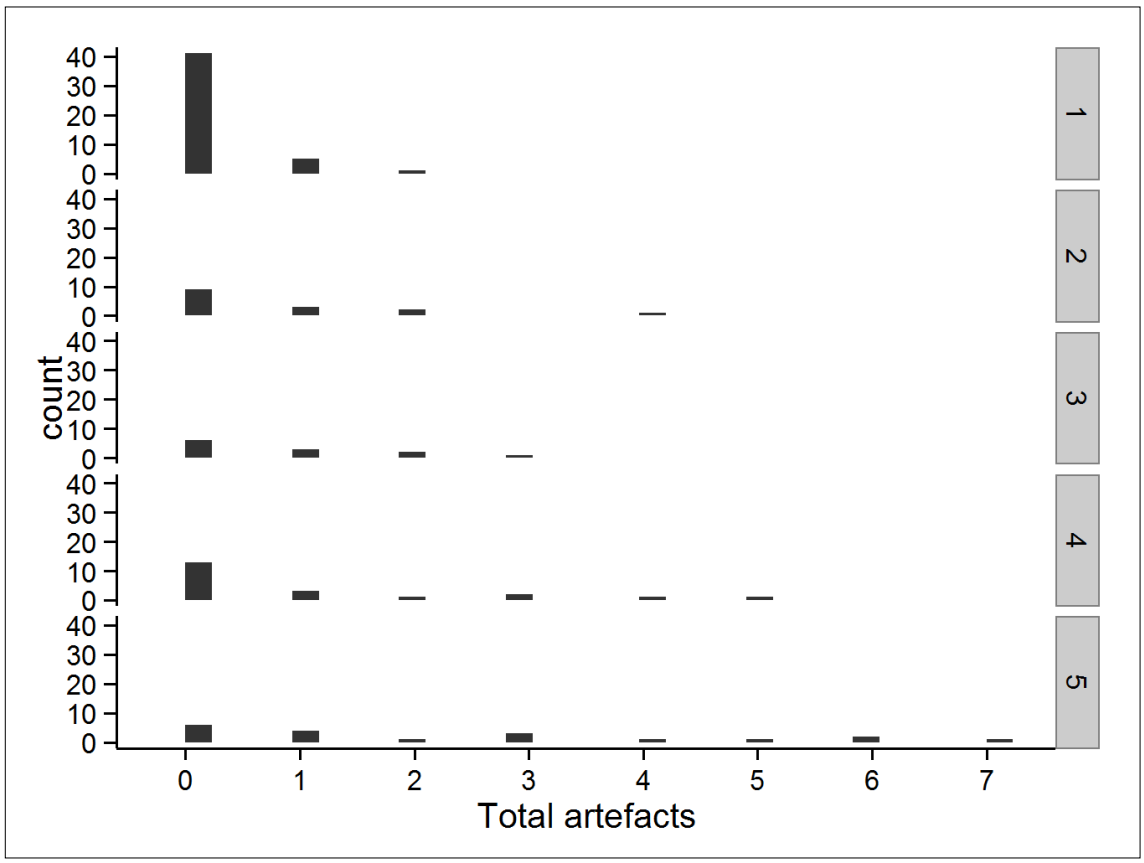


Figure 6.34 Frequency of pits excavated, by order of closest drainage line and total number of artefacts recovered

The order of the highest drainage line within 100 metres of excavated pit exhibits a similar effect on the numbers of artefacts recovered per pit.

The number of artefacts recovered is significantly different according to the order of the highest drainage line within 100 metres (Kruskal-Wallis chi-squared=13.44, d.f.=4, p=0.009).

A plot of the frequency of excavated pits according to the number of artefacts recovered per pit shows that locations with higher order drainage lines within 100 metres were more likely to yield higher numbers of artefacts (Figure 6.35). In locations where the highest order drainage line within 100 metres was only a 1st order drainage, by contrast, the majority of excavated pits were sterile.

The positive correlation between the highest order of stream within 100 metres and the number of artefacts per pit is statistically significant (Spearman's rho=0.308, p=0.001).

These data again indicate that proximity to a high order drainage line influences the areal density of artefacts.

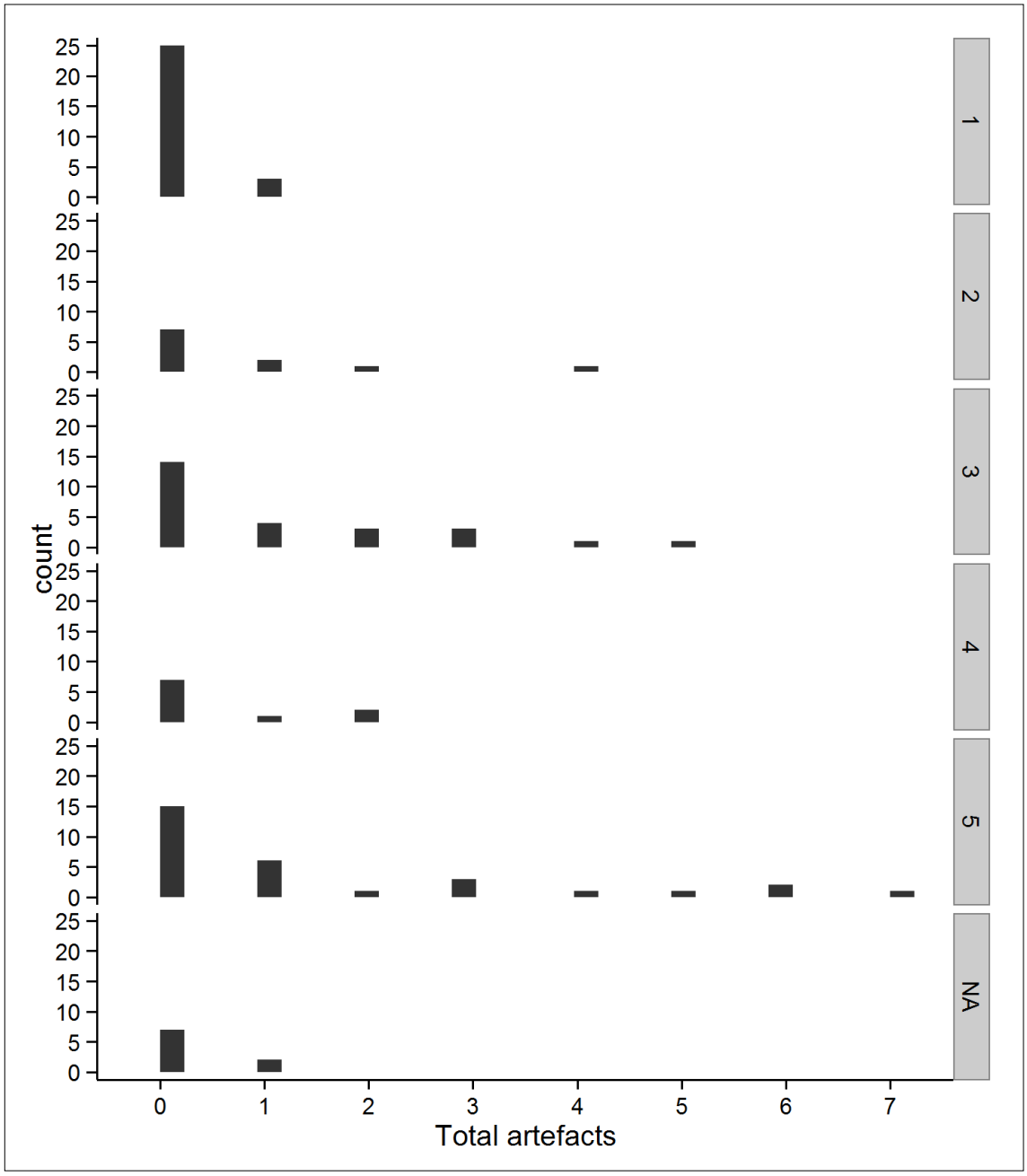


Figure 6.35 Frequency of pits excavated, by the highest order of drainage line within 100 metres and total number of artefacts recovered

A negative correlation exists between the elevation of excavated pits and the number of artefacts recovered per pit, with lower pits yielding greater numbers of artefacts.

The absolute elevation of excavated pits is negatively and significantly correlated with the number of artefacts recovered per pit (Spearman's rho=-0.451, p<0.001).

A scatterplot of artefacts recovered against the elevation of each individual pit shows that pits placed at low elevations contained artefacts more frequently than pits placed at higher elevations (Figure 6.36).

These data indicate that lower lying parts of the study location have a greater areal density of artefacts than higher locations of the landscape.

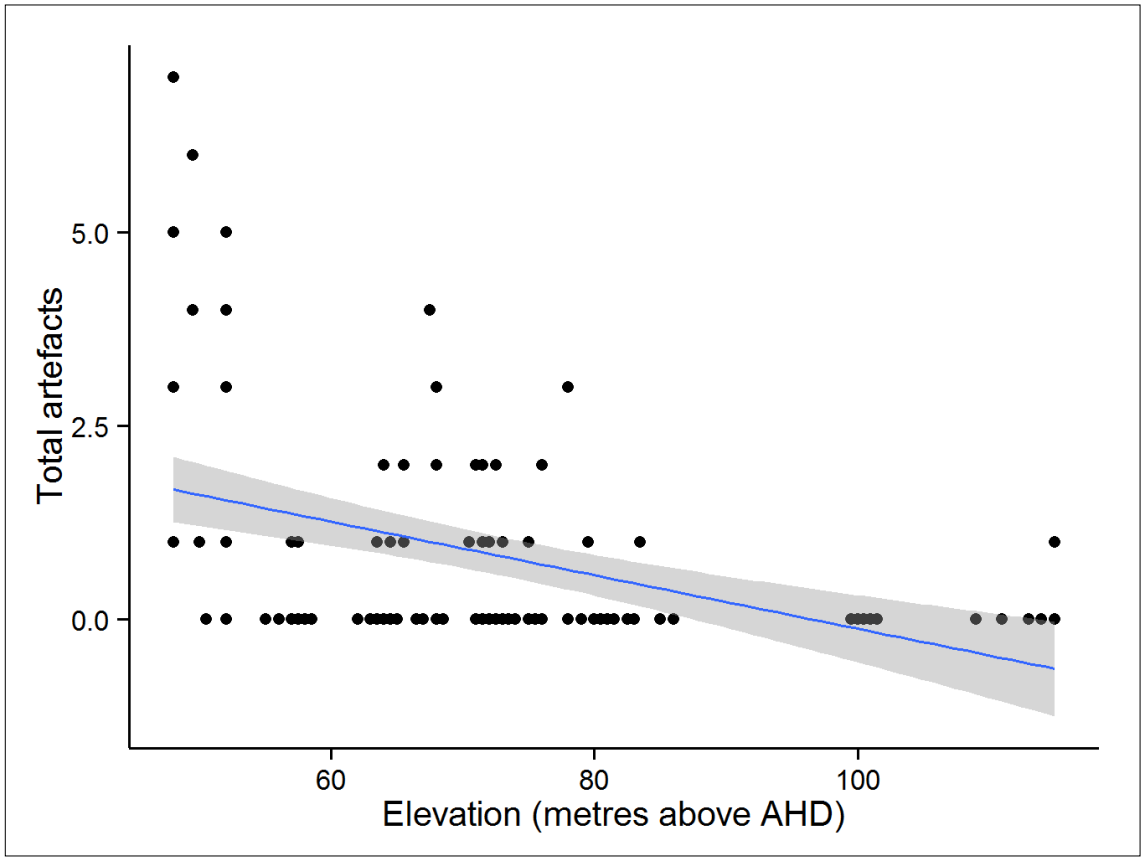


Figure 6.36 Scatterplot of the total number of artefacts recovered per pit against the elevation of the pit. Linear trend-line with 95 per cent confidence intervals drawn

The elevation of excavated pits relative to the nearest >1st order drainage line is also negatively correlated with the number of artefacts recovered per pit, and this correlation is statistically significant (Spearmans rho=-0.369, p<0.001).

A scatterplot of these two variables shows that pits located more than 10 metres above the nearest >1st order drainage line were almost invariably sterile, while pits at lower elevations contained artefacts more frequently (Figure 6.37).

These data are consistent with the pattern seen in artefact numbers relative to absolute elevation of pits.

Both data sets indicate that more elevated locations of the landscape have a lower areal density of artefacts, while lower lying locations have a higher areal density.

For locations on or near ridgelines, the watershed spurline order of the nearest ridgeline was recorded. The watershed spurline order is determined on the basis of the order of the drainage lines between which the ridge or spurline acts as a watershed. Consequently, a spurline separating two locations that drain into two different 5th order streams would be designated as a 5th order spurline. If a spurline only separated two 1st order drainages, however, which did not flow into two separate 2nd order drainages, then it would be designated as a 1st order spurline.

The spurline ridge order associated with excavation pits is negatively correlated with the number of artefacts recovered per pit, and this negative correlation is statistically significant (Spearman's rho=-0.342, p=0.006). This means that excavated locations associated with major watersheds yielded fewer artefacts per pit than locations associated with more minor watersheds.

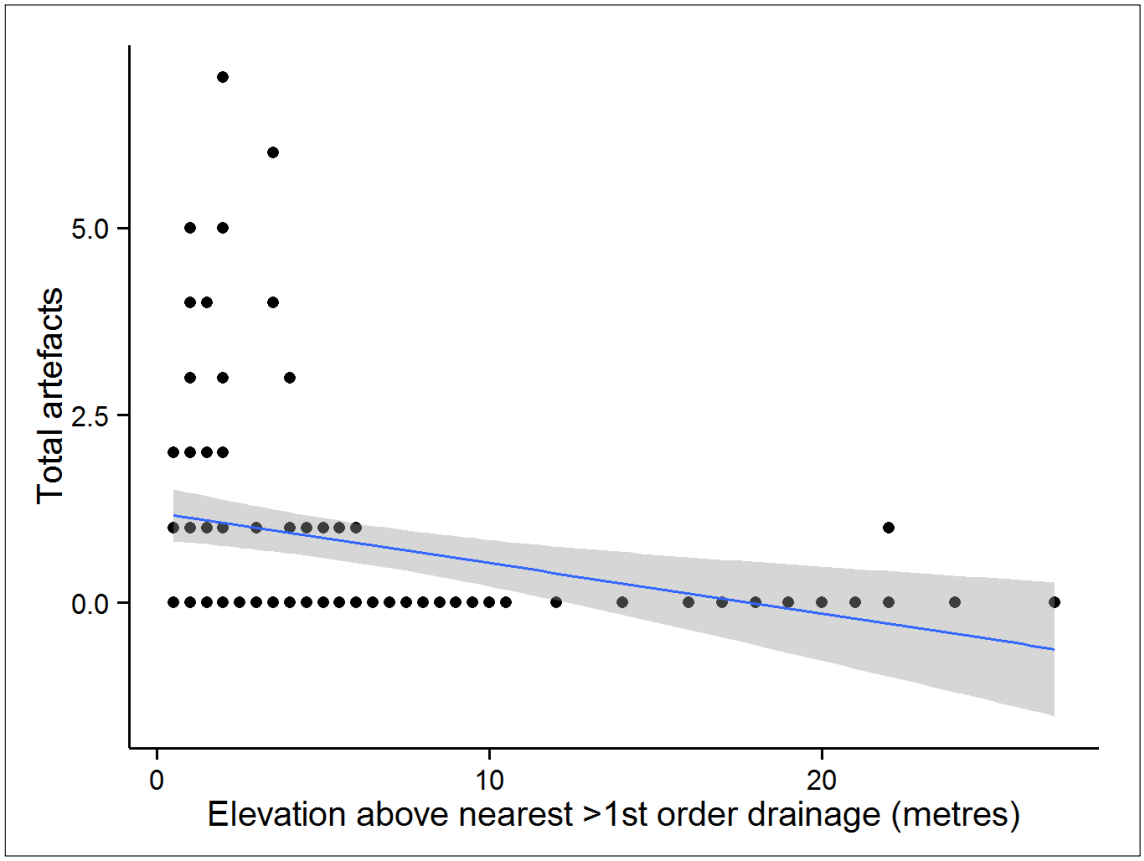


Figure 6.37 Scatterplot of the number of artefacts recovered per pit against the elevation of the pit above the nearest >1st order drainage line. Linear trend-line with 95 per cent confidence intervals drawn

A scatterplot of these two variables (Figure 6.38) shows that pits associated with low order spurlines contained greater numbers of artefacts than pits associated with high order spurlines, which were more frequently sterile. These data indicate that locations associated with higher order spurlines have lower areal density of artefacts than locations associated with lower order spurlines. The reason for this negative correlation is that higher order spurlines are generally located further away from drainage lines.

These major watersheds are usually highly elevated, and consequently further from water sources. Lower order drainage lines, by contrast, are more likely to occur on lower lying locations, and be in locations where streamlines are closer, and consequently more accessible. This is confirmed if the data-points shown in Figure 6.38 are divided into pits that are within 100 metres of a drainage line greater than 1st order, or not (Figure 6.39).

The resulting scatterplot is of a drainage line that is larger than 1st order. The pits located within 100 metres of a 2nd order or larger drainage line are more likely to contain artefacts than other pits.

These data strongly indicate that the correlation between spurline order and areal density is a result of minor spurlines being more likely to be located close to water sources, while major spurlines are more likely to be located further away from water sources.

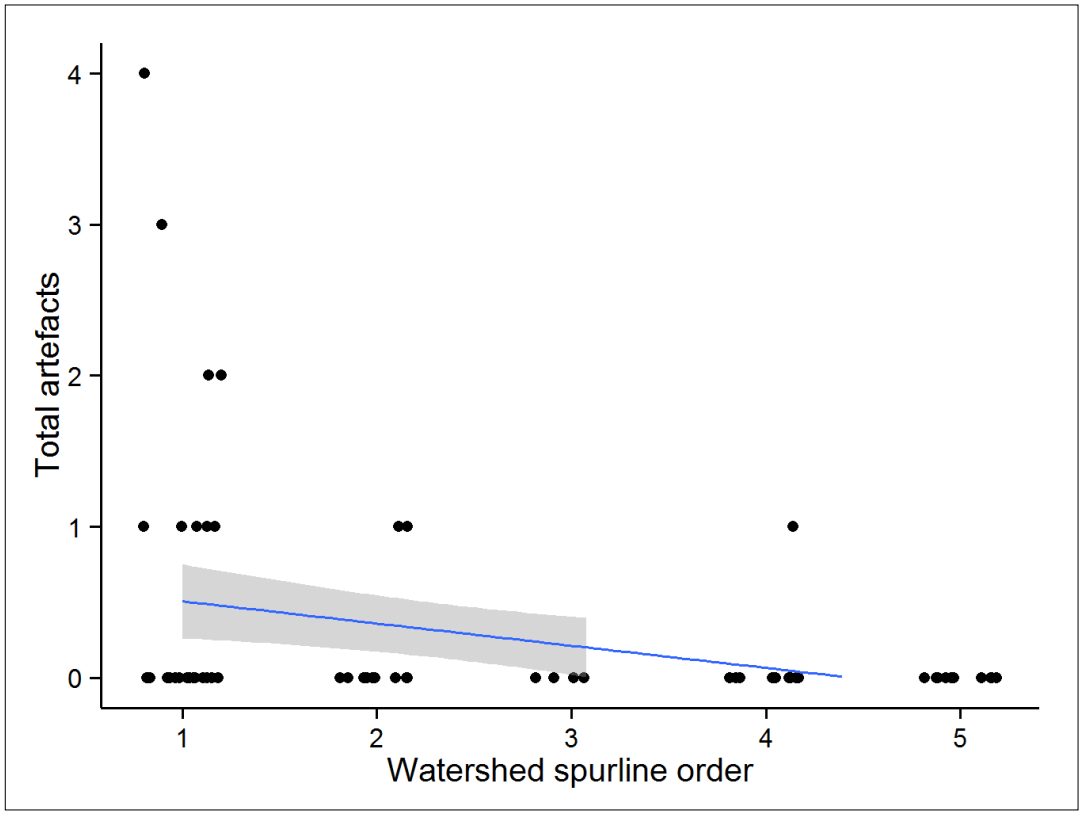


Figure 6.38 Scatterplot of the number of artefacts recovered per pit against watershed spurline order. Linear trend-line with 95 per cent confidence intervals drawn.

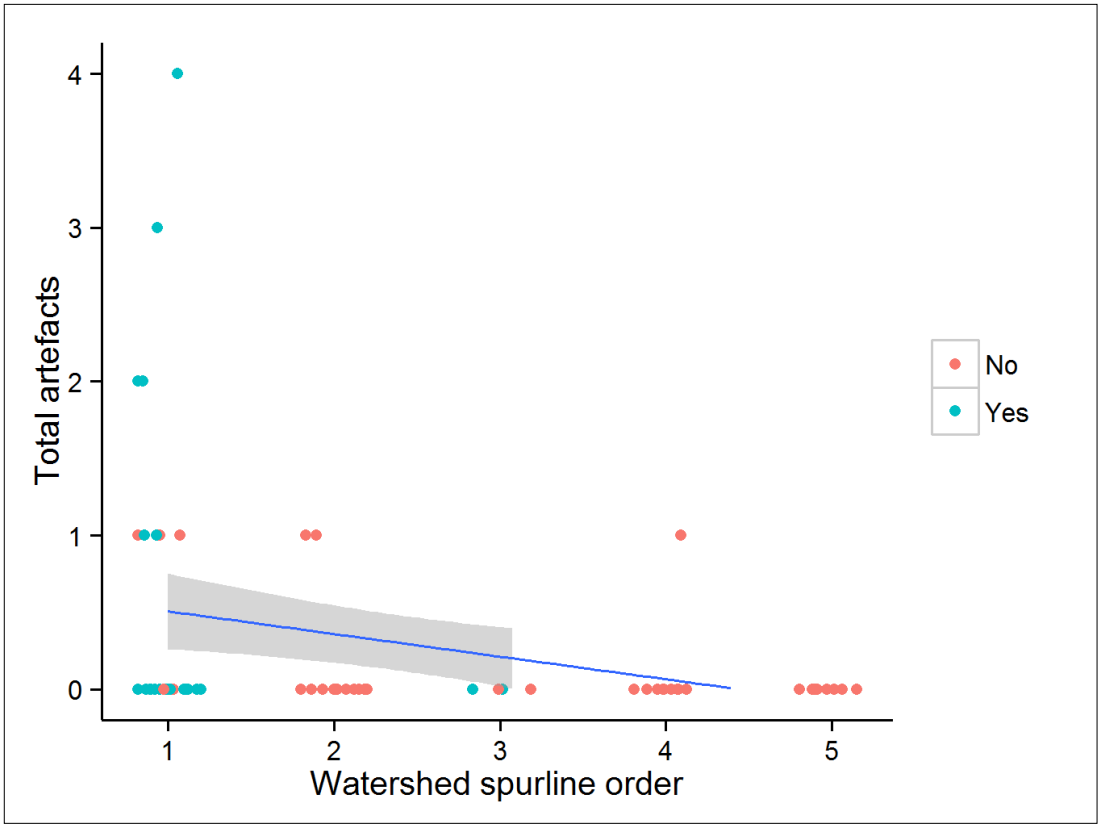


Figure 6.39 Scatterplot of the number of artefacts recovered per pit against watershed spurline order. Pits are coloured by whether they are located within 100 metres of a 2nd order or larger drainage

A number of landform categories are not associated with any differences in the numbers of artefacts recovered from pits. The number of artefacts recovered per pit showed no detectable difference according to the slope category (designated as flat, low, low to moderate, or moderate) on which pits were located (Kruskal-Wallis chi-squared=6.10, d.f.=3, p=0.107). These data indicate that the gradient of the landform is unimportant in determining the areal density of artefacts located on it. It must be noted, however, that only flat to moderate slopes were subjected to excavation in the course of this study.

No excavation was carried out on steeper slopes, as these locations were judged to have low archaeological potential at the outset of this study. The data obtained do not allow us to fully test whether the gradient of slopes affects areal artefact density across the full range of slope gradients in the study location.

The number of artefacts recovered per pit did not differ significantly according to the aspect of the ground surface on which they were located (Kruskal-Wallis chi-squared=8.66, d.f.=7, p=0.278). This is likely to be due to the gentle undulating nature of the terrain. In the absence of high or steep-sided landforms, the sunlight experienced by locations with different aspect would not be particularly variable. As a consequence, the aspect of the ground surface is unlikely to have been an important criterion in the selection by Aboriginal people of places in which to camp.

6.3.5 Discussion of assemblage density relative to landform

The results of the statistical tests conducted to explore the variation in areal density (measured as total number of artefacts per pit) across different landform categories are summarised in Table 6.17. Following general convention, a “significant” result is interpreted as being one in which the p-value falls below the arbitrary 0.05 threshold (Fisher 1925). The p-values are included in the table to show when values are strongly significant (<0.01) or non-significant.

The exploration of artefact density relative to the different landform categories defined in this study indicates consistently that proximity to water is the major factor influencing the areal density of artefacts. The first two variables analysed (broad scale landform category; fine scale landform category) both detected a statistically significant increase in artefact densities in valley floor (and more specifically, alluvial flat) contexts relative to all other locations. The increase in artefact density on valley floors is most simply explained as resulting from Aboriginal groups preferentially occupying locations close to water. All else being equal, valley floor contexts are closer to drainage lines than other landforms such as slopes and crests.

Variables that relate excavated locations to the size of nearby drainage lines support this interpretation, and also indicate that the size of the drainage line has an influence on artefact density. Artefact density is positively correlated with the order of the closest drainage line, and with the order of the largest drainage line located within 100 m. Higher order drainage lines are likely to be less ephemeral than low order drainage lines, and more likely to develop ponds and wetland environments, simply due to the greater volume of water that flows along them.

All else being equal, higher order drainage lines are more likely to be a predictable and stable source of water, and of associated animal and plant resources, as a consequence of this. The correlation between the density of artefacts in the landscape and the size of nearby drainage lines is therefore unsurprising, and can be explained as a result of Aboriginal groups preferentially carrying out activities in locations where water and associated resources was easily accessible.

The changes in artefact density with elevation add supporting data to the interpretation that artefact densities increase in locations associated with higher order drainage lines. A significant inverse correlation was found between artefact density and elevation, measured in absolute terms (metres above AHD) and in relative terms (metres above the nearest >1st order drainage line). Both results indicate that lower-lying locations in the landscape have higher artefact densities.

Table 6.17 Summary of tests exploring areal density across landform categories

Landform variable	Significant difference between landform categories (Kruskal-Wallis test)	Significant correlation with landform category (Spearman's correlation)	Notes
broad scale landform category	yes: p=0.003	na (ordinal variable)	density higher on valley floors than other categories
fine scale landform category	yes: p=0.006	na (ordinal variable)	density higher on alluvial flats than other categories
overall valley context	yes: p<0.001	na (ordinal variable)	density higher in lower valley contexts than other categories
order of closest drainage line	yes: p<0.001	yes: p<0.001	density positively correlated with drainage line order
highest order drainage line within 100 m	yes: p=0.009	yes: p=0.001	density positively correlated with drainage line order
elevation above AHD	na (continuous variable)	yes: p,0.001	density inversely correlated with elevation
elevation relative to nearest 1st order drainage line	na (continuous variable)	yes: p<0.001	density inversely correlated with elevation
watershed spurline order	no: p=0.095	yes: p=0.006	density inversely correlated with spurline order
slope category	no: p=0.107	na (ordinal variable)	
aspect	no: p=0.278	na (ordinal variable)	

All else being equal, it would be expected that locations within the landscape that have lower elevation are more likely to be located closer to drainage lines. In addition, as elevation decreases, the order of drainage lines in the landscape would be expected to increase, as drainage lines converge. The elevation of the excavated locations might, therefore, be providing a proxy for the accessibility of water in the landscape. Empirically, when the elevation of excavated locations is compared with the order of the closest drainage line, it is found that these variables are correlated with one another.

Absolute elevation of the excavated pits is inversely correlated with the order of the nearest drainage line (Figure 6.40). The correlation is strong, and highly significant (Spearman's rho=-0.796, p<0.001). Elevation of pits above the nearest >1st order drainage line is also inversely correlated with the order of the nearest drainage line (Figure 6.41). This correlation is also strong, and also highly significant (Spearman's rho=-0.504, p<0.001). Both of the elevation variables, in other words, are closely associated with the size of the nearest drainage line. As elevation (both in absolute and relative terms) decreases, the size of the nearest drainage line increases.

The increase in artefact density observed with decreasing elevation is also associated with an increase in the order of nearby drainage lines. The increase in artefact densities observed with decreasing elevation, therefore, is likely to be the result of increased Aboriginal activity in locations associated with higher order drainage lines. The linkage between elevation and drainage line order

means that data on artefact density relative to elevation provides supporting evidence for preferential occupation of locations with access to more stable water sources.

A similar linkage exists between the overall valley context of the excavated pits and the order of their closest drainage line. There is a significant difference in the order of the closest drainage line across the three categories of valley context (Kruskal-Wallis chi-squared=51.99, d.f.=2, p<0.001). A scatterplot of the two variables shows why this is the case (Figure 6.42): pits located in upper valley contexts all have a 1st order stream as the closest drainage line, while only pits located in lower valley contexts have 4th or 5th order drainage lines nearby. This is an unsurprising result: lower valley contexts by definition occur in lower-lying locations of the landscape, where there is a greater likelihood of a number of drainage lines having converged to create higher-level drainage lines.

As a consequence, upper valley contexts are generally populated by 1st order drainage lines, while middle and lower valley contexts are more likely to have higher order drainage lines running through them. The pits excavated in lower valley contexts yielded significantly higher artefact densities than pits excavated in middle and upper valley contexts.

The fact that lower valley contexts are associated with higher level drainage lines means that the high artefact densities encountered in lower valley contexts is most simply explained as a result of Aboriginal groups preferentially occupying locations near to higher order drainage lines.

The data on artefact density relative to overall valley context provides supporting evidence for the preferential occupation by Aboriginal groups of locations with access to more stable water sources.

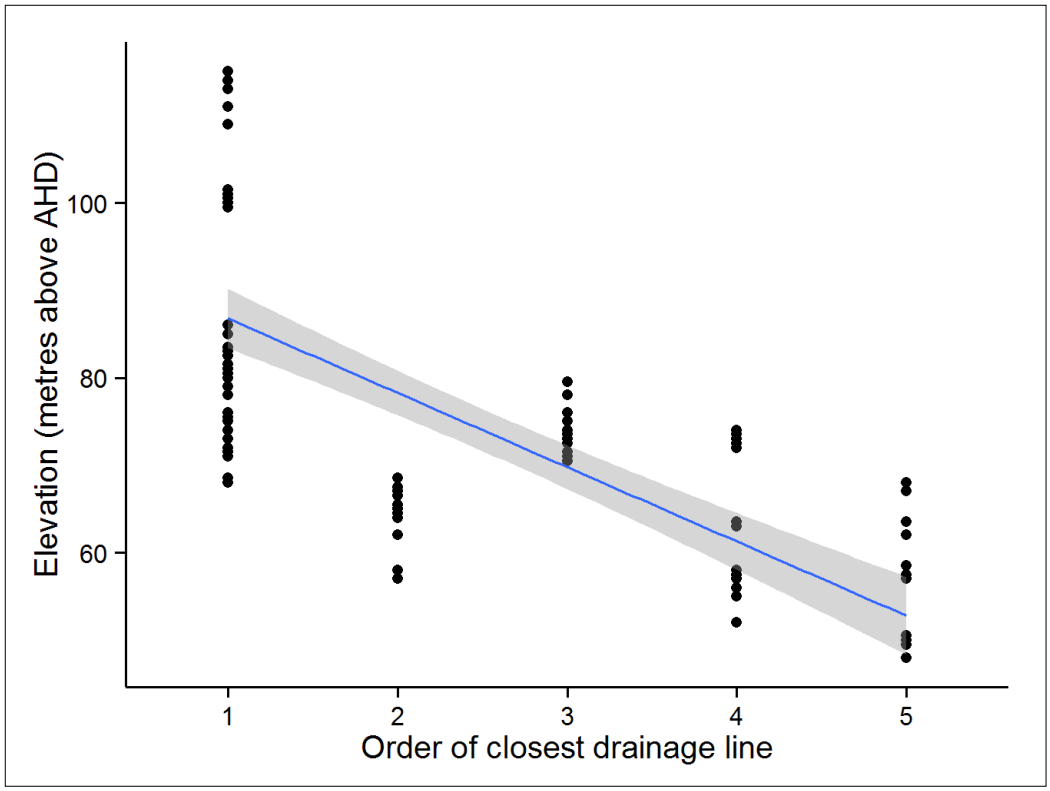


Figure 6.40 Scatterplot of the elevation of pits and the order of the closest drainage line. Linear trend-line and 95 per cent confidence intervals drawn

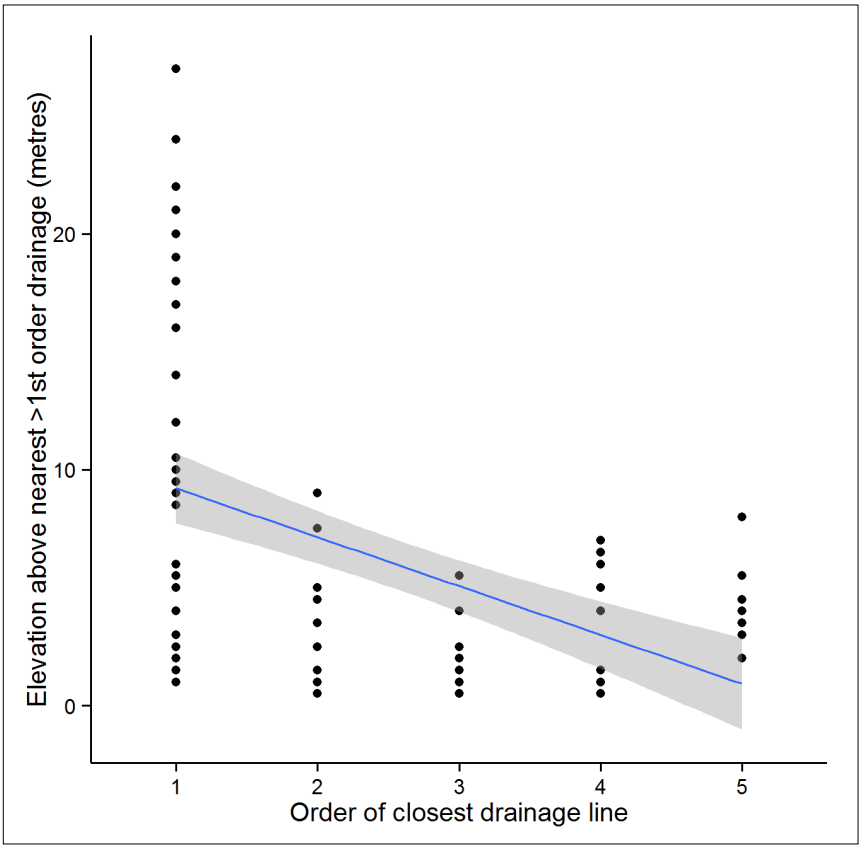


Figure 6.41 Scatterplot of the elevation of pits above the nearest >1st order drainage line, and the order of the closest drainage line. Linear trend-line and 95 per cent confidence intervals drawn

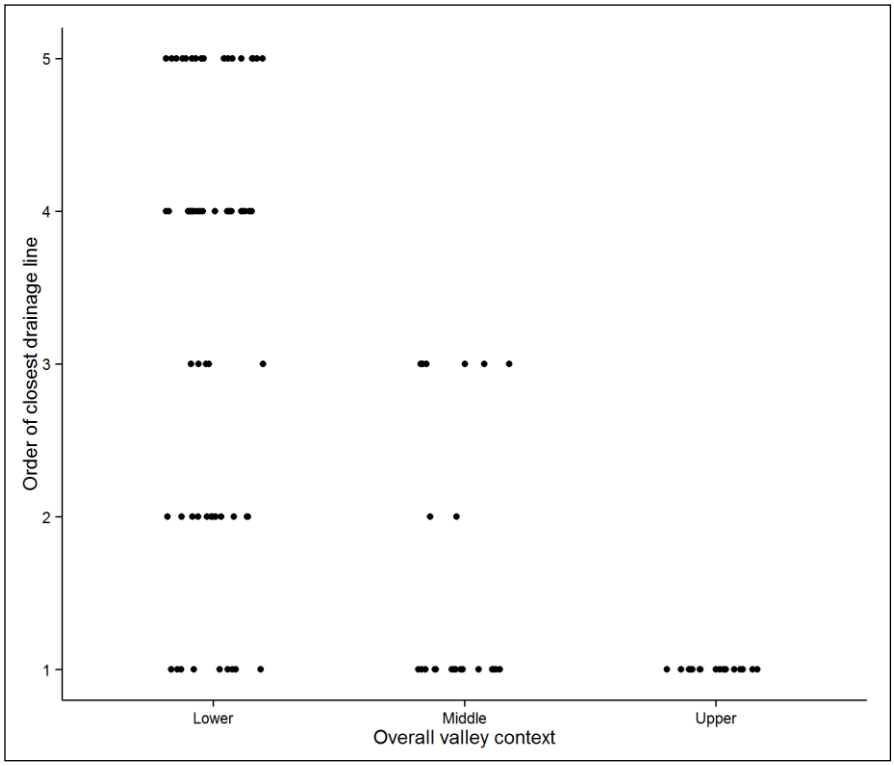


Figure 6.42 Scatterplot of the order of closest drainage line against overall valley context. Data points jittered horizontally for clarity

Watershed spurline order is inversely correlated with the order of the closest drainage line (Spearman's rho=-0.561, p<0.001). Excavated pits located on high order watershed spurlines are more likely to be associated with lower order drainage lines. By contrast, pits excavated on low-order watershed spurlines are more likely to be associated with higher order drainage lines. The inverse correlation between watershed spurline order and drainage line order means that this variable also provides a proxy measure of the order of drainage line associated with the excavated pits.

The finding that artefact density is higher in pits associated with low order watershed spurlines can therefore be explained by the fact that these spurlines are more likely to be associated with higher order drainage lines. The data on artefact density relative to watershed spurline order provides supporting evidence that Aboriginal occupation was focused on locations associated with higher order drainage lines, and consequently with access to more stable water sources.

The landform variables investigated in this study consistently indicate that proximity to water, and the size of nearby water sources, was the major factor influencing where Aboriginal groups chose to focus their activities. Direct measures (such as the order of the nearest drainage line, and the size of the largest drainage line within 100m) show that artefact density increases with the size of nearby drainage lines. Other variables (such as elevation and valley context) that are also associated with changes in artefact density, are closely linked to the size of drainage lines in the landscape. These variables therefore provide proxy data on the order of nearby drainage lines.

The fact that these variables are associated with changes in artefact density provides supporting evidence to the conclusion that the proximity of higher order drainage lines is associated with an increase in artefact density. Examining the data on all the landform variables in concert, there is a consistent signal of increasing artefact density being associated with proximity to water, and proximity to higher order drainage lines. The data strongly indicate that access to the stable sources of water, and associated plant and animal resources, that higher order drainage lines are likely to have provided, was the major determining factor in where Aboriginal activity was focused. Access to water appears to be the strongest deciding factor for Aboriginal groups in choosing where to focus their activities across the study location.

6.4 Discussion: stone artefact analysis and the predictive model

The data gained from the test excavation program provide support for many of the principles of the predictive model detailed in section 5.6. Some of the predictive statements in the model are not supported by the results of the test excavation program, but in these cases this is because the excavation program was unsuited to testing these statements. The results of the test excavation program do not provide evidence contradicting any of the principles of the predictive model.

The starting point of the predictive model is the statement that artefactual material can occur in any landform context. In other words, there is no landform within the study area and the wider Sydney Basin in which prehistoric artefacts will never be present. This does not mean that all landform categories have an equal probability of containing artefactual material, but that none of them lacks any possibility. The findings of this study are consistent with this principle, in that the majority of landform categories subjected to test excavation yielded artefacts. While some landform categories yielded no artefacts, the number of test pits excavated to sample each landform category was certainly not great enough for these negative results to prove a complete lack of artefactual material in these landforms.

Establishing a complete lack of archaeological material within a sampled area or landform requires a very large number of samples to be taken, since by definition the lower the density of artefacts, the more likely it is to be missed by a given sample. As artefact density approaches zero, the sample size required to detect it approaches 100 per cent. As a consequence, demonstrating an absence of archaeological material with any confidence would require a large sample size, and is not within the scope of this study.

The excavations provided strong support for the statement that surface artefact density does not accurately reflect the density of subsurface artefacts. The majority of the excavated areas had no visible surface artefacts, and the density of surface artefacts was not a predictor of the density of subsurface artefacts within or between the different excavated areas. The presence and abundance

of visible surface artefacts within the study area seems to be primarily a product of the nature and extent of sediment erosion, rather than a result of the richness of artefactual material remaining in subsurface sediments.

The general makeup of the artefact assemblage recovered from the test excavations conforms to the predictive model. The model predicts that the majority of an assemblage of flaked stone artefacts found on an archaeological site will be made up of unretouched flakes, with other artefact types (retouched flakes and cores) being much less abundant. This was the case in the assemblages recovered from all of the excavated areas. It was noted, however, that the proportion of retouched flakes in the combined assemblage of artefacts recovered during test excavations is higher than that usually found on archaeological sites in this region of Australia.

The uneven distribution of artefacts between different landform categories provides strong support for various statements in the predictive model. The predicted association between archaeological sites and sources of water is strongly supported by the results of this study. The great majority of the excavated pits that yielded artefacts were situated within 100 metres of a drainage line, and are therefore likely to have been within 100 metres of a source of water (either ephemeral or permanent) in the prehistoric period. In addition to the general association between archaeological material and drainage lines, there is also a strong association between the density of subsurface artefacts and the order of the drainage lines nearby.

Areas near to higher order drainage lines yielded more artefacts per pit than areas near to lower order drainage lines, an association that was significant and measurable using both of the variables employed that quantified the size of an area's neighbouring drainage lines. Comparing the numbers of artefacts recovered per pit with the order of the nearest drainage line, and the highest order drainage line within 100 metres both resulted in a statistically significant positive correlation. These data strongly signal that the density of subsurface archaeological material is associated with the order of drainage lines in the neighbouring landscape.

In addition to the order of neighbouring drainage lines, the subsurface artefacts recovered are predominantly located on landform types that are the most likely to have been associated with water sources throughout the prehistoric period. Pits excavated on valley floors, and in particular on alluvial flats, yielded significantly higher numbers of artefacts than pits located in other landform contexts. Valley floor contexts are likely to have consistently been associated with sources of water, despite any possible movement of drainage lines across these valley floors that might have occurred during the prehistoric period, or after European colonisation and the consequent clearing of the land and increase in sedimentation along watercourses.

Although we cannot be certain that the current location and ordering of drainage lines accurately reflects the prehistoric situation, and might have varied through time through prehistory, it is more safe to assume that the overall patterning of hills, ridgelines and valleys has remained constant across the post-contact and prehistoric periods, and that these features of the landscape reflect the situation that existed prehistorically. Valley floors have a greater likelihood of being close to sources of water, such as drainage lines, ponds and swamps, than slopes and ridgelines. The higher densities of subsurface artefacts on valley floor and alluvial flat landforms is a good indicator that archaeological material in the study area is associated with areas that were close to sources of water during the prehistoric period.

Similarly, the association between artefact yields and lower valley contexts (as opposed to middle and upper valley contexts) is a robust indicator of an association between subsurface artefact densities and proximity to water sources. Although the patterning of drainage lines, and the location of water-holding features such as ponds and swamps, might have changed following European contact, it is safe to assume that the lower valley contexts have consistently been more likely to hold permanent sources of water than areas in middle and upper valley contexts. The association between artefact numbers and lower valley contexts discovered in this study is consequently a robust indicator that subsurface artefact densities in the study area are associated with landforms with the greatest likelihood of possessing permanent sources of water throughout the prehistoric period.

It is noted that the surface artefact occurrence site B115 is an exception to two general site location trends:

- low numbers and low areal incidences of artefacts on the surface and subsurface of ridgeline crests (3rd order ridges and greater); and

- sites with relatively larger artefact numbers or areal incidence mostly occur within 100 metres of a substantial water source (2nd order streamline or greater).

B115 contains at least 20 surface artefacts within an area of 5 x 5 m. A possible explanation is that the site is representative of a minority category for higher incidence artefact occurrences located on high ground with strategic importance. This importance may be manifest in the viewshed afforded by the landform, or its amenity in across-country movement and access. The landform context of B115 is consistent with both of these characteristics, having an elevation of 120 metres (AHD), close to the maximum in the airport site, and situated at the junction of two major watersheds – the Nepean River and Badgerys Creek.

The data gathered by this study do not allow us to draw conclusions regarding the association between the technological complexity of artefact assemblages relative to their proximity to water. The model predicts that archaeological sites associated with higher order drainage lines (and which are consequently inferred to have had readier access to permanent water sources) will have greater technological complexity in addition to being larger and more dense.

Unfortunately, the overall low numbers of artefacts recovered from each individual excavated pit do not allow an informative analysis of complexity (which could be measured in the number of raw materials, or the number of artefact types) of the assemblages recovered from each pit, and whether this is associated with the landform variables recorded. It has been shown, however, that the excavation locations that yielded the highest number of artefacts also yielded assemblages with the greatest variety of material types and artefact types, a result that is outlined in section 6.3.1. There is, therefore, a general correlation between assemblage size and assemblage complexity, which is a pattern frequently observed in archaeological sites (Grayson and Cole 1998; Plog and Hegmon 1993; Hiscock 2001; Rhode 1988; Langley, Clarkson, and Ulm 2011). Given this correlation, it can cautiously be inferred that the landforms that are richer in subsurface artefacts are likely to contain more varied and complex assemblages. The limitations of the size of the available sample, however, do not allow us to test this proposition directly.

The data gathered by this study do not allow us to evaluate the predictive statement that sites will be focused on creek junctions in preference to other streamline morphologies. The placement of excavated pits was not designed to sample areas near to and removed from creek junctions, and consequently, a comparison of the richness of subsurface artefact assemblages between these two landform types could not be made.

The predicted dominance of silcrete as a material from which stone artefacts are produced has been strongly supported by the data gained in this study. Across all excavated areas, the assemblages of stone artefacts recovered were mostly produced from silcrete, with ambiguous fine-grained material being the second most common material utilised. Other projects in the Sydney basin have identified cherts and tuffs as being commonly utilised materials, and it is likely that the FGS artefacts recorded in this study are made from one or both of these materials.

This study supports the general finding of archaeological research in the Sydney basin that sources of silcrete are plentiful across the landscape, occurring in the form of outcrops or transported nodules deposited in river gravels. The preferential utilisation of this material for the production of flaked stone artefacts is a typical feature of sites across the Sydney basin, and this project's study area conforms to this pattern.

In summary, not all of the predictive statements made by the model can be evaluated using the data gathered in this study. In the case of assemblage complexity, this is due to the small size of the artefact assemblage recovered from all excavated pits in total. Simply, some questions require a larger body of data than can practicably be gathered in the course of a program of test excavations.

The predictive model's statement that assemblages will be denser close to creek junctions could not be evaluated, as a consequence of the placement of excavation pits not being designed to test this prediction. In order to enable a robust testing of the majority of the predictive model's statements, resources were not available to test this particular prediction.

Where sufficient data was gathered to evaluate the predictive statements made by the model, the test excavation program provided support for these statements. The multiple lines of data showing the association between the density of subsurface artefacts and the proximity of water sources is the primary example of this.

Multiple predictions of the model relate to the principle that sites will preferentially occur near water sources, and that the size of archaeological sites is directly correlated with the size and permanence of nearby water sources. The analysis of artefact numbers recovered from the excavated pits relative to the landform variables recorded for each pit provide a strong basis for inferring that these predictions accurately describe the distribution of artefacts across the study area.

Several other predictive statements, such as the dominance of silcrete and the predominance of unretouched flakes over other artefact types, are also supported by the data gathered by the test excavation program.

6.5 Conclusions of the artefact analysis

As a result of the analysis of the stone artefacts recovered during the test excavation program, it has been established that:

- Subsurface artefacts were unevenly distributed between the different excavated areas, with the majority of areas yielding relatively few artefacts, and a small number of the excavated areas being relatively rich.
- Assemblages from all excavated areas were dominated by silcrete over other raw materials, and by unretouched flakes over other artefact types.
- Retouched artefacts make up 12 per cent of the combined artefact assemblage, with the majority of these being backed artefacts.
- The majority of flakes in the combined assemblage have little or no dorsal cortex. Flakes are generally small in size, with a diverse variety of platform types. It is inferred from this that the flake assemblage was produced from small parent rocks, which had been heavily reduced (by the removal of flakes), and which were being treated economically (ie exploited as a valuable resource).
- There is no evidence that the production of flakes within the study area was geared toward the preferential production of any particular flake morphology.

The analysis of landform variables relative to the tested subsurface archaeological resource provided the following findings:

- Subsurface artefact density is unevenly distributed between landform categories, with valley floors and alluvial flats having significantly higher artefact densities than other landforms.
- Subsurface artefact density is significantly higher in lower valley contexts than it is in middle and upper valley contexts.
- Subsurface artefact density is positively correlated with the order of the closest drainage line, and with the order of the largest drainage line within 100m.
- Subsurface artefact density is inversely correlated with elevation, with lower-lying areas having higher densities of subsurface artefacts. These areas are also associated with higher order drainage lines.

- Subsurface artefact density is inversely correlated with watershed spurline order, with areas associated with lower spurline orders having higher artefact densities. Low order spurlines are generally associated with higher order drainage lines.

- As a general inference from multiple lines of data, subsurface artefacts are associated with areas likely to have had easier access to sources of water.

6.6 The archaeologically sensitive landscape

The average areal incidence (artefacts per square metre) of subsurface artefacts according to key landform units is presented in Table 6.18. These figures provide an effective means of gauging archaeological sensitivity across the airport site.

With one exception, landforms with a relatively high average artefact incidence (equal to or greater than 1.0 artefacts per square metre) are:

Valley floor.....3.1 a/m^2
Basal slopes .....1.1 a/m^2
First order spurlines .....1.2 a/m^2
Within 100 m of a second order streamline.....1.5 a/m^2
Within 100 m of a third order streamline .....2.2 a/m^2
Within 100 m of a fourth order streamline .....1.0 a/m^2
Within 100 m of a fifth order streamline .....3.0 a/m^2

The exception is the mid slope category with an average incidence of 1.3 artefacts per square metre. This figure is not considered to accurately reflect the full geographic scope of this category because most of the test pits conducted in this landform were situated adjacent to basal slopes and are therefore only representative of the lower and down-slope portion of this unit.

Evidence from surface recordings and elsewhere across the Cumberland Plain (as evidenced in the predictive model) indicate that mid slope contexts are unlikely to contain sites with relatively high artefact incidence.

The net areas of those landform units with an average areal subsurface artefact incidence of 1.0 a/m^2 or greater (excluding the mid slope result) are tabulated in Table 6.19.

Table 6.18 Parametric statistics of areal incidence (artefacts per square metre) of subsurface artefacts per pit, according to key landform categories

Broad scale landform	Valid N	Mean	Standard Deviation
Valley floor	45	3.066	3.922
Mid slope	15	1.3334	2.468
Basal slope	17	1.0588	1.434
Upper slope	5	0.400	0.894
2nd Watershed ridgeline	10	0.200	0.632
Secondary Spurline crest	11	0.1818	0.604
Major Watershed ridgeline	10	0.0000	0.000

Watershed ridge/ spurline order	Valid N	Mean	Standard Deviation
1	27	1.186	2.094
2	13	0.308	0.752
3	4	0.000	0.000
4	10	0.200	0.632
5	10	0.000	0.000

Highest drainage line order within 100m	Valid N	Mean	Standard Deviation
1	28	0.214	0.630
2	11	1.454	2.544
3	26	2.154	2.936
4	10	1.000	1.700
5	30	3.000	4.258

Table 6.19 The net areas of landform units with an average areal subsurface artefact incidence of 0.5 a/m2 or greater (excluding mid slopes)

Non-exclusive categories

Landform category or feature	Initial Development (ha)	Longer Term development area (ha)	Whole airport site (ha)
Riparian corridor (100 m either side of drainage line)			
2nd order corridor	266.7	127.6	394.3
3rd order corridor	115	58.5	173.5
4th order corridor	44.3	22.1	66.4
5th order corridor	3.7	73.1	76.8
Ridges and spur crests			
1st order crest	104.7	82.4	187.1
Broad scale landform			
Valley floor	47.8	136.2	184.0
Basal slopes	127.5	86.7	214.2

Exclusive categories

(Note: fluvial corridor and ridge/spurline zones which overlap with valley floor and basal slope units have been excluded)

Landform category or feature	Initial development (ha)	Longer Term development area (ha)	Total within airport site	Proportion of airport site (1845 ha[1])
Riparian corridor (100 m either side of drainage line)				
2nd order corridor	219.3	105.4	324.7	17.6%
3rd order corridor	38.2	6.7	44.9	2.4%
4th order corridor	0	0	0	
5th order corridor	0	0	0	
Ridges and spur crests				
1st order crest	68.7	51.6	120.3	6.5%
Broad scale landform				
Valley floor	47.8	136.2	184.0	10.0%
Basal slopes	127.5	86.7	214.2	11.6%
Total	501.5	386.6	888.1	48.1%

Note 1. The area total includes Australian Government owned lands which are non-contiguous with the airport site

7. Results of stakeholder consultation

7.1 Aboriginal cultural values

This section reports on cultural values which have been communicated by Aboriginal stakeholders, and which are not derived from archaeological interpretation.

All of the stakeholders consulted for this assessment have identified the airport site as a place of Aboriginal cultural significance and continuing cultural connection. The reasons for this are outlined under the following headings:

Material evidence of occupation

The presence of archaeological sites throughout the airport site is a manifest link with their ancestors, with a past way of life, and with a continuing cultural association with the land. Archaeological sites are a tangible component of cultural identity and traditional ownership. In this regard, it is also pointed out that all archaeological sites have cultural significance, regardless of their size, complexity or archaeological interpretation. The relationship between the position of an artefact and its surrounding landscape also has cultural significance. This is often expressed by stakeholders when they specify that after analysis, salvaged artefacts should be returned back to 'their country'.

Cultural landscape values

Although information relating to remembered traditional events in specific places has not been provided, many stakeholders state that the airport site landscape has cultural significance according to traditional lore. A number of landscape features, including prominent ridgelines, and the Badgerys Creek corridor, can be interpreted with reference to traditional knowledge held by various custodians. Many stakeholders expressed the view that there would have been areas and features that would have held special significance, including relationships to stories and law associated with gender roles.

Significant plants, animals and resources

The continuing presence of native animals and plants, and the habitat they require, is considered to be an important part of the cultural significance of the airport site. These are important as traditional sources of food, medicine and raw materials, and for the specific stories and lore associated with them. Some stated examples of significant resources were yams, fresh water mussel, possums, tree timber and bark, and the water from Badgerys Creek. Areas of remnant native vegetation and the riparian corridors of the main creek lines were specifically referenced in this regard.

Educational value

Many stakeholders made reference to their need to educate young people about their culture, lore and traditions. The importance of conserving Aboriginal sites so that they can be accessed for teaching and interpretation is considered to be an important part of maintaining cultural identify, practice and continuity. The educational value of the Badgerys Creek sites was recognised in general by many stakeholders, and in particular, the grinding groove site (B120) and the scarred tree (B40). Similarly, the remnant natural vegetation and riparian corridors across the study area were seen as important educational resources.



A disappearing heritage

A repeated concern expressed by stakeholders was the cumulative impact on Aboriginal sites caused by the continuing urban and industrial development of Sydney across the Cumberland Plain. Given the loss of sites, to date, the remaining sites, such as those in the airport site, are now recognised to have cultural value because of:

- their increasing rarity,
- the need to retain artefacts and sites in their original locations and natural landscapes, and
- the relationship with the land and the sense of cultural identity they support.

Table 7.1 presents specific comments and statements about the cultural values of the airport site provided by Aboriginal stakeholders during the current assessment.

Table 7.1 Tabulation of specific comments and statements from Aboriginal stakeholders regarding Aboriginal cultural values of the airport site

Date	Stakeholder Group	Comment
23/4/15 17/4/15	Darug Land Observations and Darug Custodian Aboriginal Corporation	This area is significant to the Darug people due to this evidence of continued occupation Landscapes and landforms are significant to us for the information that they hold and the connection to Darug people. Darug sites are all connected, our country has a complex of sites that hold our heritage and past history, evidence of the Darug lifestyle and occupation are all across our country, due to the rapid development of Sydney, many of our sites have been destroyed, our sites are thousands of years old and within the short period of time that Australia has been developed pre contact our sites have disappeared. The sites that are low density or single materials are as important as the higher density sites as they show us the connection and the movement of people across the country. Women in the groups were the gatherers, much of the diet of the Darug was plants, and the yam was a staple diet and grew along the waterways in floodplain areas. Darug is the word meaning yam. Included in the diet were berries, seeds (ground down to make flour), tubers, small and large reptiles, mammals, birds and water dwelling animals. Trees were used to make canoes, coolamons, shields, digging sticks, spears, spear throwing tools and boomerangs. The roots and saps were used in tool making as glues for axes and spears. Different reed type plants were used for weaving baskets, ropes and fish traps. Sinew from some animals was also used for rope making. Skins from animals were used for protection and clothing in the colder seasons, skins were cleaned, scraped and treated. Darug people had medicines for all ailments the traditional medicines were of today's standards, many native plants and animals were used to produce medicines. Plants were also used as drink sweeteners and chewed on in

Date	Stakeholder Group	Comment
		dry conditions to prevent dehydration. Many different plants were used as dyes for decorative colours and ceremonial purposes
28/1/15	Walbunja Aboriginal Corporation	Mr Tekowhai stated that the Badgerys Creek area included many significant Aboriginal sites which should be salvaged (via phone).
24/4/15	Gundungurra Aboriginal Heritage Association	Ms Halls stated that she was against the airport proposal being built at Badgerys Creek based on Aboriginal cultural grounds (via phone). The sites should not be destroyed. Darug descendants used to live at Badgerys Creek prior to the airport proposal.
22/5/15	Kamilaroi-Yankuntuatjara Working Group Phil Khan	Mr Khan stated that it was possible that burial sites occur on the flood plains of the airport site, good campsites as well.

7.2 Archaeological values

The Aboriginal stakeholders were consistent in acknowledging the importance of information gained from archaeological recording and analysis. Examples given include the evidence of radiocarbon dating, and the ability to identify past patterns of behaviour, occupation, adaptation, and technological and social change. Archaeological information is seen as complementary to remembered tradition and lore, and evidence from historical records.

While the value of the archaeological method, and the information it generates, is recognised as clearly distinct from Aboriginal cultural evaluation, it is also acknowledged by Aboriginal stakeholders that the potential of a site or an archaeological deposit to provide information about the past has high Aboriginal cultural value.

7.3 Suggested mitigation and management strategies

Aboriginal stakeholders have suggested a variety of mitigation and management strategies for consideration in the assessment. These are noted below:

- Conduct of a 100 per cent surface coverage survey and recording of the airport site.
- Conservation of sites *in situ* wherever possible.
- Conservation and rehabilitation of the natural environment wherever possible.
- Conservation of the two rare sites: B40 (scarred tree) and B120 (grinding grooves) *in situ* and within a riparian reserve along Badgerys Creek.
- Recovery of all surface artefacts prior to development impact
- Recovery, through archaeological excavation, of as much of the subsurface archaeological resource as possible. This is required not only to manage archaeological values, but also the cultural values of the artefacts.
- Exploratory archaeological test pitting for potentially occurring deep deposits, below the clay horizon of the modern soil profile.
- Conduct of salvage excavation if and where appropriate.

- Monitoring of all groundworks by appropriately trained Aboriginal community representatives.
- Damage from construction activities to stone artefacts which remain on-site after the completion of salvage programs is a significant issue and needs to be addressed.
- Ensure the long term archival storage of salvaged cultural material.
- Reburial of salvaged archaeological material (following the completion of recording and analysis) within a specially allocated and managed portion of the airport site.
- Management of all or some of the recovered (salvaged) cultural material in a local, above ground facility which would allow archival storage, periodic display and interpretation, and access by traditional owners and researchers.
- Management should be commensurate with the cumulative impact of the development. It is widely held that this measure of equity has not been evident in past Cumberland Plain development projects.
- There should be adequate compensation provided to the traditional owners and Darug community for the physical destruction of Aboriginal sites, and of the cultural landscape of which they are a part.
- The airport should be given a name sourced from the Darug culture and language.
- The Darug culture and the cultural values of the airport site should be commemorated and interpreted through the public space and infrastructure of the airport.
- The airport should include a prominent and featured public interpretive display about Darug culture and the values of the airport site.

7.4 Non-Aboriginal stakeholder views

The following issues were raised during consultation with the NSW Office of Environment and Heritage, and the Liverpool City Council:

Cultural landscape values

It was considered important that the cultural landscape values of the airport site be addressed in the EIS assessment. The recording of oral history is one avenue for managing the loss of social values resident in a place and its landscape.

Recording social history

It was noted that the recording of local oral tradition, especially from former land owners and occupiers of the airport site could be an important management strategy in the event that the airport development proceeded.

Cumulative impacts

The continuing impact of spreading development across the Cumberland Plain was acknowledged and the impact this was having, and would continue to have, on the archaeological resource and Aboriginal cultural values. It was conceded that cumulative impact has not, for the most part, been effectively mitigated or managed in the past. Very few open space areas or conservation parks in developed contexts, have been established with the conservation management of Aboriginal heritage as a primary criterion.

Neither authority could advise of studies which have quantified the current and projected encroachment of urban and industrial development across the Cumberland Plain and its associated cumulative impacts.

Continued development of the Cumberland Plain is certain. In the face of this reality, the management of cumulative impacts must involve: archival recording, salvage programs and curation, recording of oral history, public interpretation, and commemoration through the use of names, public art, sponsorship and other dedicated facilities.

Management of Aboriginal artefacts which remain on-site during development

The lack of consideration given to Aboriginal artefacts which remain on a development site, or in topsoil spoil heaps, after the completion of archaeological salvage programs, is an increasing source of criticism from Aboriginal stakeholders. A means of managing this material in a culturally sensitive way is required.

The need for a keeping place, and cultural interpretation

It was recognised that despite the extent of development already evident across the Cumberland Plain, there remains no dedicated, secure or effective place for the curation and conservation management of salvaged Aboriginal objects, outside of the Australian Museum. The Museum has increasingly limited storage space and is now highly selective regarding the material it will accept. As a consequence there is no repository where salvaged archaeological or other culturally significant material can be stored according to conservation management standards and as a matter of course.

This would be the function of a 'Keeping Place'. Currently this type of facility is limited to locales in reserved open space areas in which salvaged materials are reburied in relative proximity to their find locations. The current absence of a Keeping Place, where archival curation of salvaged material which cannot or should not be reburied, is undermining the value of archaeological salvage as an effective long term management strategy.

Management of cultural heritage values

Potential means by which the cultural significance of the airport site could be commemorated and the subject of continuing local recognition include:

- the local establishment of a Keeping Place
- the use of Darug names for new infrastructure
- the establishment of commemorative public spaces, plantings, art and activities
- the use of interpretive signage
- interpretation which integrates both Aboriginal and European heritage values
- displays of Aboriginal items and artefacts from the site, and
- the inclusion of a retail shop which sells items created for sale, and which relate to Darug tradition and culture.

8. Significance Assessment

8.1 Assessment Criteria

8.1.1 The Burra Charter

The Burra Charter is a foundation document upon which most local, State and Australian Government conservation management policy and action is based (Aust. ICOMOS 1987). The Charter defines basic concepts, aims and objectives, and outlines a framework for the assessment of significance.

The Charter defines cultural significance as 'aesthetic, historical, scientific or social value for past, present and future generations' (Aust. ICOMOS 1987). The criteria used to assess significance vary according to statutory context and relevance to subject, places, movable heritage and intangible values. The Burra Charter outlines five broad categories applicable to the assessment of the significance of Aboriginal sites. These are:

- significance to contemporary aboriginal people;
- scientific or archaeological significance;
- aesthetic value;
- representativeness; and
- value as an educational and/or recreational resource.

Cultural significance is recognised as a relative value based on variable references within social and scientific practice. The cultural significance of a place is therefore not a fixed assessment and may vary with changes in knowledge and social perceptions.

8.1.2 Commonwealth assessment criteria

The status of the airport site as land owned by the Australian Government places the assessment of cultural significance within the ambit of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Concurrent with the Significance of Impact assessment criteria 1.2, the EPBC Act specifies two sets of criteria for the assessment of heritage significance, one for determining significance which would meet a standard for listing on the National Heritage List, and another for listing on the Commonwealth Heritage List.

The National and Commonwealth Heritage Lists employ nine similar assessment criteria but attach different thresholds. The National Heritage criteria specify a threshold of 'outstanding heritage value to the nation'. None of the cultural values identified from the airport site are considered to fulfill this threshold and further detail regarding the National Heritage List is not presented here.

The Commonwealth Heritage List is a register of natural and cultural heritage places owned or controlled by the Australian Government. Nominations are assessed by the Australian Heritage Council. In accordance with the EPBC Act, a place has a Commonwealth Heritage value if it meets one of the following Commonwealth Heritage criteria (section 341D):

a) The place has significant heritage value because of the place's importance in the course, or pattern, of Australia's natural or cultural history.

b) The place has significant heritage value because of the place's possession of uncommon, rare or endangered aspects of Australia's natural or cultural history.

c) The place has significant heritage value because of the place's potential to yield information that will contribute to an understanding of Australia's natural or cultural history.

d) The place has a significant heritage value because of the place's importance in demonstrating the principal characteristics of:

   i) A class of Australia's natural or cultural places, or

   ii) A class of Australia's natural or cultural environments.

e) The place has a significant heritage value because of the place's importance in exhibiting particular aesthetic characteristics valued by a community or cultural group.

f) The place has significant heritage value because of the place's importance in demonstrating a high degree of creative or technical achievement at a particular period.

g) The place has significant heritage value because of the place's strong or special association with a particular community or cultural group for social, cultural or spiritual reasons.

h) The place has significant heritage value because of the place's special association with the life or works of a person, or group of persons, of importance in Australia's natural or cultural history.

i) The place has significant heritage value because of the place's importance as part of Indigenous tradition.

Thresholds

As well as assessing a place against criteria for its heritage value, the Australian Heritage Council applies a 'significance threshold' test. This test helps the Council to judge the level of significance of a place's heritage value by asking 'just how important are these values?'. To be entered on the Commonwealth List, a place must have 'significant' heritage value (Department of the Environment, Heritage website, accessed June 2015). In guidlines prepared by the Australian Heritage Council for Commonwealth agencies on the identification of Commonwealth Heritage Values, it is stated that 'the threshold for inclusion on the Commonwealth Heritage List is local heritage significance' (AHC 2010, p.7). This application of a local level threshold underlines the function of the Commonwealth Heritage List as an instrument for managing places with heritage significance. It is not intended to be a list of places with a Commonwealth or National level of significance.

8.2 Individual site assessments

An assessment of each site recording against the Commonwealth Heritage criteria is provided in table form in Table 8.1. The justification for these evaluations is presented below.

8.2.1 Artefact occurrences

Artefact occurrences comprise 97 per cent (72) of the 74 recorded sites in the airport site.

Fifteen of these include confirmed subsurface archaeological deposits, and 48 have assessed moderate or high subsurface archaeological potential.

Thirty-five of these recordings (49% of artefact occurrences) comprise a single artefact, of which four are recorded from archaeological test pits.

Nine recordings include more than ten artefacts, seven of which were recorded from surface contexts (B45, 46, 66, 80, 102, 113 and 115), and two from subsurface test pits (B88 and 121).

The highest recorded number of artefacts is 64 from the 2014 surface reinspection of site B80 by AMC (AMC 2014), followed by 38 from B121, 36 of which were recovered from test pits.

Based on the maximum artefact count across the various inspections and tests at each site, there is a total of 371 stone artefacts from the recorded sites within the airport site.

Criterion c) – Significance because of potential to yield information that will contribute to an understanding of Australia's cultural history

Fifty-one or 71 per cent of the artefact occurrences are assessed as having significance according to this criterion. This assessment has been based on the archaeological potential of each site, where there is confirmed or predicted moderate or high potential for subsurface archaeological material. In one case (B66), a site with low subsurface potential has been included within this criterion, due to the value of the surface artefact assemblage.

Criterion g) - Significance because of a strong or special association with a cultural group for social, cultural or spiritual reasons.

All of the artefact occurrences are considered to have significance according to this criterion. This assessment is based on statements made consistently across all stakeholders that there is a strong association between persons who identify as Darug, or as Darug descendants, and all archaeological sites situated on traditional Darug lands.

This association is expressed both in terms of cultural identify and typically also involving a spiritual dimension. The latter may relate to the memory or 'presence' of Darug ancestors, together with a concern that artefacts 'belong to', and should remain 'in country' where their makers and users left them.

Criterion i) - Significance because of a place's importance as part of indigenous tradition.

All of the recorded artefact occurrences are also considered to have significance according to this criterion. The Macquarie dictionary defines tradition to be 'the handing down of statements, beliefs, legends, customs, etc., from generation to generation, especially by word of mouth or by practice (Butler 1988:1798).

Based on statements by Darug stakeholders, the Aboriginal sites within the airport site are important to a wider regional tradition which remembers and celebrates the Darug relationship with their land for thousands of years. The sites are an integral part of a cultural landscape which acts as the foundation for this remembrance and an inspiration for continued cultural interpretation and traditional practice.

8.2.2 B40 - Possible Aboriginal scarred tree

There is one recording of a scarred tree from the airport site. The likelihood that the scar has an Aboriginal origin is assessed as 'possible'. The condition of the scar is poor, as is that of the tree, which has a hollow trunk and a missing crown. Despite the poor condition of the heartwood and the un-occluded scar, the regrowth around the margin of the scar appears to be intact. This means that the tree retains a tree-ring record of regrowth following the scarring event.

This tree is considered to have significance according to criteria: b), c), g) and i).

Criterion b) - Significance because of uncommon, rare or endangered aspects of Australia's cultural history.

The rarity of scarred trees on the Cumberland Plain can be demonstrated by a search of the AHIMS Aboriginal sites register. Within the core area of the Cumberland Plain, the register includes only 68 modified tree recordings (all but one of which are scarred trees) (search date: 18 June 2015). This portion of the Cumberland plain is defined as the central and majority portion of the Plain, formed from Wianamatta Group bedrocks, and in which exposures of the underlying Hawkesbury sandstone do not occur. This area comprises 1540 km^2 and contains an incidence of one modified tree recording per 22.6 km^2.

As a core area example of this site type, it can be concluded that site B40 is a rare site type and has significance according to this criterion. Given that a 230 year history of European tree clearance and agricultural development has severely limited the population of surviving old-growth trees on the

Plain, the continued and forecast growth of Sydney's urban areas reinforces the status of Aboriginal scarred trees as an endangered component of the Aboriginal cultural record.

Criterion c) – Significance because of potential to yield information that will contribute to an understanding of Australia's cultural history

Despite the poor condition of the tree and scar, and limitations due to the assessed 'possible' nature of an Aboriginal origin, the B40 site still has significance under criterion c). This is due to the potential of its intact record of regrowth across the scar, to provide information about the original age and shape of the scar. A dendrochronological analysis of the tree's regrowth could provide valuable information relevant to a refined interpretation of the scar's origin, and also provide data to a regional dataset to assist in the interpretation of other tree scars with a cultural origin.

Criterion g) - Significance because of a strong or special association with a cultural group for social, cultural or spiritual reasons.

All scarred trees of possible or greater assessed likelihood of an Aboriginal origin are considered to have significance according to this criterion. This assessment is based on statements made consistently across all stakeholders that there is a strong association between persons who identify as Darug, or as Darug descendants, and all archaeological sites situated within the traditional lands of the Darug.

This association is expressed both in terms of cultural identify and typically also involving a spiritual dimension. The latter may relate to the memory or 'presence' of Darug ancestors, together with a concern that artefacts 'belong to', and should remain 'in country' where their makers left them. Scarred trees are particularly valued by the Aboriginal community because they provide a highly visual marker and easily interpreted feature of a place's Aboriginal history and occupation.

Criterion i) - Significance because of a place's importance as part of indigenous tradition.

In concert with criterion g), all scarred trees of possible or greater assessed likelihood of an Aboriginal origin are considered to have significance according to criterion i). Based on statements by Darug stakeholders, Aboriginal sites within the airport site are important to a wider regional tradition which remembers and celebrates the Darug relationship with their land over thousands of years. Scarred trees preserve a past act of harvest, and as such provide inspiration for both modern oral interpretation, and the continued practise of bark removal for the manufacture of traditional material culture.

Scarred trees can be a valuable aid in teaching past and traditional Aboriginal practice. Where accessible, scarred trees are often incorporated into cultural tours and cultural teaching by Aboriginal community teachers and Elders.

8.2.3 B120 – Grinding grooves

This site consists of at least four grinding grooves on a series of small sandstone outcrops on the edge of a hill side bench, 14 m above, and around 100 metres from Badgerys Creek. The site is a rare example of grinding grooves located on Minchinbury sandstone within the Cumberland Plain and has significance across five assessment criteria:

Criterion b) - Significance because of uncommon, rare or endangered aspects of Australia's cultural history.

A search of the AHIMS Aboriginal sites register within the core area of the Cumberland Plain reveals only three other recordings of grinding grooves situated on Minchinbury sandstone (search date: 18 June 2015). One is situated on the flood plain of South Creek, 1.7 km to the north of the study area (AHIMS site no. 45-5-0215), and the other two in the Toongabbie Creek area in the northeastern portion of the Plain. This provides a site incidence of one Minchinbury sandstone grinding groove recording per 385 km^2 of core Cumberland Plain. This is in contrast, to hundreds of grinding groove sites situated on Hawkesbury sandstone across the Sydney basin, and also from the margins of the Cumberland Plain where down cutting of drainage lines has exposed the Hawkesbury sandstone.

Despite the common nature of grinding groove sites elsewhere across the Sydney Basin, the Minchinbury sandstone grooves are significant for their demonstration of Aboriginal use of a limited resource on the shale dominated landforms of the Cumberland Plain.

Criterion c) – Significance because of potential to yield information that will contribute to an understanding of Australia's cultural history

The B120 site has considerable potential to yield information on the Aboriginal use of Minchinbury sandstone on the Cumberland Plain.

This potential is a result of the following attributes

- The site has the potential to contribute data on a very limited population of similar sites and is thus of great value for future archaeological research, and in providing robust results from statistical analyses.
- The site is one of only two known from the South Creek catchment. Both of these sites are likely to complement each other in presenting opportunities for future research.
- Although no artefacts were detected in three archaeological test pits conducted within 10 metres of the groove outcrops on the adjacent bench, there remains untested potential for subsurface archaeological material to be present in close proximity to, and downslope of the grooved outcrops.

Criterion d) – Significance because of importance in demonstrating the principal characteristics of class of Australia's cultural places

This site appears to demonstrate a number of charcteristics which could be expected of its class. These include:

- the creation of grooves on Minchinbury sandstone;
- the exploitation of sandstone outcrops is most likely when situated in relative proximity to a water source; and
- the use of the Minchinbury sandstone at B120, despite the less-than-ideal quality of the matrix and surfaces for grinding. This suggests that the incidence of sandstone in relative proximity to water, in core areas of the Cumberland Plain, was rare and that available exposures would be used despite their limitations.

It is recognised that, to the knowledge of NOHC staff, no scientific characterisation or comparative analysis of Minchinbury sandstone groove sites has been conducted. Further research is required to validate if this site type can be differentiated from Hawkesbury sandstone sites, based on traits other than bedrock type.

Criterion g) - Significance because of a strong or special association with a cultural group for social, cultural or spiritual reasons.

Based on statements made consistently across all stakeholders, this site type has a strong association with persons who identify as Darug, or as Darug descendants. This association is expressed both in terms of cultural identify and typically also involving a spiritual dimension. The latter may relate to the memory or 'presence' of Darug ancestors, together with a respect for the permanent placement of these sites as significant foci within a cultural landscape. Grinding grooves are particularly valued by the Aboriginal community because they provide easily interpreted visual marker of a place's Aboriginal history and occupation. The grooves are evocative of past expertise, social interaction, and repeated visitation.

Criterion i) - Significance because of a place's importance as part of indigenous tradition.

In parallel with criterion g) values, the B120 site is considered to have significance according to this criterion. Based on statements by Darug stakeholders, high value Aboriginal sites such as B120 are important to a wider regional tradition which remembers and celebrates the Darug relationship with their land over thousands of years. Grinding grooves mark a place of tool manufacture and the application of expert skills and knowledge. As such they provide inspiration for both modern oral interpretation and the continued practise of traditional tool manufacture.

Grinding grooves can be a valuable aid in teaching past and traditional Aboriginal practice. Where accessible, grinding grooves can be incorporated into cultural tours and cultural teaching by Aboriginal community teachers and Elders.

Table 8.1 Individual site significance assessments

Site ID	Site type	No. of recorded artefacts	Archaeological subsurface potential	Significance Criteria								
				a	b	c	d	e	f	g	h	i
B3	sao	1	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B4	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B5	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B7	sao	1	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B15	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B24	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B25	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B31	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B32	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B39	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B40	mt(st)	1	-	bst	fulfils criterion	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B41	sao	1	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B42	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B43	sao	5	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B44	sao	3	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B45	sao	12	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B46	sao	13	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B54	sao	2	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B55	sao	2	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B59	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion

Site ID	Site type	No. of recorded artefacts	Archaeological subsurface potential	Significance Criteria								
				a	b	c	d	e	f	g	h	i
B66	sao	16	low	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B67	sao	1	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B68	sao	1	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B69	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B70	sao	5	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B71	sao	1	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B74	sao	1	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B75	sao	1	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B76	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B77	sao	9	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B78	sao	1	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B79	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B80	sao	64	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B81	sao	1	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B82	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B84	sao	7	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B86	sao	5	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B87	sao	5	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B88	sao +ssao	2 + 16	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B90	sao	2	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B91	sao	2	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B92	sao	4	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion

Site ID	Site type	No. of recorded artefacts	Archaeological subsurface potential	Significance Criteria								
				a	b	c	d	e	f	g	h	i
B93	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B94	sao	1	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B95	sao	8	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B101	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B102	sao	19	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B103	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B104	sao	1	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B112	sao	3	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B113	sao	20	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B114	sao	10	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B115	sao	20	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B116	sao	2	low	bst	bst	bst	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B117	sao	3	high	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B118	sao	2	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B119	sao	2	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B120	gg	4, poss.6	low (refer TL23)	bst	fulfils criterion	fulfils criterion	fulfils criterion	bst	bst	fulfils criterion	bst	fulfils criterion
B121	sao +ssao	2 + 36	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B122	sao	1	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B123	ssao	7	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B124	ssao	3	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B125	ssao	2	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B126	ssao	2	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion

Site ID	Site type	No. of recorded artefacts	Archaeological subsurface potential	Significance Criteria								
				a	b	c	d	e	f	g	h	i
B127	ssao	1	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B128	ssao	6	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B129	ssao	2	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B130	ssao	1	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B131	ssao	1	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B132	ssao	2	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B133	ssao	5	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B134	ssao	6	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B135	ssao	1	confirmed	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion
B136	sao	1	moderate	bst	bst	fulfils criterion	bst	bst	bst	fulfils criterion	bst	fulfils criterion

bst - below significance threshold for this criteria
mt – modified tree
st – scarred tree

sao – surface artefact occurrence
ssao – subsurface artefact occurrence

8.3 The archaeologically sensitive landscape

The results of the test excavation program, in combination with the surface survey results, have confirmed an interrelated distribution of archaeological sensitivity which is graded and distributed according to key landform variables. Key factors in combination are: proximity to water, the order of the water source (here used as an approximation of size and degree of permanence), locally elevated ground and first order spurlines within valley floor and basal slope contexts, low gradients and aggrading depositional contexts.

Landforms and zones in which relatively higher subsurface artefact incidences have been detected (1.0 or more artefacts per m^2), comprise just under half (48%) of the airport site. The highest average subsurface artefact incidence was 3.1 artefacts per square metre, from select topographic contexts on the valley floor. The valley floor accounts for 10 per cent of the airport site.

Highest potential artefact occurrences on the valley floor are predicted to occur within the 100 metres of third, fourth and fifth order streamlines. These fluvial corridors account for 17 per cent of the airport site (316 ha), and occur roughly equally across the valley floor and basal slope landform categories. The latter two categories also contain the greatest potential for subsurface archaeological deposits, and for potentially rare and higher value archaeological deposits.

Two hundred and eighty stone artefacts have to date been recorded from the surface of the airport site. The corpus of the predicted assemblage of subsurface artefacts within the landforms with relatively high artefact incidence would far exceed this number. The predicted archaeological resource resident within the identified sensitive archaeological landscape must therefore be a foundation component of any assessment of the cultural heritage values resident within the airport site.

8.3.1 Assessment against all criteria

The predicted Aboriginal archaeological resource of the airport site is assessed as having significance according to criteria: b), c), g) and i).

Criterion a) - Significant because of importance in the course, or pattern, of Australia's cultural history

The archaeological resource within the airport site is not assessed as having significance under this criterion. It does not display evidence of, or the potential for evidence of Aboriginal occupation, adaptation or innovation which can be related to persons, events or developments which were important in the course or pattern of Australia's cultural history.

Criterion b) - Significance because of uncommon, rare or endangered aspects of Australia's cultural history.

The predicted and collective subsurface archaeological resource present across the airport site is not considered to be outstanding in terms of artefact incidence or the technological diversity of the sampled assemblages. The content and variability of the analysed artefact assemblage remains consistent with the predictive model for the Cumberland Plain. This resource can be regarded as characteristic of archaeological material from upper catchment and watershed regions of the Cumberland Plain, (with the exception of such areas which occur in proximity to substantial sources of silcrete).

The planned and continuing urban development of the Cumberland Plain will further impact upper catchment landscapes of which the airport site is part. As the proportion of undeveloped land decreases, this cumulative impact is expected to confer an increasing degree of rarity to the remaining archaeological record. Based on this outline, the predicted archaeological resource of the airport site is assessed as an endangered aspect of Aboriginal cultural history, and significant according to this criterion.

Criterion c) – Significance because of potential to yield information that will contribute to an understanding of Australia's cultural history

The predicted archaeological resource within the airport site has considerable potential to yield information that will contribute to an understanding of the Aboriginal cultural history of the Sydney Basin. Based on the evidence of the sampled archaeological deposits, the airport site provides a substantial opportunity to conduct systematic archaeological research on a representative sample of sites within an upper catchment landscape. This resource, and the opportunity to investigate it as a whole, will become increasingly limited in the future. Such research would complement previously conducted large area archaeological investigations which have typically occurred in lower catchment landscapes, and in association with higher order drainage lines.

The distribution of aggrading landforms across the valley floor and basal slopes, and at a lesser and finer scale across the remainder of the airport site, provides potential for encountering rarer sites, such as cultural deposits associated with buried former land surfaces. Although this potential is considered to be highly limited and difficult to quantify using stage one test excavation methodologies, a review of geotechnical borehole data indicates scope for addressing this potential in future studies.

Criterion d) – Significance because of importance in demonstrating the principal characteristics of class of Australia's cultural places

The substantial degree of European land use impact evident across the airport site has reduced the value of the associated archaeological resource to a level below the significance threshold for this criterion. There are no examples of land surfaces, landforms or broader landscapes which display a necessary degree of intactness or integrity to demonstrate the principal characteristics of Aboriginal occupation within such a landscape. The high degree of land surface modification is particularly evident along drainage lines and the valley floor where erosion, the creation of dams and agricultural cropping has transformed much of the landscape.

Criterion e) - Significant because of importance in exhibiting particular aesthetic characteristics valued by a community or cultural group

The predicted archaeological resource of the airport site is not considered to have significance according to this criterion. Some individual artefacts may be considered to display aesthetic characteristics however it is not a value which can considered applicable to the corpus of the predicted artefact assemblage.

Criterion f) - The place has significant heritage value because of the place's importance in demonstrating a high degree of creative or technical achievement at a particular period

The predicted archaeological resource of the airport site is not considered to have a sufficient value which reaches the necessary threshold for this criterion. A range of technical skills and techniques are demonstrated in the sampled stone artefact assemblage but are not considered to display a high degree of creative or technical achievement relative to the period or in comparison to more technologically complex sites from other Cumberland contexts.

Criterion g) - Significance because of a strong or special association with a cultural group for social, cultural or spiritual reasons

Based on statements made consistently across all stakeholders, the remaining Aboriginal archaeological record across the airport site has a strong association with persons who identify as Darug, or as Darug descendants. This association is expressed both in terms of cultural identify and a spiritual dimension. The latter may relate to the memory or 'presence' of Darug ancestors, and a belief that artefacts 'belong to', and should remain 'in country' where their makers and users left them. The presence of artefacts within the soil matrix, and as a part of the landscape itself, is often referenced as evidence of traditional ownership and a cultural

relationship with country. Aboriginal stakeholders frequently state that all archaeological sites, ranging from single artefacts to large assemblages are considered to have cultural significance in this way.

Criterion h) - The place has significant heritage value because of the place's special association with the life or works of a person, or group of persons, of importance in Australia's natural or cultural history

The predicted archaeological resource of the airport site is not considered to have significance according to this criterion. A number of Darug family groupings are historically associated with the central and western districts of the Cumberland Plain, and the eighteenth century Darug warrior Pemulwuy is thought to have recruited followers from the same region. These associations do not however reach a sufficient threshold for recognition according to this criterion.

Criterion i) - Significance because of a place's importance as part of indigenous tradition.

Based on statements by Darug stakeholders, all Aboriginal sites within the airport site, including those not yet detected (the predicted archaeological resource) are important to a wider regional tradition which remembers and celebrates the Darug relationship with their land. This is a relationship which is described both in terms of a long time depth (thousands of years), and as a continuing living tradition. The Macquarie dictionary defines tradition to be 'the handing down of statements, beliefs, legends, customs, etc., from generation to generation, especially by word of mouth or by practice (Butler 1988:1798). The Aboriginal sites on the airport site are an integral part of a cultural landscape which acts as the foundation for this remembrance and an inspiration for continued cultural interpretation and traditional practice.

8.4 Potential for nomination of places to the Commonwealth Heritage List

This assessment has identified places within the airport site with cultural heritage values that are significant as measured against the Commonwealth Heritage List significance criteria. These findings provide a basis for the consideration of nominating one or more places for listing on the Commonwealth Heritage List. Consideration should also be given to any consequential obligations defined by the EPBC Act for Australian Government agencies, and the DIRD Heritage Strategy (DTRS 2005, Godden Mackay Logan 2011).

The Commonwealth would need to consider the Commonwealth heritage provisions of the EPBC Act in developing its strategy for managing heritage as part of the development of the proposed airport.

In the event that consideration is given to nominating places for listing on the Commonwealth Heritage List, the following issues should be addressed:

- the long term role of the Australian Government in the tenure and control of the subject place;
- the potential impact of the airport development and the potential for long term conservation of the place; and
- the need to prepare management plans for all listed places which are consistent with Commonwealth heritage management principles.

9. Assessment of Impacts

9.1 Impact Categories

9.1.1 Construction

Construction impacts are defined as those which are a result of the construction of the airport. A majority of the airport construction impacts would be direct impacts where material items, sites and landforms are substantially modified, removed, or destroyed.

The potential to avoid these impacts is largely negated by the broad-scale and transformative nature of the development. A limited number of indirect impacts could also be anticipated such as impact to the visual and landscape context of sites. These include noise and impact to surrounding landscape features.

For the purposes of this assessment, construction impacts are considered separately according to an initial airport development and a subsequent longer term development stage. The former is considered in detail and according to the specifications of the development as currently known. The latter stage is considered in general terms only.

9.1.2 Operational

Operational impacts are defined as those which result from the day-to-day operation of the airport. These relate to indirect impacts, such as impact to the visual, aural and landscape contexts of adjacent sites.

As for construction impacts, operational impacts are considered separately in this assessment according to an initial airport development and a subsequent longer term development stage. The former is considered in detail and according to the specifications of the development as currently known. The latter stage is considered in general terms only.

9.1.3 Cumulative

Cumulative impacts are defined as the incremental, collective or aggregate effect of a development upon a region or area with respect to the existing or surviving regional Aboriginal archaeological resource and cultural heritage values (Buckley 1994).

Cumulative impact analysis necessarily takes into consideration past and current impacts and may also refer to the anticipated future consequences of a development. The assessment of cumulative impact aims to consider the potentially deleterious effect of the development from a broad regional perspective, rather than as a localised impact within a development boundary. An assessment requirement is therefore a characterisation of the relevant archaeological region within which the development is located. The impact of the development with respect to the regional resource may then be estimated.

For the purposes of this analysis the archaeological region relevant to the airport is defined as the core portion or the ‘Shale Slopes’ of the Cumberland Plain. This is the landscape in which only landforms derived from the shale dominated Wianamatta Group of rocks are evident. It is exclusive of the river plain and dissected plateau divisions of the Cumberland Plain (refer to Section 3.1.2). The airport site comprises around 1.2 per cent of the Shale Slopes landscape.

The cumulative impact of the airport development can be divided into two components:

- impact relative to the aggregate of previous similarly impactive development; and
- future impacts which are a likely consequence of airport operation.

An important premise for the assessment of cumulative impact is that similar landforms, in similar contexts, will be associated with a similar archaeological resource. This is supported by

the predictive model, but with the important rider that the associated resource may be variably degraded according to the degree of land surface disturbance. This premise allows for comparative analyses by using area measurements of similar landforms and disturbance levels.

9.2 Initial airport development

9.2.1 Construction

The proposed initial airport development area includes 39 Aboriginal sites within areas of land disturbance works. All of these recordings comprise artefact occurrences. Construction and development related works would also occur outside of the initial airport development area in the form of drainage swales, detention ponds, and potentially other works in accordance with the Airport Plan and subject to any requirements under the Airports Act. The planned drainage swales which would link the initial airport development area with detention ponds adjacent to Badgerys Creek have the potential to impact additional sites, as could other as yet unspecified works. Quantification of this impact is dependent on future design. The ID numbers of sites affected by the initial construction impact are shown in Table 9.1.

Table 9.1 Sites which would be directly impacted by Initial development construction works

Development area	Affected surface sites	Total
North and west of proposed boundary fence and earthworks boundary	B24, B25, B32, B39, B43, B44, B69, B70, B71, B77, B78, B79, B80, B81, B82, B84, B86, B87, B88, B91, B92, B94, B95, B112, B113, B114, B115, B116, B119, B122, B127, B128, B129, B131, B134	35
Detention Ponds south and east of the proposed boundary fence and earthworks boundary	B5, B101, B102 and B136	4
Drainage swales between earthworks boundary and detention ponds	Subject to design	
Other potential works in accordance with Airport Plan and subject to Airports Act	Subject to design	
Total		at least 39

With regard to the predicted subsurface archaeological resource, the initial construction works would directly impact 501 hectares of archaeologically sensitive landform. This constitutes 27 per cent of the whole airport site. These landform categories, and their affected proportions, are shown in Table 9.2.

The proposed initial development would directly impact all of the archaeologically sensitive landforms associated with the airport site's three north flowing, third and fourth order tributary drainage lines. A portion of the riparian corridor within the airport site along Badgerys Creek would be protected within an environmental conservation zone. The archaeological resource within this zone would also be protected by this zoning. The extent to which the drainage swales would impact the catchment remains to be outlined and quantified.

In addition, all of the higher relief and prominent topography of the airport site would be transformed into a level and graded platform. This would substantially alter and remove the natural topography which acts as an important medium for Aboriginal people to 'read' and experience the Aboriginal cultural values of the land. The loss of the natural landscape across this area would thus represent an appreciable loss of Aboriginal cultural value.

9.2.2 Operation

The operational impacts of the proposed initial airport development would be limited to indirect impacts on the contextual values of adjacent and nearby sites. All known sites within 500 m of the proposed Stage 1 development consist of artefact occurrences. The heritage values of sites of this type, unless valued for their public interpretation or visitation based on Aboriginal cultural reasons, are unlikely to be vulnerable to indirect impacts such as loss of context. Consequently, it can be concluded that the operational impacts of the proposed initial development would be of a low level.

Table 9.2 The area and proportion of archaeologically sensitive landforms subject to direct construction impact from initial development of the airport

Landform category[1] or feature	Area within Initial development area (ha)	Proportion of airport site	Total of this landform category within whole of airport site (ha)	Proportion of total landform area within airport site (1845 ha[2])
Riparian corridor (100 m either side of drainage line)				
2nd order corridor	219.3	11.9%	324.7	17.6%
3rd order corridor	38.2	2.1%	44.9	2.4%
Ridges and spur crests				
1st order crest	68.7	3.7%	120.3	6.5%
Broad scale landform				
Valley floor	47.8	2.6%	184.0	10.0%
Basal slopes	127.5	6.9%	214.2	11.6%
Total	501.5	27.2%	888.1	48.1%

Notes: 1. The categories in this table are mutually exclusive. The area of fluvial corridors and crests which overlap valley floor or basal slope topography have not been tabulated

2. The area total includes Australian Government owned lands which are non-contiguous with the airport site.

9.2.3 Cumulative

The initial development areas would comprise around 60 per cent of the airport site, and include around 27 per cent of the site's archaeologically sensitive landforms. As such, the degree of cumulative impact, relative to the aggregate of past regional development would be approximately half that of the whole site, and roughly equal with the impact of the longer term development area. Despite this, the initial stage would have a substantially greater impact on future surrounding development because it will establish a focus for further commercial and industrial development in adjoining lands. This effect is anticipated and allowed for in the South West Growth Centre through an intended zoning for industrial development along the eastern side of Badgerys Creek adjacent to the airport site.

Figure 9.1 presents the position of the airport site, relative to a 2005 Landsat image and an outline map of the Cumberland Plain. A visual comparison of the two reveals a preference for past and current urban development to be situated on the plain, especially where associated with a transport corridor to the central city regions. The Landsat image reveals how prominent the size the airport site is in relation to the remaining undeveloped portions of the Cumberland Plain. It also reveals the high proportion of the plain which has been cleared of native vegetation for agriculture – thus supporting the evidence for the rarity of Aboriginal scarring on old-growth trees.

The planned and projected future urban and industrial growth areas in the western Cumberland Plain are shown in Figures 9.2 and 9.3. The combined area of the North West and South West Growth Centres, together with the Broader Western Sydney Employment Area is approximately 38,000 ha. This area of planned urban and industrial development would infill a substantial majority of the remaining non-developed lands across the Cumberland Plain. Both the Broader Western Sydney Employment Area and South West Growth Centre are situated within the Shale Slopes division of the Cumberland Plain. Together these zones cover 28,000 hectares, which is approximately 22 per cent of the Shale Slopes division.

Another regional measure of cumulative impact is the developed area as a proportion of the South Creek catchment (Figure 9.3). This catchment comprises 620 square kilometres and dominates the central and northern half of the western Cumberland Plain (Rae 2007:7). In 2000, urban development occupied 12,536 ha of the catchment. The remaining undeveloped catchment lands at this time, amounted to approximately 495 square kilometres, the proposed airport site being 3.4 per cent of that area. Almost all of the combined area of the North West and South West Growth Centres, and the Broader Western Sydney Employment Area are situated within the South Creek catchment. These areas comprise 380 square kilometres, and together with the existing urban development of at least 125 km^2, represent 505 square kilometres or 81 per cent of the catchment. The proposed airport site would then represent 15 per cent of remaining undeveloped lands.

It can be concluded that the cumulative impact of the proposed initial airport development would be substantial. This is a consequence of both its incremental effect on the aggregate of past development across comparable portions of the Cumberland Plain, and especially the aggregate of future planned development. The proposed airport would serve as a key infrastructure component amongst planned growth centres. The generation of secondary commercial enterprises would stimulate development of adjoining areas. It can be predicted that the aggregate future impact of the planned Western Sydney growth centres will be the survival of a very small proportion of the Cumberland Plain natural landscape, especially when measured as a proportion of the South Creek catchment or the low relief rolling terrain of the core areas of the plain.

The observation by the Aboriginal stakeholder community that management of the cumulative impacts of most past developments on the plain has been non-existent or ineffective, lends emphasis to this conclusion. The absence of an Aboriginal Keeping Place for the storage of cultural material salvaged from the Cumberland Plain is raised as evidence of the short-comings of past approaches to cumulative impact.

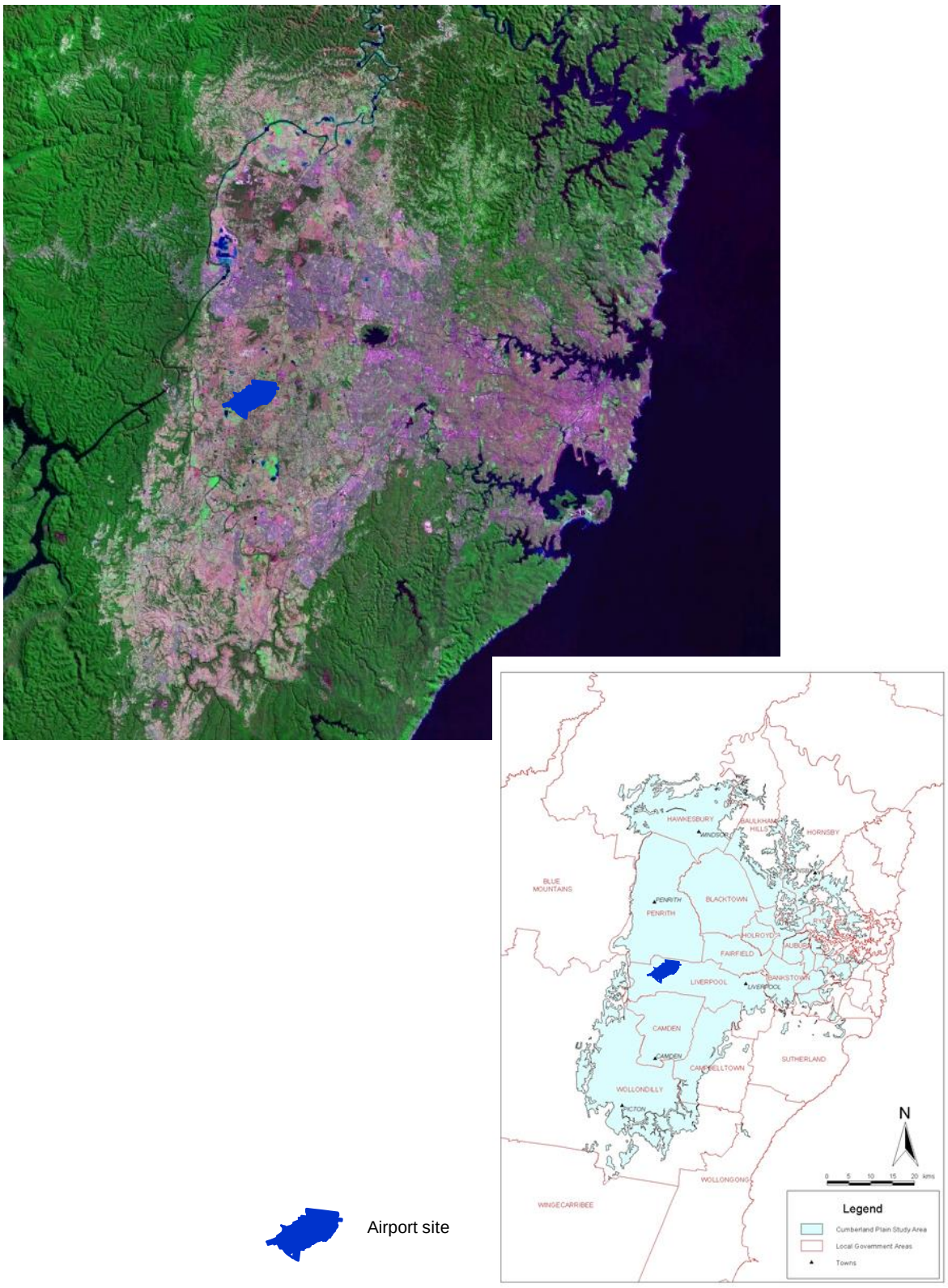


Figure 9.1 Comparison of a 2005 false colour Landsat image of Sydney and the Cumberland Plain, showing built up urban areas as purple, and cleared areas as pink. An outline of the Cumberland shale based landforms is provided for comparison. (Top image: Sydney suburbs geocover". Licensed under Public Domain via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Sydney_suburbs_geocover.png#/media/File: Sydney_suburbs_geocover.png. Bottom image: http://www.environment.nsw.gov.au/threatenedspecies/MapOfTheCumberlandPlain.htm)

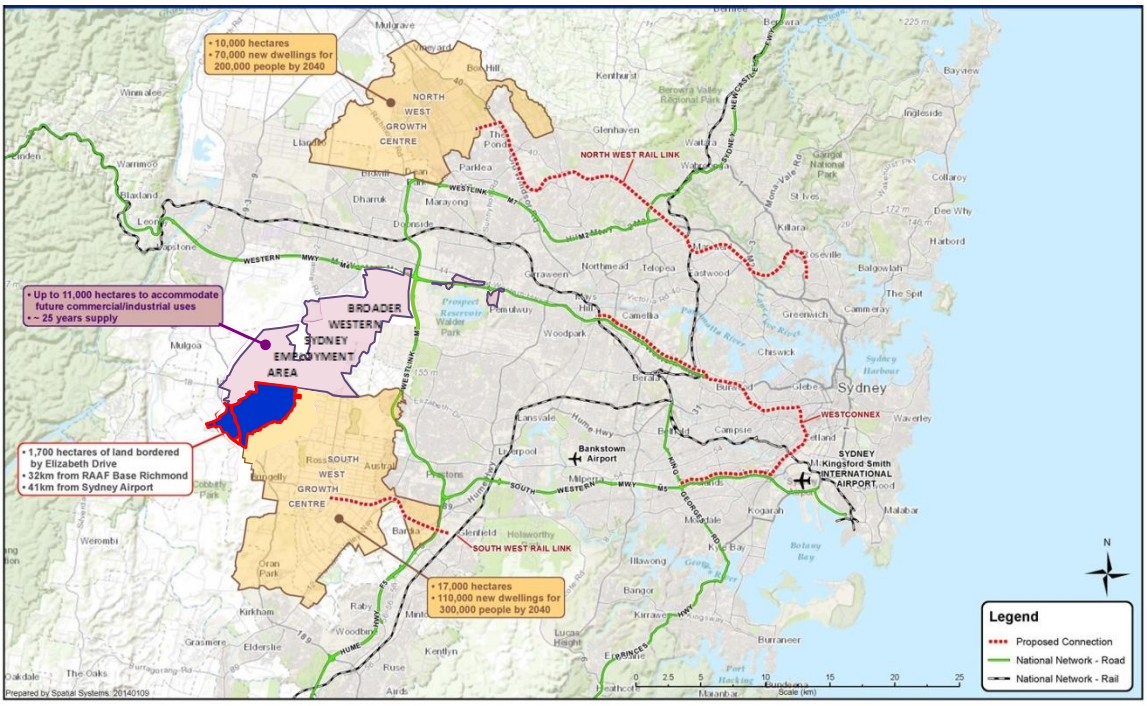


Figure 9.2 The airport site relative to existing urban development (grey) and planned future infrastructure and growth areas on the Cumberland Plan: North West Growth Centre, Broader Western Sydney Employment Area, and the South West Growth Centre (from the Western Sydney Infrastructure Plan, source: http://www.inspiredfinance.com.au/Images/badgerys_creek/Badgerys_Creek_Map.jpg).

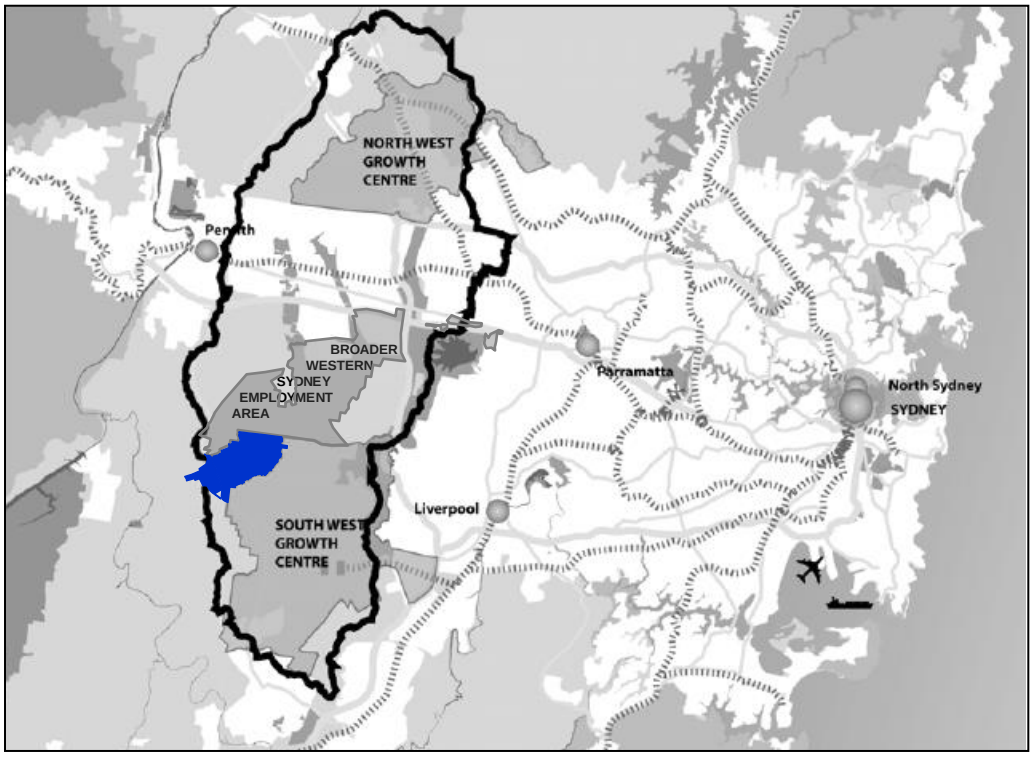


Figure 9.3 The catchment of South Creek (black boundary), relative to the airport site (blue), existing urban development (white) and planned growth centres (darker grey) (base map source: Rae 2006:Figure 6, p.9).

9.3 Longer Term Development

9.3.1 Construction

The proposed longer term development area includes 21 Aboriginal sites within areas of land disturbance works. All of these recordings comprise artefact occurrences. Eleven sites, including grinding groove site (B120), and the possible Aboriginal scarred tree (B40), occur in relative proximity to Badgerys Creek and as they would remain unaffected, present an opportunity to be incorporated into an open space conservation zone between the west bank of the creek and a boundary fence. The ID numbers of sites that would be directly impacted by longer term construction are shown in Table 9.3.

With regard to the predicted subsurface archaeological resource, the longer term construction works would directly impact about 387 hectares of archaeologically sensitive landform. This constitutes 21 per cent of the whole airport site. These landform categories and their affected proportions are shown in Table 9.4.

The proposed longer term development of the airport site would directly impact a major proportion of the remaining Badgerys Creek catchment across the eastern half of the site.

The location of the longer term development area on the eastern fall of the Badgerys Creek catchment means that the levelling of the landscape to create a graded level platform, continuous with the initial development, would substantially alter and remove the natural topography framing Badgerys Creek. The 'lie of the land' acts as an important medium for Aboriginal people to 'read' and experience the Aboriginal cultural values of the land. Its loss on the western side of the creek would represent an appreciable loss of Aboriginal cultural value.

9.3.2 Operation

The operation impacts of proposed development within the longer term development area would be limited to indirect impacts on the contextual values of adjacent and nearby sites. All but two of the known sites within 500 m of the longer term development area consist of artefact occurrences. The heritage values of this site type, unless valued for their pubic interpretation or visitation based on Aboriginal cultural reasons, are unlikely to be vulnerable to indirect impacts such as loss of context.

The two exceptions are the grinding groove site (B120) and possible Aboriginal scarred tree (B40). Both of these sites could potentially be situated in close proximity to the boundary fence. Given the cultural heritage values of these sites and their potential for public interpretation, the indirect impacts of the adjacent development area on their contextual values are likely to be appreciable.

9.3.3 Cumulative

The longer term proposed development area comprises around 40 per cent of the airport site, and includes around 21 per cent of the site's archaeologically sensitive landforms. As such, the degree of cumulative impact, relative to the aggregate of past regional development would be approximately half that of the whole site, and roughly equal with the initial development area. Development of the longer term area would have a considerably smaller impact on future surrounding development because it would simply extend an already established enterprise. The broad scale cumulative impacts of further commercial and industrial development in adjoining lands are likely to have already occurred by the time of its development. The urban and industrial zoning originally planned for, and paired with, the airport development is most likely to have been established by this time. Cumulative impacts from further development in the region are likely to involve infill or redevelopment within these already established zones. As a consequence, and in contrast to Stage 1, the cumulative impact of the longer term development would be considered only to be moderate in scale.

Table 9.3 Sites which would be directly impacted by construction works in the longer term development area

Development area or land use zone	Affected surface sites	Total
North and west of the proposed boundary fence	B3, B15, B31, B42, B46, B59, B66, B67, B68, B75, B76, B95, B104, B117, B118, B121, B123, B124, B125, B126, B132,	21
Potentially situated in environmental conservation zone including Badgerys Creek	B4, B7, B40, B41, B54, B55, B74, B90, B120, B130, B133	11
Total		32

Table 9.4 The area and proportion of archaeologically sensitive landforms subject to direct construction impact from longer term development of the airport site. Note these are mutually exclusive categories. The area of fluvial corridors and crests which overlap valley floor or basal slope topography have not been separately tabulated.

Landform category or feature	Area within longer termdevelopment area (ha)	Proportion of airport site	Total of this landform category within whole of airport site (ha)	Proportion of total landform area within airport site (1845 ha[1])
Riparian corridor (100 m either side of drainage line)				
2nd order corridor	105.4	5.7%	324.7	17.6%
3rd order corridor	6.7	0.4%	44.9	2.4%
4th order corridor	0		0	
5th order corridor	0		0	
Ridges and spur crests				
1st order crest	51.6	2.7%	120.3	6.5%
Broad scale landform				
Valley floor	136.2	7.4%	184.0	10.0%
Basal slopes	86.7	4.7%	214.2	11.6%
Total	386.6	20.9%	888.1	48.1%

Note 1. The area total includes Australian Government owned lands which are non-contiguous with the airport site

9.4 Greater Blue Mountains World Heritage Area

At its closest point, the Greater Blue Mountains World Heritage Area (GBMWHA) is situated approximately seven kilometres to the west of the airport site. The Area was listed on the World Heritage List in 2000 based on its fulfilment of two of the criteria for natural values of outstanding universal value. These involve outstanding examples of ongoing biological processes significant in the evolution of Australia's ecosystems, and significant natural habitats for the *in situ* conservation of biological diversity (NSW NPWS 2009).

The World Heritage listing does not refer to the area's Aboriginal cultural heritage values, however the strategic plan for the GBMWHA notes that protection of the area's other important values, such as Aboriginal cultural heritage, is an integral component of managing the reserves that constitute the GBMWHA, both individually and as a whole (NSW NPWS 2009:11,32).

The Aboriginal cultural heritage values of the Greater Blue Mountains (GBM) Area are derived from a broad spectrum of material evidence, lore and practice. These can be summarised by the following:

- The landscape and its features, especially those which relate to Dreamtime and other cultural and historical stories
- The biota, including animals and plants with special cultural significance as sources of medicine, bush tucker and raw material
- The archaeological and cultural sites present, including a large corpus of rock art and rock shelter sites
- Oral tradition, stories and lore, and
- Continuing traditional practice and interpretation conducted by traditional owners.

There is little potential for the proposed airport to directly impact the Aboriginal cultural heritage values of the Greater Blue Mountains Area.

Fuel dumping is an extremely rare event, and normally conducted at an altitude which makes it very unlikely that any significant quantity of fuel, if any, will reach the ground. Potential impacts on World Heritage values from this source have been considered further in other technical studies undertaken to support the EIS.

Indirect impact to cultural heritage values potentially include those associated with temporary loss of contextual value from the periodic intrusion of aircraft noise or from aircraft arriving at or departing from the proposed airport. This could potentially affect sites, such as rock shelters and open sites, where there is an expectation or requirement for a quiet and natural surrounding environment. Sites within this category could include those developed for public access and interpretation, sites at which traditional Aboriginal activities are performed, and sites within wilderness zones. A limited number of sites have been developed or interpreted for public visitation in the Blue Mountains National Park, these include: Shaws Creek K1, Burralow, Red Hands Cave, Campfire Creek, Kings Tableland, Lyre Bird Dell and Asgard Swamp (NSW NPWS 2001:47; Attenbrow 2010:186).

Wilderness zones form part of the current management zoning in the GBM Area and incorporate objectives such as the conservation of 'pre-European' landscapes with minimal historical and European intrusion, including aircraft noise and vapour trails (NSW NPWS 2001). The potential intrusion of low flying general aviation aircraft undertaking sightseeing flights is currently managed over the Blue Mountains National Park through the implementation of a voluntary code of practice known as a Fly Neighbourly Advice (NSW NPWS 2001:40). This code of practice does not apply to regular public transport aircraft operations.

In conclusion, any potential impacts from an airport development that may affect cultural heritage values of the GBM Area would be indirect in nature and relate to airport noise and visual intrusion from aircraft.

10. Mitigation and Management Strategies

10.1 Terminology

In this section, the term 'mitigation' is defined as actions and strategies which prevent the loss of cultural heritage values. Typically mitigation would involve avoiding direct impact to an item or place. Mitigation mostly occurs prior to the commencement of development-related disturbance, and involves the adoption of policy or specifications which direct planning and design.

The term 'management' is defined as actions and strategies which reduce the loss of cultural heritage values. This may involve partial conservation, discovery and handling protocols, the recovery of information and cultural material through archaeological salvage, and compensatory measures.

10.2 Discussion

This assessment has identified a range of Commonwealth Heritage values, that variously fulfil five of the nine Commonwealth Heritage List significance criteria. These relate to both individual sites and to the corpus of known and predicted archaeological resource as an aggregate. Values include those communicated by Aboriginal stakeholders regarding their cultural tradition and practice, and scientific values relating to rarity and potential to yield information.

The following is an outline of the key considerations regarding the mitigation and management of the anticipated impacts of the proposed airport on the identified Commonwealth Heritage values. It should be noted that Commonwealth Heritage values relate to the significant values of places on land owned or controlled by the Australian government. The effective management of these values, relative to the potential impact of the proposed airport, would vary according to the assessed nature of significance.

Limited scope for mitigation

The scope for mitigation is very limited due to the primary requirement of the proposed development for a broad continuous area of well drained, level ground with unencumbered flight approaches. This has the consequence that for most sites and most of the subsurface archaeological resource, there is no potential for *in situ* conservation.

A limited opportunity for *in situ* conservation management is afforded by the proposed retention of native vegetation and open space along a part of the Badgerys Creek within a proposed Environmental Conservation zone. Aboriginal sites which occur within this area include two high value sites, the grinding groove site (B120) and the possible Aboriginal scarred tree (B40).

The lack of an *in situ* conservation management option across most of the proposed airport site means that construction impacts to Commonwealth Heritage values must be addressed through the conduct of archaeological salvage, and of measures which address impacts to non-archaeological and intangible cultural values. Any program of archaeological salvage must address the broad-area nature of the impact, and ensure that variability within the archaeological record relative to the impacted landscape is adequately sampled.

Staged implementation of the proposed airport

The focus of the mitigation and management strategies in this assessment relates to the anticipated impacts of the initial proposed development of the airport site. Given that the potential longer term development of the site is known only in outline and may be assessed within a different statutory context to the current assessment, the provision of strategies for the longer term are limited to general principles and the continuity of practice from the initial stage.

Strong and current opposition to the airport proposal from many of the Aboriginal stakeholders

There is strong opposition to the airport proposal from many of the Aboriginal stakeholders based on their appreciation of the Aboriginal cultural values which would be impacted, and especially the degree of landscape change and site loss which would result from airport construction.

This emphasises the need to adopt management strategies which would effectively address the loss and/or impacts to Aboriginal cultural values. Principal concerns expressed by Aboriginal stakeholders include:

- The need to minimise, wherever feasible, direct impact to Aboriginal sites and cultural values.
- The need to offset and address the loss of Aboriginal heritage values that would result from airport development.
- The need for the Aboriginal stakeholder community to be consulted and included in the development and conduct of mitigation and management strategies which effect their heritage.
- The need to address the cumulative impacts of the development, especially with regard to the existing, and planned future development of the Cumberland Plain.
- The need to provide for the culturally appropriate repatriation, and where appropriate, the long term curation, of all salvaged Aboriginal archaeological materials.
- The inclusion of commemorative elements within the airport development which celebrate and interpret the Aboriginal cultural heritage of the site.
- The need to adopt protocols and on-site training during the construction phase. These would reduce impact to cultural values, and allow for better management of Aboriginal archaeological material that may remain on site during construction activities.

Curation of cultural materials

Two modes for the potential future management of salvaged Aboriginal archaeological material have been described as culturally appropriate by Aboriginal stakeholders. The first is reburial within a specifically reserved and managed area, within the local area of the airport site. This mode maintains cultural identity and values by replacing artefacts within the general region of their original find-locations, and to the 'country' they belong to.

The second is long term storage and curation within a 'Keeping Place' which maintains future access to the collection for cultural, educational and research purposes. The first mode is now an established strategy for many large developments across the Sydney Basin and elsewhere. The second however, remains an unfulfilled objective for the Cumberland Plain due to the lack of a physical locality, facility or supporting administrative structure. The need for such a facility is now pressing due to 2012 changes in the deposition policy of the Australian Museum, Sydney, which formerly acted as a repository for salvaged materials (Australian Museum 2012).

Addressing cumulative impacts

There is a range of means by which cumulative impacts can be managed. The most effective are those which establish long term compensatory actions, and as such, offset the loss of values which (in the absence of developmental impact) would otherwise have remained resident within the landscape, 'country' and place.

The following strategies involve long term compensatory actions which would be appropriate for addressing cumulative impacts:

- Establishment of offset conservation reserves which include a representative sample of the archaeological resource subject to direct impact;
- Establishment of long term, on-site, elements which commemorate, promote and interpret Aboriginal cultural values to the general public;
- Establishment of facilities for the long term curation, access, management and interpretation of cultural materials salvaged as a part of impact management programs. The ongoing nature and continuity of such facilities provides a valuable contribution to managing the long term losses inherent in cumulative impacts.

The first of these strategies, the establishment of offset reserves, is not a feasible option for the proposed airport, due to the nature of the airport site, the archaeological resource subject to impact, and constraints inherent in the surviving resource of the Cumberland Plain. The latter two strategies remain feasible options and each are addressed as integral components of the impact management proposals defined in sections 10.3.2 and 10.4.2.

It is recognised that protocols and facilities are required for the long term curation of Aboriginal cultural material that would be salvaged as a result of the proposed airport development. Based on the views of Aboriginal stakeholders, options for curation include:

- a “keeping place” for the conservation management of that portion of salvaged Aboriginal cultural material, which according Aboriginal stakeholders should be stored above-ground in a secure facility, and for which future access for cultural purposes, interpretation, education or research should be maintained; and

- repositioning or reburial of material at one or more appropriate locations within the local landscape, that would be determined in consultation with Aboriginal stakeholders.

It is acknowledged that the effective establishment of an above-ground ‘keeping place’ facility would require the participation of many levels of government and stakeholder representation, and include a long term view of the facility’s function and application. The potential use of such a facility for the curation of other salvage collections from Western Sydney developments would be an important consideration in planning and conception. From this basis, a commitment is made to consult with other levels of government and relevant Aboriginal community representatives with the objective of developing protocols for the long term archival storage and conservation management of Aboriginal cultural material.

10.3 Initial airport development

10.3.1 Mitigation

The following mitigation actions address the opportunity for conservation in those portions of the airport site not directly impacted by the proposed airport.

S1 The Aboriginal grinding groove site (B120) should be conserved *in situ* within open space along the western bank of Badgerys Creek, and outside of any future airport site boundary fence. A low barrier fence, which does not obstruct pedestrian traffic, should be erected around specific heritage sites as is necessary to demarcate the area as a no go area for vehicles. The barrier should be situated so that it does not intrude upon the immediate visual and landscape quality of the heritage site surrounds.

S2 The possible Aboriginal scarred tree (B40) should be conserved *in situ* within open space along the west bank of Badgerys Creek, and outside of any airport site boundary fence. A low barrier fence, which does not obstruct pedestrian traffic, should be erected around as much of the site as is necessary to demarcate the area as a no go area for vehicles. The barrier should be situated so that it does not intrude upon the immediate visual and landscape quality of the heritage site surrounds.

S3 Any environmental conservation zones established as part of the airport development should be managed with the conservation of known and predicted Aboriginal sites as one of the principal objectives. This strategy relates in particular to the planned conservation zone along Badgerys Creek and to the west of Willowdene Avenue.

S4 A conservation management plan (CMP) should be developed that defines the future care and management of sites B40 and B120 and all Aboriginal sites situated within the environmental conservation zone(s) identified in the Airport Plan. The management plan should consider future public interpretation and access to sites, as appropriate and subject to meeting safety and security requirements.

10.3.2 Management Strategies

The following management strategies are drafted with specific reference to the initial development area of the airport site. They do, however, include actions which relate to the whole airport site, where it is necessary to address impacts from the construction and operation of the initial development.

Continued consultation with Aboriginal stakeholders

S5 An Aboriginal stakeholder consultation plan should be developed and adopted which specifies the nature and frequency of consultation to be conducted throughout the design and construction phase of the proposed development. The aims of the consultation program would be:

- to inform on, and provide an opportunity for feedback, regarding all matters relating to the mitigation and management of Aboriginal cultural heritage values across the airport site;
- to provide a forum for organising future stakeholder participation in mitigation and management works; and
- to provide opportunities to comment on all policy and documentation drafted in regard to the mitigation and management of Aboriginal cultural values.

S6 Opportunity should be provided to Aboriginal stakeholders to participate in field actions involving the mitigation and management of Aboriginal cultural values. This participation would be arranged according to a fair and equitable scheme.

Recording and salvage

S7 A targeted archaeological surface survey of the initial construction area *not previously subject to surface survey* (and excluding highly disturbed areas) should be conducted prior to the conduct of development-related ground surface disturbance. The aim of this survey would be to ensure that all visible surface Aboriginal sites have been recorded and can be managed prior to development impact.

S8 A salvage program of surface artefact recovery should be conducted across known Aboriginal artefact occurrences in the construction disturbance area with the aim of avoiding damage from construction related activities. This action addresses strongly held concerns by Aboriginal stakeholders concerning the protection of artefacts from construction impact. The collection program would be conducted using an archaeological methodology and the resulting collection could be integrated into the archaeological analysis of salvaged material, where appropriate.

S9 A comprehensive archaeological inspection of surface sandstone outcrops across the whole airport site should be conducted prior to, and as required during construction-related activities. This action has the aim of ensuring that any stone surface with evidence of Aboriginal marking is appropriately recorded and salvaged.

S10 An archival recording of the Aboriginal grinding groove site (B120) and the possible Aboriginal scarred tree (B40) should be conducted prior to the conduct of any development-related ground disturbance works within the area of these heritage sites. This has the objective of providing a baseline record and information upon which to develop a CMP.

S11 A program of oral history recording should be conducted with the aim of recording memories and stories from Aboriginal people which relate to the airport site and its district. It is intended that this record would serve as an archive and a resource for future interpretation of the Aboriginal heritage values of the site.

S12 A selective archaeological salvage program should be conducted prior to, and as necessary during, construction works across the initial development area subject to construction impact. The objective of the program would be to manage impacts to archaeological or scientific values. The aim of the program would be to recover and analyse a representative sample of surface and subsurface archaeological material from the areas subject to construction impact. The program would aim to:

- Recover archaeological material from all landform types based on a systematic and representative sampling matrix;
- Recover additional archaeological material from areas with assessed relatively higher archaeological value, with the objective of providing a large enough artefact population for statistical analysis and from which robust results can be derived; and
- Apply archaeological excavation methodologies which are appropriate to the expected archaeological resource and the objectives of the salvage.

As a part of designing the salvage program, the results of a review of relevant and existing geotechnical data (refer Appendix 6), should be integrated into the process of determining the location and scope of the salvage program.

Protocols

S13 Protocols for the unanticipated discovery of Aboriginal objects (artefacts), and for the discovery of any suspected human remains should be developed and implemented for all development related works involving ground disturbance. These protocols would define legal obligations to be complied with, and management strategies to be followed in the event that suspected human remains are encountered, and/or Aboriginal archaeological material is encountered which is outside of the expected or predicted nature of the archaeological resource (and thus not managed by the conduct of the strategies listed here). It is recommended that the protocols presented in Appendix 8 be adopted, or alternatively be used as a first draft in the development of such protocols.

S14 An investigation should be conducted into the feasibility of a protocol for the management of top soil or other soil matrix material which is assessed as likely to contain a relatively high density of Aboriginal stone artefacts. The aim of this protocol would be to ensure that the excavation, storage and placement of this material is managed in a culturally appropriate manner and the potential for damage to the artefacts is minimised. The protocol would be developed in consultation with Aboriginal stakeholders. The protocol would address the following issues:

- the appropriate identification and tracking of spoil containing artefacts;
- the minimisation of physical damage to the artefacts during mechanical processing and movement; and
- end-use of the spoil in contexts which minimise potential future impact to the artefacts, and where possible, are culturally appropriate.

Induction training

S15 Training in the identification of Aboriginal artefacts and the management of Aboriginal heritage values should be included, at appropriate levels, in compulsory induction courses for site workers. The content of this component would vary according to the stage of construction. After the completion of major cut and fill actions, training may focus on the management of spoil where there is a risk of impacting artefacts, and on no-go areas where relevant.

Conservation Management Plan

S16 A conservation management plan (CMP) should be prepared which defines and integrates all strategies for mitigating and managing Aboriginal heritage values across the airport site. This plan should be developed in consultation with Aboriginal stakeholders and relevant government agencies. The plan should include both short and long term strategies, and address actions required prior to, during and after construction.

Commemoration of Aboriginal heritage

S17 The Aboriginal cultural heritage values of the airport site should be commemorated and interpreted as part of the airport development and its infrastructure. Consideration could be given to a range of options for realising this strategy. These include:

a. The use of Darug words and language in the naming of places and infrastructure.

b. The dedication of various spaces and places for the placement of art and interpretive elements, storage and display of cultural items, and/or the conduct of cultural activities.

c. The provision of public access and interpretive facilities at Aboriginal sites conserved *in situ* within the airport site (such as for sites B40 and B120), subject to safety and security requirements.

Curation and repatriation

S18 Following the completion of archaeological description and analysis, Aboriginal cultural material salvaged from the airport site should, in the first instance, be stored at an appropriate place to be determined in consultation with Aboriginal stakeholders and relevant government agencies. The longer term storage of this material, and potentially material salvaged from other developments in Western Sydney, should be managed in accordance with protocols to be developed through further consultation with Aboriginal stakeholders and relevant state, federal and local government agencies. Longer term storage options could include:

a) a 'keeping place', if feasible, that would provide secure, above ground storage enabling future access for cultural purposes, interpretation, education or research; and

b) re-positioning or reburial at an appropriate time, at one or more locations within the local landscape to be determined in consultation with Aboriginal stakeholders.

Greater Blue Mountains World Heritage Area

S19 The potential noise and visual impact from aircraft flying over wilderness areas of the Greater Blue Mountains Area, and Aboriginal sites promoted for public visitation should be considered in the development and refinement of flight paths to and from the airport, subject to requirements for safe and efficient aircraft operations.

10.4 Longer term development

10.4.1 Mitigation

S20 The Aboriginal grinding groove site (B120) should remain as an *in situ* conserved site within an open space area along the west bank of Badgerys Creek and outside of the airport boundary fence. The airport boundary fence should be located in such a way that the distance between the grinding grooves and the fence (and any required adjacent vehicle track or service easements) is maximised.

S21 The possible Aboriginal scarred tree (B40) should remain as an *in situ* conserved site within the reserved area along the west bank of Badgerys Creek and outside of the airport boundary fence. The airport boundary fence should be located in such a way that the distance between the scarred tree and the fence (and any required adjacent vehicle track or service easements) is maximised.

S22 All environmental conservation areas established or maintained as part of the further development of the airport should be managed with the conservation of known and predicted Aboriginal sites as one of the principal objectives.

S23 The conservation management plan (CMP) for all Aboriginal sites situated within environmental conservation areas should be maintained and revised, as necessary, to define the care and management of all Aboriginal sites which continue to be included in such lands.

10.4.2 Management Strategies

Continued consultation with Aboriginal stakeholders

S24 Regular consultation should be conducted with the invited participation of relevant Aboriginal stakeholders throughout the design and construction phase of any further development of the airport site. The aims of this program would be the same as for Strategy 5.

S25 Opportunity should be provided to Aboriginal stakeholders to participate in all field actions involving the mitigation and management of Aboriginal cultural values. This participation should be arranged according to a fair and equitable scheme.

Recording and salvage

S26 An archaeological surface survey of the development areas *not previously subject to surface survey* (and excluding highly disturbed areas) should be conducted prior to the conduct of development related ground surface disturbance. The aim of this survey is to ensure that all surface Aboriginal sites have been recorded and can be managed prior to development impact.

S27 A salvage program of surface artefact recovery should be conducted across all known Aboriginal artefact occurrences within the development areas, with the aim of avoiding damage from construction related activities. The collection program should be conducted using an archaeological methodology and the resulting assemblage can be integrated into the archaeological analysis of salvaged material, where appropriate.

S28 A comprehensive archaeological salvage program should be conducted prior to, and as necessary during, construction works across the further development areas. The aims, scope and methodology of this program would be the subject of a further assessment which justifies any required management actions in the context of current knowledge and research.

Protocols

S29 The protocols for the unanticipated discovery of Aboriginal objects, and for the discovery of suspected human remains would be reviewed and revised as necessary, and enacted for all development related works involving ground disturbance.

S30 A protocol should be enacted for the management of top soil or other soil matrix material which is assessed as likely to contain a relatively high density of Aboriginal stone artefacts. The aim of this protocol is to ensure that the excavation, storage and placement of this material is managed in a culturally appropriate manner and the potential for damage to the artefacts is minimised. The protocol may be based on the protocol developed for the initial development of the airport and should be developed in consultation with Aboriginal stakeholders.

Induction training

S31 Training in the identification of Aboriginal artefacts, and the conduct of airport site strategies for the management of Aboriginal heritage values should be included, at appropriate levels, in the compulsory induction courses for site workers.

Conservation Management Plan

S32 The conservation management plan (CMP) prepared at the time of the initial construction works would be reviewed and revised as necessary. The CMP would define and integrate all strategies for mitigating and managing Aboriginal heritage values across the airport site. This revised plan would be developed in consultation with Aboriginal stakeholders, and relevant statutory authorities and construction proponents.

Commemoration of Aboriginal heritage

S33 The Aboriginal cultural heritage values of the airport site would continue to be commemorated and interpreted as part of the airport development and its infrastructure.

Curation and repatriation

S34 All salvaged Aboriginal cultural material would be curated and managed in consultation with Aboriginal stakeholders, as appropriate and according to available facilities and contemporary protocols.

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Appendix 1

Aboriginal Consultation Documentation

A1.1 Public Notice inviting registration by Aboriginal stakeholders

PROPOSED WESTERN SYDNEY AIRPORT
CULTURAL HERITAGE ASSESSMENT
ABORIGINAL STAKEHOLDER REGISTRATION

The Australian Government is developing a proposal for the construction and operation of an airport, to be located at Badgerys Creek, approximately 3km east of Luddenham, and situated within the Liverpool Local Government Area.

A robust and rigorous environmental assessment is being conducted for the proposed airport. Navin Officer Heritage Consultants Pty Ltd (NOHC) has been commissioned to conduct an Aboriginal cultural heritage assessment of the project.

NOHC are implementing a programme of Aboriginal stakeholder consultation as an integral part of this assessment. This programme will be guided by Commonwealth government standards and guidelines and the Office of Environment and Heritage *Aboriginal cultural heritage consultation requirements for proponents 2010*. It will assist NOHC in the preparation of an application for an Aboriginal Heritage Impact Permit, should one be required.

We invite Aboriginal people and organisations who wish to participate in the programme, and who hold cultural knowledge relevant to determining the cultural significance of objects and places in the project area, to register an interest in the project.

Please forward expressions of interest to:

The Secretary
Navin Officer Heritage Consultants Pty Ltd
4/71 Leichhardt Street
Kingston ACT 2604

The closing date for registration is 10th March 2015

For further information about the proposed Western Sydney airport, visit www.infrastructure.gov.au/westernsydneyairport

Publication record:

- Blacktown Advocate Wednesday 18 February 2015
- Liverpool Leader Wednesday 18 February 2015
- Fairfield City Champion Wednesday 18 February 2015
- Camden Advertiser Wednesday18 February 2015
- Penrith Press Friday 20 February 2015
- Macarthur Chronicle Tuesday 24 February 2015

A1.2 List of registered Aboriginal stakeholders and representatives

Registered stakeholder entities

- Badu
- Bilinga CHTS
- Butucarbin Aboriginal Corporation
- Cubbitch Barta Native Title Claimants Aboriginal Corporation
- Darug Aboriginal Cultural Heritage Assessments
- Darug Aboriginal LandCare
- Darug Custodian Aboriginal Corporation
- Darug Land Observations
- Darug Tribal Aboriginal Corporation
- Deerubbin Local Aboriginal Land Council
- Dhinawan-Dhigaraa Culture and Heritage Pty Ltd
- EORA
- Gandangara Local Aboriginal Land Council
- Gangangarra
- Goobah
- Gundungurra Aboriginal Heritage Association Inc.
- Gunyuu
- Kamilaroi-Yankuntuatjara Working Group
- Kawul Cultural Services
- Mungunya (sic) CHTS
- Murrumbul
- Ngunawal
- Ngunawal Heritage Aboriginal Corporation
- Nundagurri
- Tharawal Local Aboriginal Land Council
- Tocomwall Pty Ltd
- Walbunja
- Wandandian
- Warragil Cultural Services
- Wingikarah CHTS
- Wullung
- Wurrumay
- Yerramurra

Seventeen registrations have been received following the completion of the fieldwork program:

- Bidawal
- Bulling Gang Elders
- Curwur Murre Elders
- Dharug
- Djiringanj
- Elouera
- Gadung Elders
- Golangaya Elders
- Gulla Gunar Elders
- Kuringgai
- Murrin
- Ngarigo
- Peter Falk Consultancy
- Tharawal
- Thauaira
- Walbunja Elders
- Walgalu

Stakeholder representatives who participated in the field program

Registered Stakeholder Entity	Representatives
Badu	Andrew Bond
Bilinga CHTS	Robert Parsons Chris Brierley Chris Payne (observer)
Butucarbin Aboriginal Corporation	Jack Gibson Johnathan Whitton
Cubbitch Barta Native Title Claimants Aboriginal Corporation	Glenda Chalker
Darug Aboriginal Cultural Heritage Assessments	Gordon Morton
Darug Aboriginal Land Care	Shaun Lynch
Darug Custodian Aboriginal Corporation	Elizabeth Coplin Tylah Blunden Lana Wedgwood
Darug Land Observations	Jamie Workman Jamie Eastwood
Darug Tribal Aboriginal Corporation	John Reilly
Deerubbin LALC	Steve Knight Steve Randall Wayne Boney
Dhinawan-Dhigaraa Culture and Heritage Pty Ltd	Donald Nixon Jamarl Leroy
EORA	Wayne Brierley
Gandangara Local Aboriginal Land Council	Brad Maybury
Gangangarra	Richard Andy
Goobah	Michael Williams
Gundungurra Aboriginal Heritage Association Inc.	Kieren McNally
Gunyuu	Sam Juparulla Wickman
Kamilaroi-Yankuntuatjara Working Group	Marbuck Khan Philip Khan
Kawul Cultural Services	Greg Slater
Munyunga [Mungunya] CHTS	Shaun Wellington Peter Foster (Observer)
Murrumbul	Trae Andy
Ngunawal	Edward Stewart Chris Brierley
Ngunawal Heritage Aboriginal Corporation	Graeme Dobson
Nundagurri	Thomas Tighe
Tharawal Local Aboriginal Land Council	Abbi Whillock
Tocomwall Pty Ltd	John Phillips
Walbunja	Leonard ‘Jacko’ Nye
Wandandian	Sam Juparulla Wickman
Warragil Cultural Services	Aaron Slater
Wingikarah CHTS	Michael Williams
Wullung	Leeroy Boota
Wurrumay	Bo Field
Yerramurra	Edward Stewart Peter Foster

A1.3 Native Title Search

National Native Title Tribunal

Sydney Office, Operations East
Level 16
Law Courts Building
Queens Square
Sydney NSW 2000
GPO Box 9973
Sydney NSW 2001
Telephone (02) 9227 4000
Facsimile (02) 9227 4030

19 February 2015

Nicola Hayes
Principal Archaeologist
Navin Officer Heritage Consultants
4/71 Leichhardt Street
Kingston ACT 2604

Our Reference: 0419/15MO
Your Reference: WSA

Dear Ms Hayes

Native Title Search Results for Badgerys Creek within Liverpool Local Government Area

Thank you for your search request received on 13 February 2015 in relation to the above area.

Search Results
The results provided are based on the information you supplied and are derived from a search of the following Tribunal databases:

Register Type	NNTT Reference Numbers
Schedule of Applications (unregistered claimant applications)	Nil.
Register of Native Title Claims	Nil.
National Native Title Register	Nil.
Register of Indigenous Land Use Agreements	Nil.
Notified Indigenous Land Use Agreements	Nil.

At the time this search was carried out, there were **no relevant entries** in the above databases.

Please note: There may be a delay between a native title determination application being lodged in the Federal Court and its transfer to the Tribunal. As a result, some native title determination applications recently filed with the Federal Court may not appear on the Tribunal's databases.

Tribunal accepts no liability for reliance placed on enclosed information
The enclosed information has been provided in good faith. Use of this information is at your sole risk. The National Native Title Tribunal makes no representation, either express or implied, as to

Facilitating timely and effective outcomes.

Freecall 1800 640 501
www.nntt.gov.au

the accuracy or suitability of the information enclosed for any particular purpose and accepts no liability for use of the information or reliance placed on it.

If you have any further queries, please do not hesitate to contact me on the numbers listed below.

Yours sincerely

Melissa O'Malley | RECEPTIONIST/CLIENT SERVICES OFFICER
National Native Title Tribunal | Sydney Office
Level 16, Federal Law Courts Building, Queens Square, Sydney, New South Wales 2000
Telephone (02) 9227 4000 | Facsimile (02) 9227 4030 | Email melissa.o'malley@nntt.gov.au
Freecall 1800 640 501 | www.nntt.gov.au
Shared country, shared future.

Searching the NNTT Registers in New South Wales

Search service
On request the National Native Title Tribunal may search its public registers for you. A search may assist you in finding out whether any native title applications (claims), determinations or agreements exist over a particular area of land or water.

In New South Wales native title cannot exist on privately owned land including family homes or farms.

What information can a search provide?
A search can confirm whether any applications, agreements or determinations are registered in a local government area. Relevant information, including register extracts and application summaries, will be provided.

In NSW because we cannot search the registers in relation to individual parcels of land we search by local government area.

Most native title applications do not identify each parcel of land claimed. They have an external boundary and then identify the areas not claimed within the boundary by reference to types of land tenure e.g., freehold, agricultural leasehold, public works.

What if the search shows no current applications?
If there is no application covering the local government area this only indicates that at the time of the search either the Federal Court had not received any claims in relation to the local government area or the Tribunal had not yet been notified of any new native title claims.

It does not mean that native title does not exist in the area.

Native title may exist over an area of land or waters whether or not a claim for native title has been made.

Where the information is found
The information you are seeking is held in three registers and on an applications database.

National Native Title Register
The National Native Title Register contains determinations of native title by the High Court, Federal Court and other courts.

Register of Native Title Claims
The Register of Native Title Claims contains applications for native title that have passed a registration test.

Registered claims attract rights, including the right to negotiate about some types of proposed developments.

Register of Indigenous Land Use Agreements
The Register of Indigenous Land Use Agreements contains agreements made with people who hold or assert native title in an area.

The register identifies development activities that have been agreed by the parties.

Schedule of Native Title Claims
The Schedule of Native Title Claims contains a description of the location, content and status of a native title claim.

This information may be different to the information on the Register of Native Title Claims, e.g., because an amendment has not yet been tested.

How do I request a native title search?
Download the Search Request Form from the Tribunal's website at - http://www.nntt.gov.au/assistance/Pages/Searches-and-providing-Register-information.aspx

Email to: NSWEnquiries@nntt.gov.au
Post to: GPO Box 9973 Sydney NSW 2001
For additional enquiries: 02 9227 4000

Background Paper and Proposed Methodology

for Aboriginal Stakeholder review and comment

Western Sydney airport project

2015 Environmental Impact Statement - Aboriginal Cultural Heritage Assessment

Navin Officer Heritage Consultants *25 March 2015*

What is the purpose of this document?

The purpose of this document is to provide all Registered Aboriginal Parties (RAPs) an opportunity to review and comment on the proposed methodology for the conduct of an archaeological survey and subsurface testing program and cultural heritage assessment for the Western Sydney airport Environmental Impact Statement (EIS).

Navin Officer Heritage Consultants (NOHC) has developed this methodology in accordance with the *Code of Practice for Archaeological Investigations of Aboriginal Objects in New South Wales (DECCW 2010a)*.

All comments received will be documented in the final version of this document and in the report for the project. All comments will be addressed and amendments made to the methodology where appropriate.

What is the Western Sydney airport proposal?

The Australian Government has commenced a new environmental assessment for the proposed Western Sydney airport. The airport site has been identified as approximately 1700 hectares of Commonwealth-owned land at Badgerys Creek, New South Wales. (Figure 1).

The proposed airport would be developed in accordance with an airport plan that identifies concept designs for the airport and a more detailed proposal for an initial development stage. Development of the proposed airport would be staged in response to demand, with an initial stage including one runway and an ultimate layout potentially comprising two parallel runways of up to 4,000 metres in length.

To maximise the potential of the site and its commercial viability, the proposed airport would operate on a 24-hour basis.

Construction of the airport could commence in 2016 with airport operations commencing in the mid-2020s.

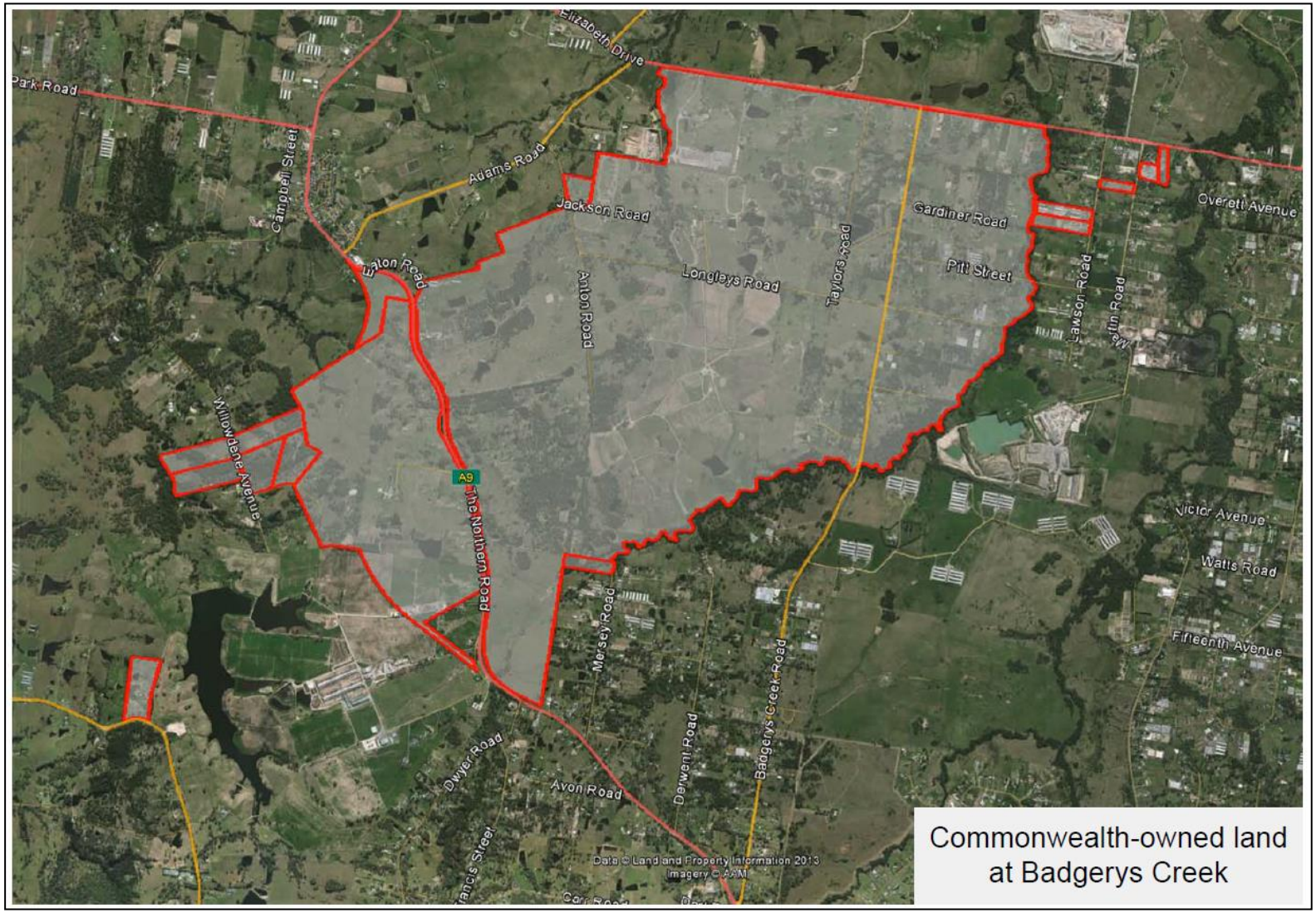


Figure 1 Indicative Project Area

About the Assessment Process

This EIS is being conducted in accordance with the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act). Note that this is not a NSW or State legislative process.

The proposal was referred under the EPBC Act by the Western Sydney Unit of the Australian Government Department of Infrastructure and Regional Development (WSU) to the Minister for the Environment on 4 December 2014. A delegate of the Minister determined on 23 December 2014 that approval is required as the proposal has the potential to have a significant impact on the following matters of national environmental significance (NES) and other matters that are protected under Part 3 of the EPBC Act:

- Listed threatened species and ecological communities;
- The heritage values of a National Heritage place;
- The world heritage values of a declared World Heritage property; and
- The environment because the proposal is a Commonwealth action.

While the Commonwealth also has guidelines addressing heritage investigations, for example *Identifying Commonwealth Heritage Values and Establishing a Heritage Register; a Guideline for Commonwealth agencies* (Australian Heritage Council 2010), the WSU has chosen to adopt the NSW Office of Environment and Heritage (OEH) Aboriginal stakeholder consultation protocols and the *Code of Practice for Archaeological Investigations of Aboriginal Objects in New South Wales* for consistency and to address stakeholder expectations.

How can I provide a comment on this methodology?

Registered Aboriginal parties are invited to provide comments and suggestions back to NOHC by 23 April 2015.

NOHC contact information is as follows:

The Secretary
Navin Officer Heritage Consultants Pty Ltd
4/71 Leichhardt Street
Kingston ACT 2604

email: navinofficer@nohc.com.au
phone: 02 62829415
fax: 02 62829416

Additionally, a meeting will be held in the Badgerys Creek area to discuss the project and this methodology during the week of the 6th April. Further details of this meeting will be forwarded to you at least 1 week prior.

Project Assessment Background

A number of previous EIS studies have been conducted at the proposed airport site over several decades; including:

1985 - Second Sydney Airport: Site Selection Program (Department of Aviation)

1997-1999 – Second Sydney Airport Proposal (Department of Transport and Regional Development)

The most recent and comprehensive EIS of the Badgerys Creek study area was conducted in 1997-1999 where three possible airport layout options were investigated. A total of 110 recordings were made resulting from sample surveys of the Badgerys Creek study area. Surveys were undertaken for all airport options, as well as some areas which subsequently fell outside of the finalised option boundaries. No test excavations were conducted.

Option A of the 1997-1999 EIS relates to the current proposal. A total of 60 known sites or isolated finds were located within the area of Option A. These comprised 25 open artefact scatters, five scarred trees, and 30 isolated finds. Five of these recordings are associated with recorded potential archaeological deposits. The valley floors and fringing basal slopes associated with major creek lines were identified as having moderate or higher subsurface archaeological potential. Aboriginal cultural values were identified not only in association with the archaeological sites, but also with surviving native plants and animals.

A targeted re-inspection of 21 Aboriginal heritage sites identified within areas of moderate and high archaeological potential by the 1997-1999 EIS study, was undertaken by Australian Museum Consulting archaeologists on 22 –23 September2014. Surface artefacts were found to be visible at only seven of the 21 sites. The seven sites consisted of two possible scarred tree sites and five stone artefact sites. This indicates that conducting further surface survey is unlikely to reveal much more information about the project area. The best option to advance our understanding of the archaeology of the project area is to now conduct a program of test excavation.

Based on the existing information and the previous assessments conducted, the priorities for this current investigation are considered to be:

- The conduct of an archaeological test excavation program, across a sample of landforms, to investigate the presence and significance of Aboriginal sites and deposits below-the-ground surface;
- Assessment of Aboriginal cultural values and intangible values held by contemporary Aboriginal stakeholders; and
- An assessment of the impacts of the current project in the context of other past, present and future projects on the Aboriginal cultural heritage of the project area and the wider region.

Proposed Methodology

The EIS assessment of the impacts of the proposal on Aboriginal cultural heritage values will involve:

- Review of existing and background information, and assessment requirements
- Liaison with statutory authorities
- Conduct of Aboriginal stakeholder consultation program
- Aboriginal stakeholder inspections
- A focused archaeological test excavation program to determine the nature and significance of the Aboriginal subsurface archaeological resource
- Analysis and compilation of all data and findings, significance assessment
- Impact assessment and development of impact mitigation strategies
- Preparation of draft cultural heritage impact assessment technical report(s)
- Input to Draft EIS
- Exhibition of Draft EIS including review of interim heritage report and Draft EIS by Aboriginal stakeholders
- Responses to public submissions including comments from Aboriginal stakeholders on the findings and recommendations of the interim heritage report
- Final EIS

Field Program

The field program will commence on 27 April 2015 and conclude on 17 May 2015.

Stakeholder inspections

The first week of field program, 27 April – 1 May 2015 will involve inspection of the project area with RAPs, to identify cultural values, concerns, issues and to provide firsthand experience of the project area and likely scope of development impact. All potential test excavation locations will be subject to field inspection during this time. Potential land acquisition areas will be reviewed; however site access to these areas is expected to be restricted and targeted survey is unlikely to be possible.

Archaeological test excavation program

To be conducted in the second and third weeks of the field program:

- Thirty-eight potential locations for archaeological test locations have been identified after a review of landform types, access conditions and ground disturbance.
- Between 10 and 20 locations will be subject to test excavation, the final number will depend on how resources are expended based on an assessment of field results.
- Test excavation will be conducted at up to twenty selected locations between the dates 1 May – 17 May 2015. Around 10 pits will be conducted at each test location, arranged in a grid pattern and/or along straight line transects, with pits spaced at regularly intervals.
- Excavations at each test location will last approximately one or two days.
- Excavation will be conducted according to OEH 'Code of Conduct' protocols. All excavation will be conducted by hand, and excavated material will be dry sieved on site and then used to back fill the pits.

RAP participation in the field program

A roster will be developed for the participation of all RAPs in the fieldwork program. Each RAP will be given equal time to participate in the field including in the test excavation and inspection days.

We ask that each group nominate a representative or representatives to participate in the program. Each representative must have the appropriate levels of insurance including Workers Compensation and Public Liability, certificates of currency must be supplied.

Analysis

All artefacts recovered will be examined in detail by stone artefact specialist Dr Oliver McGregor (or other suitably qualified lithic specialist, depending on availability). Descriptions of each artefact will be entered into a database and digital photographs may be taken of selected artefacts, where appropriate. Information for each artefact recorded in the analysis will be provided in an appendix in the heritage report.

Recovered material will be analysed in the NOHC lab in Canberra.

The only destructive analysis will be the use of recovered charcoal, or shell or bone material for radiocarbon dating.

Report Drafting

Information gained in the course of the test excavation program and information provided by the Aboriginal community will be documented in a heritage report (except where information has been identified as culturally sensitive and therefore restricted). The report will detail the methodology,

results and assessment of significance of identified sites. An impact assessment will be completed and recommendations will be provided for the management of sites.

Stakeholder review of the report

All registered stakeholders will be provided with a copy of the Draft EIS report and supporting Aboriginal heritage specialist report with an invitation to provide comments and responses.

Unlike the NSW EIS process, exhibition of a Draft EIS is required by the Commonwealth EIS process and all community and stakeholder comments on the Draft EIS received and responded to as part of a Final EIS. The Final EIS will not be exhibited in the same way as the Draft EIS.

For this project, the review of the Draft EIS and interim heritage report by registered stakeholders will coincide with the public review of the Draft EIS. The comments and responses of registered stakeholders will subsequently be included and addressed in the Final EIS report.

Return of cultural material

Disposition and storage of collected stone artefact assemblages during the test excavation will be dealt with in accordance with the Code of Practice under Requirement 26.

After analysis, all recovered artefacts would be stored individually in standard resealable plastic bags or bagged in appropriate and identifiable units. The bags would be labelled using a permanent black pen with the item's unique identification number (where generated and appropriate), and/or details of its provenance within the excavation (as appropriate).

Following completion of the analysis of the recovered artefacts, it is proposed that all Aboriginal objects be repositioned back into the landscape (‘returned to country’) in accordance with Requirement 26 of the Code of Practice.

All locations of repositioned artefacts would be recorded on appropriate OEH forms and lodged with the AHIMS, administered by OEH.

What will happen if human remains are encountered?

In the event that suspected human remains are encountered during any of the proposed test or salvage excavations, protocols for the unanticipated discovery of archaeological material and suspected human remains (presented in Attachment 1) would be adopted.

Attachment 1: Protocol to be followed in the event that suspected human remains are encountered

1. All ground surface disturbance in the area of the finds should cease immediately after the finds are uncovered.

    a. The discoverer of the find(s) will notify all field workers and machinery operators in the immediate vicinity of the find(s) so that work can be halted; and

    b. The excavation director, site supervisor and representatives of the proponent will be informed of the find(s).

2. If there is substantial doubt regarding a human origin for the remains, then consider if it is possible to gain a qualified opinion within a short period of time. If feasible, gain a qualified opinion (this can circumvent proceeding further along the protocol for remains which turn out to be non-human). If conducted, this opinion must be gained without further disturbance to any remaining skeletal material and its context (Be aware that the site may be considered a crime scene containing forensic). If a quick opinion cannot be gained, or the identification is positive, then proceed to the next step.

3. Immediately notify the following people of the discovery:

    a) The local Police (this is required by law);

    b) The Western Sydney Unit of the Australian Government Department of Infrastructure and Regional Development;

    c) The Australian Government Department of the Environment

    c) An archaeologist or Aboriginal Heritage Officer (as appropriate) from the Office of the Environment and Heritage (OEH) (Environment hotline: 131 555);

    e) Representative(s) from the registered Aboriginal parties (as appropriate); and

    f) The project archaeologist (if not already present).

4. Facilitate the evaluation of the find(s) by the statutory authorities and comply with any stated requirements. Depending on the evaluation of the find(s), the management of the find(s) and their location may become a matter for the Police and/or Coroner.

5. Excavation works in the area of the find(s) may not resume until the proponent receives written approval from the relevant statutory authority: from the Police or Coroner in the event of an investigation, or from OEH in the case of Aboriginal or Non-Aboriginal remains outside of the jurisdiction of the Police or Coroner.

In the event that the proponent continues an active role in the evaluation and/or management of the find(s), via a direction or advice from the Police, Coroner and/or the OEH or Heritage Council, then all or some of the following steps *may* be conducted:

6. Facilitate, in co-operation with the appropriate authorities, the definitive identification of the skeletal material by a specialist (if not already completed). This must be done with as little further disturbance to any remaining skeletal material and its context as possible.

7. If the specialist identifies the remains as non-human then, where appropriate, the protocol for the discovery of Non-Aboriginal or Aboriginal artefacts should be followed.

8. If the specialist determines that the remains are human, then the proceeding course of action may be of three types:

a. The remains are of an Aboriginal or non-Aboriginal person who died less than 100 years ago. All further decisions and responsibilities regarding the remains and find location rest with the Police and/or the State Coroner.

b. The remains are of a non-Aboriginal person who died more than 100 years ago. In this case, and where the Police have indicated that they have no interest in the find(s), the following steps may be followed:

   i. Ascertain the requirements of the Heritage Branch (OEH), the proponent, the project archaeologist, and the views of any relevant community stakeholders;

   ii. Based on the above, determine and conduct an appropriate course of action. Possible strategies could include one or more of the following:

      1. Avoiding further disturbance to the find and conserving the remains in situ (this option may require relocating the development and this may not be possible in some contexts);
      2. Conducting (or continuing) archaeological salvage of the finds following receipt of any required statutory approvals;
      3. Scientific description (including excavation where necessary), and possibly also analysis of the remains prior to reburial;
      4. Recovering samples for dating and other analyses; and/or
      5. Subsequent reburial at another place and in an appropriate manner determined by the Heritage Council and in consultation with other relevant stakeholders.

c. The remains are of an Aboriginal person who died more than 100 years ago. In this case the following steps may be followed:

   i. Ascertain the requirements of the relevant registered Aboriginal parties, the OEH, the proponent, and the project archaeologist;

   ii. Based on the above, determine and conduct an appropriate course of action. Possible strategies could include one or more of the following:

      1. Avoiding further disturbance to the find and conserving the remains in situ, (this option may require relocating the development and this may not be possible in some contexts);
      2. Conducting (or continuing) archaeological salvage of the finds following receipt of any required statutory approvals;
      3. Scientific description (including excavation where necessary), and possibly also analysis of the remains prior to reburial;
      4. Recovering samples for dating and other analyses; and/or
      5. Subsequent reburial at another place and in an appropriate manner determined by the registered Aboriginal parties and the OEH.

Reference/Sources:

Donlan, D., McIntyre-Tamwoy, S. and A. Thorne 2002 Aboriginal Skeletal Remains Manual. NSW National Parks and Wildlife Service, Hurstville.

Heritage Office, NSW 1998 *Skeletal Remains Guidelines for the Management of Human Skeletal Remains under the Heritage Act 1977*.

A1.4.2 Presentation at Stakeholder Meeting 8 April 2015



Proposed Methodology

Aboriginal cultural heritage assessment

Proposed Western Sydney airport

Aboriginal stakeholder meeting
St Mary's Memorial Hall, St Mary.

Navin Officer Heritage Consultants
8 April 2015

What are the aims of this meeting?

- To present information about the Western Sydney airport project
- To provide some background information about the project area
- To provide registered Aboriginal stakeholders an opportunity to review and discuss the proposed methodology prior to submitting written comments
- An opportunity to identify issues and significant cultural values

Code of Conduct

- Principles we agree on
- To allow all participants to be heard and respected
- Everybody's opinion is important
- Criticism is welcome and part of the process
- Criticise ideas or concepts but not people or personalities
- It is everybody's responsibility to maintain a civil work environment and a healthy place in which debate can happen

The Western Sydney Airport proposal

- The Australian Government has commenced a new environmental assessment for the proposed Western Sydney airport
- Assessment is being directed by the Western Sydney Unit of the Dept of Infrastructure and Regional Development
- Project area consists of all the Commonwealth owned land at Badgerys Creek
- Approximately 1700 hectares

The Western Sydney Airport proposal

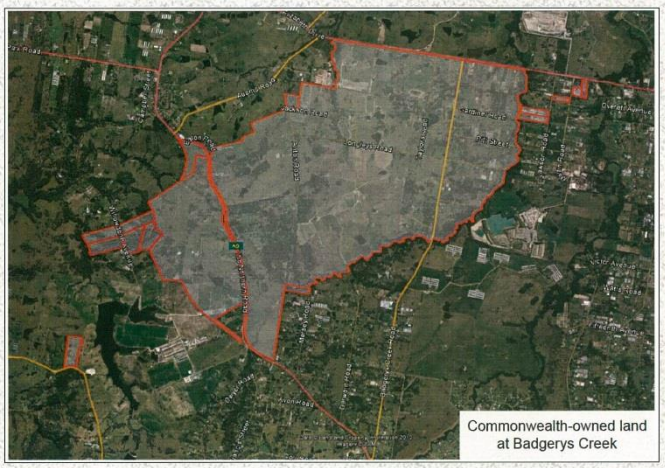
- Little or no opportunity to conserve Aboriginal sites *insitu* within the airport development
- Airport development will be staged in response to demand
- Airport to operate on a 24 hour basis
- Construction to start in 2016 and airport operations to start in mid 2020s

A previous airport proposal



1997 EIS Option A airport layout

The project area



The Assessment Process

- An EIS conducted in accordance with Commonwealth legislation
- *Environment Protection and Biodiversity Conservation Act 1999*
- Not an assessment under State legislation or the National Parks and Wildlife Act
- The OEH consultation protocols used as a guide for the consultation program
- The OEH Code of Practice for Archaeological Investigations also being used as a guide for the fieldwork program

The Assessment Process

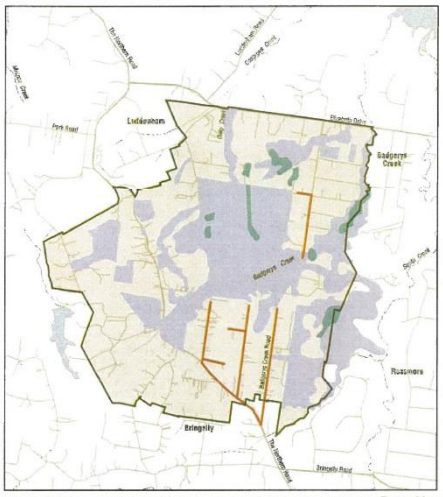
- Opportunity for Aboriginal stakeholder comment and review of the draft EIS will be conducted in parallel with the period for public comment on the draft.
- All Aboriginal stakeholder comments will be included and addressed in the final EIS

Previous Assessments

- 1985 Site Selection Program
- Second Sydney Airport EIS in 1997 – evaluated two possible sites: Holsworthy and Badgerys Creek
- Various reviews and audits of the 1997 EIS, to 1999
- Australian Museum Consulting Archaeologists re-inspected a sample of the 1997 EIS recordings in 2014

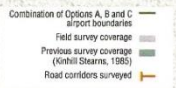
1997 EIS

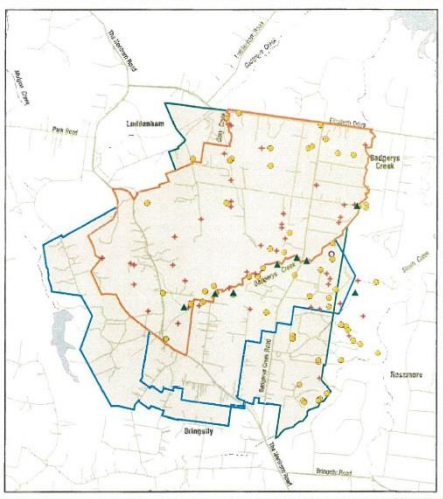
- Option A project area, 16970 hectares, roughly equivalent to current project area (some additions)
- 50% of Option A area subject to comprehensive survey
- 60 Aboriginal archaeological sites recorded:
  - 25 open artefact scatters
  - 5 scarred trees
  - 30 isolated finds
- Valley floors and fringing basal slopes along major creeklines have moderate or higher subsurface archaeological potential
- Aboriginal cultural values were identified in association with both the archaeological sites, and with surviving native plants and animals



1997 EIS

Survey coverage

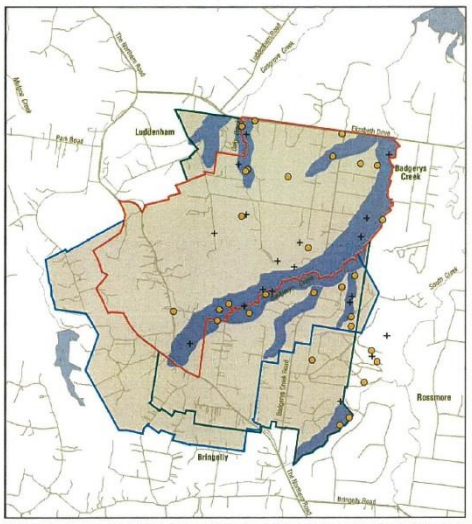




1997 EIS

All recorded sites

Boundary of airport option A
Boundary of airport option B
Boundary of airport option C
Open site (including artefact scatters and grinding groove sites)
Isolated find
Scarred tree
Potential archaeological deposit (only) in open context



1997 EIS

Recordings of moderate or greater archaeological significance

Boundary of Airport Option A
Boundary of Airport Option B
Boundary of Airport Option C
Areas of moderate or high archaeological sensitivity
Isolated find
Open site (including artefact scatters and grinding groove sites)

Criticisms of 1997 EIS

- Too reliant on surface survey results
- No subsurface testing conducted
- Aboriginal cultural values
- Intangible values
- Cumulative impacts

2014 re-inspection

- Conducted by Australian Museum Consulting Archaeologists
- 21 sites in areas of moderate or higher predicted archaeological subsurface potential revisited
- Only seven had artefacts (5) or tree scars (2) visible
- This result due to poor visibility and greater vegetation cover
- Indicates that doing further surface survey is unlikely to provide a great deal of new information

Priorities for current assessment

- Build upon (but not repeat) the results of the previous studies
- Emphasis on test excavation program
- Test a representative range of landform types
- Aboriginal cultural and intangible values
- Cumulative impacts



Typical ground surface exposure revealing stone artefacts, recorded in 1997 EIS field program. This type of exposure is now rarer in the project area

Proposed Methodology

- Review of existing information
- Predictive model
- Liaison with statutory authorities
- Aboriginal stakeholder consultation program
- Aboriginal stakeholder inspections
- Archaeological test excavation program
- Analysis and significance assessment
- Impact assessment and develop impact mitigation strategies
- Preparation of draft report
- Exhibition of Draft EIS including review of Draft by Aboriginal stakeholders
- Responses and comments from Aboriginal stakeholders included and addressed in Final EIS

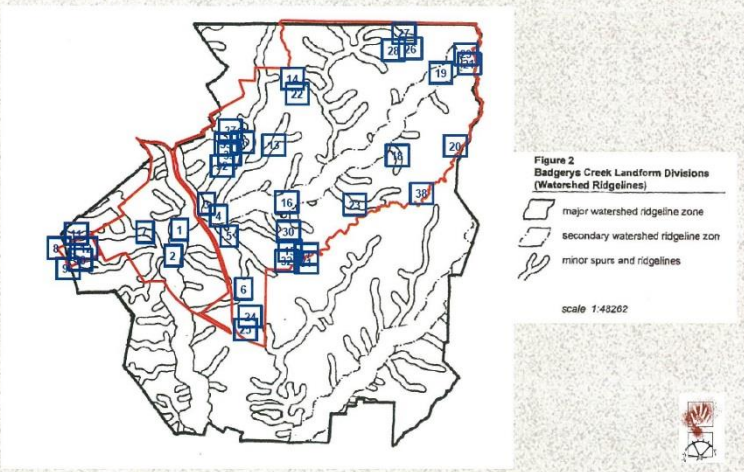
Field Program

- 27 April to 17 May (excluding weekends)
- First week to identify cultural values, concerns, issues and to provide first-hand experience of the project area and likely scope of development impact
- First week to include general inspection of project area, review and refinement of test excavation locations
- Test excavation program to be conducted in the remaining two weeks

Test Excavation

- After review of landform types, access conditions and ground disturbance, 38 possible test locations identified
- Between 10 and 20 locations will be selected for test excavation, depending on resources and assessment of field results
- Around 10 regularly spaced pits will be conducted at each test location, arranged in a grid pattern and/or along straight line transects
- Excavations at each test location will last approximately one or two days.

Possible test locations



Test Excavation & Analysis

- Excavation will be according to OEH 'Code of Conduct' protocols.
- All excavation will be conducted by hand
- Excavated material will be dry sieved on site and then used to back fill pits
- All recovered artefacts to be temporarily stored at NOHC Canberra lab and examined in detail by stone artefact specialist
- The only destructive analysis would be the use of recovered charcoal, or shell or bone material for radiocarbon dating

Stakeholder participation in field program

- Each registered stakeholder invited to nominate a representative (or representatives) to participate in the field program
- A roster will be developed for the participation of all nominated representatives in the fieldwork program. Each stakeholder will be given equal time to participate in the field, including the test excavation and inspection days
- Only one representative per registered stakeholder per day

Stakeholder participation in field program

- Each representative must show proof of Workers Compensation and Public Liability insurance and provide own personal protection equipment (PPE)
- Field participation will be paid by the Department of Infrastructure and Regional Development at a standard hourly rate, (rate to be confirmed)
- Nominations and evidence of insurance to be presented please by the 10th April (this Friday)
- Nominations forms available today

Return of all cultural material

- After analysis, all recovered artefacts would be stored and identified using standard resealable plastic bags
- It is proposed that all Aboriginal objects be repositioned back into the landscape ('returned to country') in accordance with Requirement 26 of the OEH Code of Practice
- Subject to Aboriginal stakeholder consensus
- All locations of repositioned artefacts would be recorded on appropriate OEH forms and lodged with OEH.

What will happen if human remains are encountered?

- The actions defined in the *Protocol to be followed in the event that suspected human remains are encountered* would be conducted
- Copy of protocol in Attachment 1 of the proposed methodology
- In summary:
  - Stop work in area of find
  - Confirm human origin
  - Advise authorities
  - Consult with stakeholders
  - Comply with legal requirements and follow agreed strategies or direction by authorities

How to provide comment on the methodology

- In writing please
- Submit by the 23 April 2015
- By post:

  The Secretary
  Navin Officer Heritage Consultants Pty Ltd
  4/71 Leichhardt Street
  Kingston ACT 2604

- By email: navinofficer@nohc.com.au
- By fax: 02 62829416

Agenda

Western Sydney airport project

Proposed methodology discussion and information meeting

Date: 8th April 2015

Time: 2:00pm – 4:00pm

Location: St Marys Memorial Hall, corner of the Great Western Highway and Mamre Road, St Marys Sydney

Facilitator: Kelvin Officer, Navin Officer Heritage Consultants

Agenda

1. Welcome and introduction
2. Presentation of the project background and methodology
3. Discussion and Questions

Minutes, discussion notes and issues

Meeting of Registered Stakeholders to discuss draft cultural heritage assessment methodology

Western Sydney airport EIS

Navin Officer Heritage Consultants *13 April 2015 v.1*

Date: 8th April 2015

Time: 2:00pm – 4:15pm

Location: St Marys Memorial Hall, corner of the Great Western Highway and Mamre Road, St Marys, Sydney

Facilitator: Kelvin Officer (KO), Director, Navin Officer Heritage Consultants (NOHC)

Other EIS team members present: Nicola Hayes (Principal Archaeologist NOHC)
Nick Johnson (Senior Manager, Environment, RPS Australia)

Aboriginal Stakeholders who signed attendance sheet:

Name	Organisation
Tim Wells	Darug Aboriginal Cultural Heritage Assessments
Gordon Morton	Darug Aboriginal Cultural Heritage Assessments
Jamie Workman	Darug Land Observations
Uncle Gordon Workman	Darug Land Observations
John Reilly	Darug Tribal Aboriginal Corporation
Justine Coplin	Darug Custodian Aboriginal Corporation
Glenda Chalker	Cubbitch Barta Native Title Claimants Aboriginal Corporation
Ricky Fields	Dhinawan-Dhigaraa Culture and Heritage Pty Ltd
Shane Fields	Dhinawan-Dhigaraa Culture and Heritage Pty Ltd
Aaron Slater	Kawul Cultural Services / Wurrumay
Matthew Hall	Warragil Cultural Services
Peter Foster	Murrin Nation
Chris Payne	Murrin Nation
David Bell	Murrin Nation
Pemilway Johnson	Murrin Nation
Leeroy Boota	Wullung
Michael Williams	Goobah – Murrin Nation
Basil Smith	Goobah – Murrin Nation
Robert Wester	Tocomwall Pty Ltd
Steven Randall	Deerubbin Local Aboriginal Land Council
Philip Khan	Kamilaroi-Yankuntuatjara Working Group
Hika Tekowhai	Walbunja
Kahu Brennan	Eora
Karia Bond	Bodu
Nick Glover	Yerramurra
Richard Campbell	Wandandian
Aaron Broad	Nundagurri
Kim Carriage	Gandangarra

Meeting Agenda

1. **Introduction to project and meeting (KO)**
2. **Welcome to Country - Gordon Morton**
3. **PowerPoint presentation (KO)**

   Please refer separate files — a) Background document and draft methodology; and b) Powerpoint presentation

   - Draft methodology and process
   - Identification of issues and significant cultural values
   - Code of conduct
   - Proposal and EIS conducted by the Western Sydney Unit (WSU) or the Department of Infrastructure and Regional Development (DIRD)
   - Potential for conserving sites, total impact project

- Project timeframes
- Project layout and area
- Act under which the assessment is being undertaken
- Process of reporting and comments will be sought during the public exhibition phase
- Overview of assessment to date
- 1997 EIS, Option A, 50% surveyed, summary of results including intangible values
    - Emphasised that input and direction into cultural values comes from the RAPs
- Criticisms of 1997 EIS including cumulative impacts not adequately assessed
- Up to RAPs and archaeologists to present a case for long term management and impact mitigation measures
- Reinspection in 2014
- Sites and test excavation overview
    - Emphasised the assessment based on cultural landscapes rather than just on sites
- Current assessment:
    - All effort to be put into test excavation
    - All landforms will be tested
    - Constrained by timing
    - Will extrapolate results over the whole project area, make predications to a good enough degree to build recommendations
    - Intangible values equally important to the assessment
    - Information on cumulative impacts can also come from RAPs as they have knowledge about the local area
- Methodology summary
    - The first week of fieldwork will be site visits and defining test areas
    - 10 pits per test area
- Stakeholder participation
    - Have to provide an opportunity for all to participate
- Return to country
- Human remains protocol
- Ways to provide comment

Issues raised and discussion points

Native Title over commonwealth land?

- Does Native Title exist on the project area lands?
- (KO) This is a question which should be answered by a qualified legal professional. Stakeholders were urged to seek qualified legal opinion on this question. My limited understanding is that the majority of the project area consisted of land grants and that the consequential status of the land as freehold title extinguished native title.

Cumulative development impacts

- It was noted that the Cumberland Plain has been the subject of increasingly intensive urban and industrial development and that the cumulative impact of this has resulted in an ever diminishing number of Aboriginal sites.
- Cumulative impacts within the Cumberland plain, have not been adequately taken into account in many other projects. The cumulative loss of Aboriginal sites from multiple project areas is unacceptable to stakeholders and there is little to show or compensate

for this loss, such as keeping places or salvage collections managed by Aboriginal people.

- It is a responsibility of this and future projects to adequately manage and conserve the remaining cultural heritage values.
- (KO) The assessment of cumulative impacts will be an important component of the EIS assessment.

A poor past record

- Nothing in Western Sydney has come back to stakeholders from development.
- There have been archaeological salvage programs over a small proportion of the (number and area) of sites found, and the rest have been bulldozed.
- There needs to be a better standard of management and conservation of cultural heritage values, especially with regard to the proportion of artefacts salvaged, their conservation on site, and facilities for storage and management ('Keeping places').

Not all sites encountered during archaeological surveys conducted in the 1990s and before were recorded. Were all sites in the 1997 EIS field program recorded?

- (KO) All sites encountered in the 1997 archaeological surveys were recorded, however not all surface artefacts at each site were described in detail.

Access to the Project Area

- Will there be access to all of the project area?
- (KO) Most of the project area has been, or remains the subject of leasehold agreements to private individuals or companies. The Commonwealth government is currently in the process of ending these leases. The lease agreements specify strict time periods for giving notice for entry and inspections. Given that there are long lead-times for giving notice to leaseholders, NOHC have already nominated a range of properties where it is anticipated that field work should be conducted. For these reasons, and due to this process, access will not be possible across the whole project area.
- Some stakeholders expressed that view that all of the project area should be made accessible to the assessment, and stakeholders should be able to nominate areas for field assessment, outside of those already selected by NOHC.

The Scope of the proposed field program

- All stakeholder comments on this subject were of the view that the proposed 3 week field program was inadequate and the proposed 2 weeks of test excavation could not provide a reliable sample of the archaeological material present within the project area.
- All stakeholder comments were of the opinion that:
    - more field time was required so that more of the possible test locations could be tested;
    - more stakeholder representatives should participate per day
    - more test pits should be conducted per test locations (the draft methodology suggests ten per location)
- Some stakeholders held the strong view that the whole of the project area should be the subject of a further comprehensive surface archaeological survey, and test excavation program.
- (KO) In response KO outlined how the draft methodology sought to build upon the results of the previous 1997 EIS, which were derived from an approximately 50% comprehensive archaeological survey of the project area, when ground surface visibility

was much greater than today. The focus of the current assessment is proposed to be test excavation across a representative sample of landforms, rather than the conduct of surface survey (the reasons for this were presented in the PowerPoint presentation). The scope of the proposed test excavation is limited by the overall timetable for the EIS assessment which is outside of the control of the archaeologists and the EIS team. The three week program, which includes one week of surface inspections and on-site consultation, and two weeks of test excavation, will provide a minimal sample of the archaeological deposit. Despite this, the results of the two week test excavation program would be considered to provide a reliable basis for estimating the nature and extent of the archaeological resource across the whole project area. It is conceded that a larger sample could provide greater reliability in the data generated and the findings of the analysis.

- The test excavation programs for other larger Western Sydney development areas, such as the ADI site have extended into months. The Western Sydney airport project area is similarly large and should have a comparable test excavation program.
- Imposed timelines for EIS projects have typically been too short to allow a proper level of cultural heritage assessment. This has been part of the cumulative impact of developments in Western Sydney. Timelines for EIS projects should be doing the right thing by Aboriginal people – the field program should be more like three months in duration.
- Some stakeholders stated that the Western Sydney airport project should ensure that every aspect of Aboriginal cultural heritage is salvaged and returned.

Is there a mean depth for the discovery of subsurface artefacts?

- (KO) The depth of subsurface artefacts tends to depend on the type of landform and soil deposit, however, typically in Western Sydney, artefacts occur in the top 30 centimetres. In valley floor deposits this can be much deeper. Also, where there is a distinct clay layer, artefacts will tend to move down the soil profile and lie just above the clay layer.

Management of artefacts which remain on site after the completion of archaeological salvage

- The fact that archaeological testing and salvage only recovers a small proportion of the total number of artefacts present within a project area was mentioned as a source of frustration for stakeholders, especially when subsequent development may damage those artefacts, which still have strong Aboriginal cultural values.
- (KO) Yes, this is an issue which some statutory authorities have been slow to address, such as by requiring appropriate management of stripped and stock-piled top soil where it is known to contain high proportion of stone artefacts. It is important for stakeholders to provide suggested strategies for the management of the artefacts which remain in the project area after all archaeological work is completed.
- (KO) Archaeological methodology does not normally seek to recover as many artefacts as possible. Its aim is to recover information from a representative sample of archaeological material. Even archaeological salvage programs cannot aim to recover all artefacts. New strategies are required to effectively manage the cultural values which reside in stone artefacts that remain on a development site (often in great numbers) and which may be impacted by development activities.

A ‘Keeping place’ and commemorative feature within the airport

- Some stakeholders indicated that there are very few opportunities provided in the normal processes of environmental impact assessment, to establish Keeping Places [a dedicated place for the storage and management of archaeological materials], for recovered Aboriginal artefacts, in close association with the country they came from.
- Some stakeholders would like to see a formal keeping place for Aboriginal artefacts provided within a possible future Western Sydney airport, and for the Aboriginal heritage

of the project area to be commemorated in a public and meaningful form within the development.

Participation of stakeholder representatives in the proposed field program

- All stakeholder comments were critical of the proposed level of stakeholder participation (5 representatives (varied daily according to a roster) and four NOHC staff per day [= 1 team]). All responses sought a higher degree of representation.
- Some stakeholders thought that all registered stakeholders should be represented on each field day, to be fair and to ensure information and artefacts are not missed.
- Others thought that only stakeholders who were descendants of the local Aboriginal people (the Darug or Daruk) should be represented in field work, or at least always be represented each day.
- Some stakeholders suggested that there should be more than one representative allowed per stakeholder per day.
- Representatives of the Darug groups considered that only Darug descendants should be able to identify cultural values in the project area.
- It was noted that representatives should have experience to know what they are looking at, and that only Darug descendants could effectively 'witness' the recovery and identification of the artefacts.
- Some stakeholders suggested that there should be a ratio of 5 stakeholder representatives to one NOHC staff member.
- Others felt that the proposed number of representatives per day should at least be doubled.
- A number of stakeholders suggested that field participation should be limited to those groups who were represented at this meeting.
- Some stakeholders indicated that the purpose of field representatives is to see ('witness') what is coming out of country, and not to do all the manual work.
- The number of registered stakeholders, especially those not directly representing Western Sydney traditional groups, is a concern, 'too many are putting up their hand to be involved, this needs to be sorted out now'.
- The value of getting young people involved in the field program was noted by a number of stakeholders, and reference was made to allowing for 'trainee' status field participants.

Wet Sieving

- All stakeholders were of the opinion that the proposed test excavation methodology of dry sieving should be replaced with a wet sieving methodology. It was felt that this would make sieving faster and the test program more efficient.
- (KO) Dry sieving was proposed so that the test methodology would be consisted with the OEH Code of Practice for test programs conducted without an Aboriginal Heritage Impact Permit (AHIP). However, following the recent provision of legal advice from the Australian Government Solicitor, it is now known that the permit provisions of the National Parks and Wildlife Act 1974 do not apply to the Western Sydney Airport EIS assessment. This means that it would possible to conduct the test excavation program using wet sieving techniques. It was agreed that wet sieving could speed up the test program and may allow the conduct of more test pits per test location.
- (KO) Like all of the points and suggested revisions raised at this meeting, this suggested revision will be presented to the WSU for their consideration.

Distribution of list of registered stakeholders

- It was asked if the list of registered Aboriginal stakeholders was going to be provided to Office of Environment and Heritage (OEH) and the Gandangara Local Aboriginal Land Council (GLALC)?
- (KO) There are currently 32 registered Aboriginal stakeholders for this assessment project. Five stakeholders have indicated that they do not wish to have their details provided to OEH or the GLALC.
- (KO) The provision of the list of registered Aboriginal stakeholders to the OEH and the LALC is a requirement of the OEH Aboriginal consultation protocol which is being used as a guide for this assessment. Given that compliance with this protocol is not a legal requirement for this EIS assessment, advice has recently been sought from the WSU as to whether this step in the protocol should be followed.
- Many stakeholders requested that they be provided with a copy of the list of registered stakeholders.
- Some stakeholders expressed surprise at the number of registrations and expressed frustration that some of these registrations may not be from people who are descended from local tribes. The large number of registrations means that less time may be afforded via a roster system to each field representative. This is stated to be unfair to traditional owner groups.
- (KO) Advice will be sought from the WSU as to whether the list of registered Aboriginal stakeholders should be:
    - Provided to OEH and/or the GLALC, as per the OEH protocol; and
    - Distributed to all registered stakeholders.
- (KO) It was noted that the list would eventually be included in the EIS report as a background document to the Aboriginal consultation process, however contact numbers and addresses would probably be withheld to protect the privacy of the organisations and individuals concerned.
- Many stakeholders felt that disclosure of the registered Aboriginal stakeholder list was an important test of the fairness and 'transparency' of the consultation process.
- (KO) Noted that NOHC, the EIS team and the WSU may have legal obligations to protect registered stakeholder contact information and that advice would be sought from the WSU regarding the request to distribute the stakeholder list.

Full disclosure and fairness for all aspects of the project

- A number of stakeholders indicated that they wanted to see full disclosure, transparency and fairness in all aspects of the project

Payment and fee scales for field representatives

- (KO) It was noted that a standard hourly pay rate, applicable across all registered stakeholder groups, is proposed, and that this rate was yet to be determined by the WSU (Department of Infrastructure and Regional Development).
- A wide range of opinions were expressed and debated:
    - How much is cultural knowledge worth?
    - In the past, standard pay rates, determined by the WSU, have been too low and considered to be insulting.
    - It is wrong for the Department to set a pay rate. Pay rates should conform to the standard consultation rates determined by each stakeholder group.
    - Participation and pay rates should be determined according to a tender process.

- In order to be fair and to treat all stakeholders equally, there should be a standard rate, paid equally.
- Fees should be based on Commonwealth public service rates and fees.
- Pay rates should be based on demonstrable levels of experience, such as 3) Senior Sites Officer, 2) Sites Officer, and 1) Trainee. These categories are used by the NSW Roads and Maritime Service.
- If pay rates are based on experience and the services that can be provided, how would that experienced be determined or proven?
- Should payment be made to stakeholder individuals or organisations? There was a degree of consensus that payment should go to stakeholder organisations, who would then in turn pay their representatives.

A stakeholder meeting with the 'proponent' (WSU) is requested

- A number of stakeholders requested that a meeting be held with the participation of registered Aboriginal stakeholders and the 'proponent'.
- It was felt that only the 'proponent' could effectively describe objectives and have the responsibility to provide answers to stakeholder questions and make commitments regarding project resourcing and the management of Aboriginal cultural values.
- (KO) All points of view and suggestions arising from this meeting will be passed on to the WSU for their consideration. A major objective of this meeting was the review and discussion of the draft methodology, and this was best done in a forum with the stakeholders and the EIS heritage specialist (NOHC).
- The overall EIS team is represented at this meeting by Nick Johnson (RPS) who will assist in conveying information from the meeting to the rest of the EIS team and the WSU.

A personal point of contact for the 'proponent'?

- Some stakeholders requested that a personal name and contact information for the 'proponent' (WSU) be provided to all registered Aboriginal stakeholders.
- It was noted that the OEH Aboriginal stakeholder consultation protocols require that the name and contact details of the proponent must be provided to registered Aboriginal stakeholders.

Extension of time provided for the provision of nominations by stakeholders of field representatives

- (KO) Notice for the submission of field representative nominations by the 10 April 2015 was provided in covering letters with the background document and draft Methodology.
- (KO) In order to provide a little more time for submissions following this meeting, the date for submission of nominations has been extended to the 17 April 2015.

A1.4.4 Supplementary Stakeholder Meeting

Agenda

Western Sydney airport project

Supplementary Meeting on proposed methodology
Discussion with Mr Peter Robertson, WSU.

Date: 23rd April 2015

Time: 10:00pm – 11:30pm

Location: St Marys Memorial Hall building, Multi Use Room 1, corner of the Great Western Highway and Mamre Road, St Marys Sydney

Facilitator: Kelvin Officer, Navin Officer Heritage Consultants

WSU Representative: Peter Robertson, General Manager of Environment, Legal and Communication, Western Sydney Unit (WSU), Commonwealth Department of Infrastructure and Regional Development.

Agenda

1. Welcome to country
2. Introduction and purpose of this meeting
3. Presentation by Peter
4. Discussion of Issues:
    a. The scope of the proposed archaeological field program
    b. Representation of Aboriginal stakeholders in the field program
    c. Field program pay rates
    d. Wet sieving
    e. Distribution of list of registered participants to all registered stakeholders
    f. Native title
    g. Management of recovered cultural material
5. Fieldwork next week
6. Any other Items

A1.4.5 Aboriginal stakeholder submissions on proposed assessment methodology

Date	Type of Contact (email, phone etc)	Group/Individual	Comment
23/4/15	post	Darug Land Observations	Concerns and Comments relating to two main issues: Archaeological investigation - Limited archaeological survey and excavation has been undertaken in this locality. Given the size and nature of the study area, an extensive program of investigation should be undertaken to provide information about past Aboriginal occupation of the area - The proposed sample size, consisting of 10-20 areas within a 1700 hectare site, is not large enough to provide reliable results. - The proposed three week timeframe is not enough to complete the limited survey and test excavation program proposed. - Dry sieving is not an option in this timeframe and is not as accurate as wet sieving. - The results of the limited fieldwork program proposed would not be adequate to assess the archaeological resource and heritage significance of the study area. The resulting impact assessment and management recommendations would therefore also be unreliable. Aboriginal community consultation - A large number of Aboriginal parties have registered an interest in the project. To our knowledge these include a number of sole trader/self-profit Registered Aboriginal Parties (Raps), and Raps that are based outside the local area. - The increasing involvement of such parties in cultural heritage management means that genuine local Aboriginal community groups such as ours are unable to properly care for our heritage and support our community like we have in the past. - We recommend structuring the consultation process to ensure the best outcomes for the project and the community. In particular, representatives of all traditional stakeholder groups should be on site every day for the whole of the fieldwork. Raps that are individuals only, do not represent a community and/or are based outside the local area should be provided with project information and invited to comment, but should not be engaged in the fieldwork.
8/4/15	post	Cubbitch Barta Native Title Claimants Aboriginal	It I difficult to make any informed comments on the areas being proposed for test excavation for two reason: 1. The report that was formed from the surveys carried out in 1997 are not included in this

Date	Type of Contact (email, phone etc)	Group/Individual	Comment
		Corporation	document, and to make an informed recommendation it should have been. I am therefore requesting a copy of the document as soon as possible, as in before the proposed field work, late April. 2. Again comments are being asked for before the proposed field survey takes place. As to the places for test excavations, there is not enough information, once again referring back to the report for 1997 and the field survey not yet taking place. If there are 38 potential locations for test excavation why are only 20 being proposed in the methodology. Dry sieving is not appropriate, much more information can be gained through wet sieving. All artefact are to be returned to Country when appropriate, in the appropriate place.
24/4/15	phone	Cubbitch Barta Native Title Claimants Aboriginal Corporation	Expressed that it was not appropriate that groups from other areas of the country participate in the project
22/4/15	post	Tocomwall Pty Ltd	The proposed methodology and approach is not supported by Tocomwall because of: 1. Inadequate consultation with the RAP; 2. Inadequate consideration of RAP views and perspectives; 3. A lack of transparency; 4. Insufficient data being made available for the RAP to make informed decisions; 5. An insufficient testing program that has not been fully disclosed; 6. The absence of a stratigraphic approached to the proposed testing program; and 7. That fact the unique nature of the Cumberland Plains Cultural and scientific resource is rapidly being destroyed with little or no strategic planning for the long-term or consideration of intergenerational equity.
17/4/15	email	Darug Custodian Aboriginal Corporation	Concerns and Comments relating to two main issues: Archaeological investigation - Limited archaeological survey and excavation has been undertaken in this locality. Given the size and nature of the study area, an extensive program of investigation should be undertaken to provide information about past Aboriginal occupation of the area

Date	Type of Contact (email, phone etc)	Group/Individual	Comment
			- The proposed sample size, consisting of 10-20 areas within a 1700 hectare site, is not large enough to provide reliable results. - The proposed three week timeframe is not enough to complete the limited survey and test excavation program proposed. - Dry sieving is not an option in this timeframe and is not as accurate as wet sieving. - The results of the limited fieldwork program proposed would not be adequate to assess the archaeological resource and heritage significance of the study area. The resulting impact assessment and management recommendations would therefore also be unreliable. Aboriginal community consultation - A large number of Aboriginal parties have registered an interest in the project. To our knowledge these include a number of sole trader/self-profit Registered Aboriginal Parties (Raps), and Raps that are based outside the local area. - The increasing involvement of such parties in cultural heritage management means that genuine local Aboriginal community groups such as ours are unable to properly care for our heritage and support our community like we have in the past. We recommend structuring the consultation process to ensure the best outcomes for the project and the community. In particular, representatives of all traditional stakeholder groups should be on site every day for the whole of the fieldwork. Raps that are individuals only, do not represent a community and/or are based outside the local area should be provided with project information and invited to comment, but should not be engaged in the fieldwork.
23/4/15	email	Warragil Cultural Services	No sites visits were conducted before commencing the methodology
10/4/15	email	Darug Aboriginal LandCare	Have no objections to the planned development
10/3/15	phone	Gunyuu	Repatriation of artefacts and skeletal and concerned that people off country should not have a say in repatriation procedures, concerned that precedence should be given to people from country
27/4/15	phone	Darug Land Observations	too many groups have registered an interest in the project, and that many of the groups registered do not have legitimacy to speak for the country, in the context of this project's area
8/4/15	Stakeholder	Various	Cumulative development impacts

Date	Type of Contact (email, phone etc)	Group/Individual	Comment
	Meeting		• Cumulative impacts within the Cumberland plain, have not been adequately taken into account in many other projects. The cumulative loss of Aboriginal sites from multiple project areas is unacceptable to stakeholders and there is little to show or compensate for this loss, such as keeping places or salvage collections managed by Aboriginal people. A poor past record • Nothing in Western Sydney has come back to stakeholders from development. • There needs to be a better standard of management and conservation of cultural heritage values, especially with regard to the proportion of artefacts salvaged, their conservation on site, and facilities for storage and management ('Keeping places'). Access to the Project Area • Some stakeholders expressed that view that all of the project area should be made accessible to the assessment, and stakeholders should be able to nominate areas for field assessment, outside of those already selected by NOHC. The Scope of the proposed field program • All stakeholder comments on this subject were of the view that the proposed 3 week field program was inadequate and the proposed 2 weeks of test excavation could not provide a reliable sample of the archaeological material present within the project area. • All stakeholder comments were of the opinion that: o more field time was required so that more of the possible test locations could be tested; o more stakeholder representatives should participate per day o more test pits should be conducted per test locations (the draft methodology suggests ten per location) • Some stakeholders held the strong view that the whole of the project area should be the subject of a further comprehensive surface archaeological survey, and test excavation program. • Imposed timelines for EIS projects have typically been too short to allow a proper level of cultural heritage assessment. This has been part of the cumulative impact of developments in Western Sydney. Timelines for EIS projects should be doing the right thing by Aboriginal

Date	Type of Contact (email, phone etc)	Group/Individual	Comment
			people – the field program should be more like three months in duration. • Some stakeholders stated that the Western Sydney airport project should ensure that every aspect of Aboriginal cultural heritage is salvaged and returned. Management of artefacts which remain on site after the completion of archaeological salvage • The fact that archaeological testing and salvage only recovers a small proportion of the total number of artefacts present within a project area was mentioned as a source of frustration for stakeholders, especially when subsequent development may damage those artefacts, which still have strong Aboriginal cultural values. A 'Keeping place' and commemorative feature within the airport • Some stakeholders indicated that there are very few opportunities provided in the normal processes of environmental impact assessment, to establish Keeping Places [a dedicated place for the storage and management of archaeological materials], for recovered Aboriginal artefacts, in close association with the country they came from. • Some stakeholders would like to see a formal keeping place for Aboriginal artefacts provided within a possible future Western Sydney airport, and for the Aboriginal heritage of the project area to be commemorated in a public and meaningful form within the development. Participation of stakeholder representatives in the proposed field program • All stakeholder comments were critical of the proposed level of stakeholder participation (5 representatives (varied daily according to a roster) and four NOHC staff per day [= 1 team]). All responses sought a higher degree of representation. • Some stakeholders thought that all registered stakeholders should be represented on each field day, to be fair and to ensure information and artefacts are not missed. • Others thought that only stakeholders who were descendants of the local Aboriginal people (the Darug or Daruk) should be represented in field work, or at least always be represented each day. • Some stakeholders suggested that there should be more than one representative allowed per stakeholder per day. • Representatives of the Darug groups considered that only Darug descendants should be able to identify cultural values in the project area.

Date	Type of Contact (email, phone etc)	Group/Individual	Comment
			• It was noted that representatives should have experience to know what they are looking at, and that only Darug descendants could effectively 'witness' the recovery and identification of the artefacts. • Some stakeholders suggested that there should be a ratio of 5 stakeholder representatives to one NOHC staff member. • Others felt that the proposed number of representatives per day should at least be doubled. • A number of stakeholders suggested that field participation should be limited to those groups who were represented at this meeting. • Some stakeholders indicated that the purpose of field representatives is to see ('witness') what is coming out of country, and not to do all the manual work. • The number of registered stakeholders, especially those not directly representing Western Sydney traditional groups, is a concern, 'too many are putting up their hand to be involved, this needs to be sorted out now'. • The value of getting young people involved in the field program was noted by a number of stakeholders, and reference was made to allowing for 'trainee' status field participants. Wet Sieving • All stakeholders were of the opinion that the proposed test excavation methodology of dry sieving should be replaced with a wet sieving methodology. It was felt that this would make sieving faster and the test program more efficient.

A1.4.6 Example of Invitation to participate in the field program

1 May 2015

Ms Jennifer Beale

Address obscured to maintain privacy

Navin Officer
heritage consultants pty ltd
abn: 28 092 901 605

Dear Jennifer,

Re: Western Sydney Airport EIS Aboriginal cultural heritage assessment
Invitation to participate in field program

Thank you for your organisation's acceptance of the GHD offer of employment for the participation of your nominated site offers in the WSA Aboriginal cultural heritage field program.

On behalf of GHD, NOHC are happy to formally invite the participation of one representative (Site Officer) from your organisation in the field program, per rostered day as identified in the attached fieldwork roster.

Each registered Aboriginal party has been allocated 5 days field participation spread over the 3 week period. Only the name of each group is listed on the roster therefore you are able to provide whichever nominated fieldworker is available for that day.

On the first rostered day for each representative, an ID card will be created for their use during the field program. The card will display their name, organisation and role, based on the names and information you have already provided to us. For this reason, the representative provided for each rostered day must be one of those listed on your organisation's nomination form. A portrait photo is also required for the ID card. A photo for this purpose will be taken at the time of the card issue.

In the first week for the program we will be undertaking an overall view of the project area and also visiting the nominated sites for subsurface testing with the aim of identifying the preferred sites, which will be done in consultation with you. We will also be discussing the cultural values of the project area.

We will be undertaking the subsurface testing program in weeks two and three of the field program. This will include wet sieving and hand excavation of pits.

For each field day (Monday to Friday) we will be meeting at 8am at the Badgerys Creek site office located at 2160 Elizabeth Drive Badgerys Creek (see attached map). This property is on the south side of Elizabeth Drive (on the left if you are travelling away from Sydney), 200m before you reach the intersection of Elizabeth Drive and Badgerys Creek Road.

The day will include 15 minutes for morning tea and a 30 minute lunch break and will finish at 4:45pm.

For week 1 your representative should bring their own lunch, and their own personal safety equipment and supplies:

Number 4, Kingston Warehouse
71 Leichhardt St, Kingston ACT 2604
ph 02 6282 9415 fax 02 6282 9416
navinofficer@navinofficer.com.au

- sturdy walking boots (that are also suitable for boggy ground, it is going to be wet underfoot);
- long sleeves and pants;
- high vis vest or shirt;
- sun hat;
- sunburn cream;
- wet weather gear; and
- personal water bottle (with water)

For weeks 2 and 3 your representative should bring their own lunch, and their own personal safety equipment and supplies:

- steel capped boots;
- long sleeves and pants;
- high-vis vest or shirt;
- sun hat;
- sunburn cream;
- wet weather gear; and
- personal water bottle (with water).

If you have any queries, please do not hesitate to contact me.

We look forward to continuing working with you through out this important assessment program.

Yours Sincerely



Nicola Hayes

Number 4, Kingston Warehouse
71 Leichhardt St, Kingston ACT 2604
ph 02 6282 9415 fax 02 6282 9416
navinofficer@navinofficer.com.au

Appendix 2

Inventory of Aboriginal heritage sites within the airport site

Site No.	OEH Site No.	Site type	No. surface stone artefacts (1996)	No. surface stone artefacts (AMC 2014)	No. surface stone artefacts (2015)	No. of subsurface stone artefacts recorded (2015)	Subsurface Site Pit no.	Type of ground surface exposure	Max dimensions of surface artefact distribution (1996) (m)	Dimensions of ground surface exposure(s) (1996) (m)	Dimensions of ground surface exposure (2015)	Arch'l subsurface potential (NOHC1997 and this assessment)	GDA Easting *removed from this report version*	GDA Northing *removed from this report version*
B3	45-5-2586	sao	1					Stock track		0.3m wide		high		
B4	45-5-2638	sao	1	nil				Erosion gully platform		2.6 x 3.9		low		
B5	45-5-2637	sao	1	1				Creek ford		20 x 7		low		
B7	45-5-2635	sao	1	nil				Stock track and creek bank		1 x 1		moderate		
B15	45-5-2705	sao	1					Suburban road verge		4 x 4		low		
B24	45-5-2642	sao	1					Track from dam wall				not recorded		
B25	45-5-2643	sao	1					Grassed ploughed area (vineyard)				low		
B31	45-5-2617	sao	1					Dirt track		3 x 3		low		
B32	45-5-2618	sao	1							10 x 2		not recorded		
B39	45-5-2629	sao	1					Ploughed zone between vines		100 x 2		low		
B40	45-5-2630	modified tree										-		
B41	45-5-2768	sao	1	nil				BMX bike jump		2.5 x 2.5		moderate		
B42	45-5-2631	sao	1					Building (construction) site		6 x 2		low		
B43	45-5-2783	sao	5					Salt scald	30 x 30	10 x 5		high		

Site No.	OEH Site No.	Site type	No. surface stone artefacts (1996)	No. surface stone artefacts (AMC 2014)	No. surface stone artefacts (2015)	No. of subsurface stone artefacts recorded (2015)	Subsurface Site Pit no.	Type of ground surface exposure	Max dimensions of surface artefact distribution (1996) (m)	Dimensions of ground surface exposure(s) (1996) (m)	Dimensions of ground surface exposure (2015)	Arch'l subsurface potential (NOHC1997 and this assessment)	GDA Easting *removed from this report version*	GDA Northing *removed from this report version*
B44	45-5-2632	sao	3	nil				Erosion gully and horse track	150 x 25	150 x 25		moderate		
B45	45-5-2633	sao	12	3				Scald at gate and dam bank	120 x 30	18 x 4 7 x 4		moderate		
B46	45-5-2699	sao	13	1				Channel and erosion scour and agricultural dam wall	60 x 50	25 x 5 40 x 5 15 x 20		high		
B54	45-5-2790	sao	2	nil				Eroded gully margin	11 x 1	15 x 3		low		
B55	45-5-2693	sao	2	nil				Gateway and ant nest scald	23 x 2	4 x 3		low		
B59	45-5-2690	sao	1	nil				Road margin		16 x 15		not recorded		
B66	45-5-2659	sao	16					Scald	12 x 4	25 x 4		low		
B67	45-5-2658	sao	1					Trampled and eroded soil exposure		2 x 6		moderate		
B68	45-5-2623	sao	1					Stock trail		200 x 30		high		
B69	45-5-2771	sao	1					Graded embankment for agricultural dam		10 x 5		not recorded		
B70	45-5-2770	sao	5					Drainage line scald and stock yards	7 x 3	16 x 8		moderate		

Site No.	OEH Site No.	Site type	No. surface stone artefacts (1996)	No. surface stone artefacts (AMC 2014)	No. surface stone artefacts (2015)	No. of subsurface stone artefacts recorded (2015)	Subsurface Site Pit no.	Type of ground surface exposure	Max dimensions of surface artefact distribution (1996) (m)	Dimensions of ground surface exposure(s) (1996) (m)	Dimensions of ground surface exposure (2015)	Arch'l subsurface potential (NOHC1997 and this assessment)	GDA Easting *removed from this report version*	GDA Northing *removed from this report version*
B71	45-5-2687	sao	1					Stock treadage		20 x 3		not recorded		
B74	45-5-2685	sao	1	nil				Recently ploughed field		100 x 200		moderate		
B75	45-5-2682	sao	1					Agricultural dam wall		25 x 6		moderate		
B76	45-5-2683	sao	1	nil				Side of bitumen road		100 x 5		low		
B77	45-5-2681	sao	9					Dry creek bed	10 x 2	11 x 5		high		
B78	45-5-2680	sao	1					Creek bed	10 x 15	10 x 15		high		
B79	45-5-2663	sao	1					Road cutting		50 x 10		low		
B80	45-5-2678	sao	11	64				Erosion scald above agricultural dam and creek bed	100 x 30	20 x 6 4 x 2		moderate		
B81	45-5-2679	sao	1	nil				Creek bed and banks		17 x 30		high		
B82	45-5-2764	sao	1	nil				Agricultural dam wall		40 x 5		low		
B84	45-5-2782	sao	7					Scald around dead tree	1.7 x 1.5	30 x 15		moderate		
B86	45-5-2781	sao	5	nil				Erosion scar	30 x 20	30 x 20		low		
B87	45-5-2763	sao	5					Graded vehicle track	20 x 4	20 x 4		high		
B88	45-5-2665	sao+ssao	2	nil		16		Excavated trench below dam	20 x 5	20 x 5		confirmed		

Site No.	OEH Site No.	Site type	No. surface stone artefacts (1996)	No. surface stone artefacts (AMC 2014)	No. surface stone artefacts (2015)	No. of subsurface stone artefacts recorded (2015)	Subsurface Site Pit no.	Type of ground surface exposure	Max dimensions of surface artefact distribution (1996) (m)	Dimensions of ground surface exposure(s) (1996) (m)	Dimensions of ground surface exposure (2015)	Arch'l subsurface potential (NOHC1997 and this assessment)	GDA Easting *removed from this report version*	GDA Northing *removed from this report version*
B90	45-5-2667	sao	2					Vehicle track	10 x 0.5	2.5m wide		moderate		
B91	45-5-2671	sao	2					Ploughed marked garden	6 x 1	300 x 200		low		
B92	45-5-2670	sao	4					Disused vehicle track	25 x 3	3m wide		high		
B93	45-5-2668	sao	1					Agricultural dam wall		20 x 1.5		low		
B94	45-5-2789	sao	1	nil				Salt scald/clay pan		2 x 1		high		
B95	45-5-2762	sao	8	1				Agricultural dam wall and margin		100 x 7		moderate		
B101	45-5-2673	sao	1					Gate exposure		2.5 x 1.5		low		
B102	45-5-2656	sao	19					Sheet wash areas in old horse training paddock	13.5 x 3.5	19 x 5		high		
B103	45-5-2814	sao	1					Gate exposure		7 x 2		low		
B104	45-5-2813	sao	1					Horse training track and adjacent spoil		100 x 10		low		
B112	45-5-2788	sao	3					Stock scar	10 x 1	20 x 1		moderate		
B113		sao			20			eroded track and dam wall			150 x 30	high		

Site No.	OEH Site No.	Site type	No. surface stone artefacts (1996)	No. surface stone artefacts (AMC 2014)	No. surface stone artefacts (2015)	No. of subsurface stone artefacts recorded (2015)	Subsurface Site Pit no.	Type of ground surface exposure	Max dimensions of surface artefact distribution (1996) (m)	Dimensions of ground surface exposure(s) (1996) (m)	Dimensions of ground surface exposure (2015)	Arch'l subsurface potential (NOHC1997 and this assessment)	GDA Easting *removed from this report version*	GDA Northing *removed from this report version*
B114		sao			10			eroded track, creek edge			110 x 20	high		
B115		sao			20			erosion and disturbance			5 x 5	high		
B116		sao			2			track				low		
B117		sao			2			erosion scald				high		
B118		sao			2			edge of ploughed field				moderate		
B119		sao			2			gate exposure				moderate		
B120		gg						sandstone outcrop				low (refer TL23)		
B121		sao +ssao			2	36	TL9 pits 2-10	track/gate exposure				confirmed		
B122		sao			1			dam wall				moderate		
B123		ssao				7	TL6 pits1-4					confirmed		
B124		ssao				3	TL6 pits 9&10					confirmed		
B125		ssao				2	TL8/10 pits 3&4					confirmed		
B126		ssao				2	TL8/10 pits 7&9					confirmed		
B127		ssao				1	TL13 pit 3					confirmed		
B128		ssao				6	TL14 pits 1&3					confirmed		
B129		ssao				2	TL14 pit 8					confirmed		
B130		ssao				1	TL23 pit 9					confirmed		

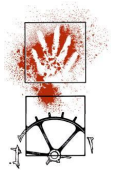
Site No.	OEH Site No.	Site type	No. surface stone artefacts (1996)	No. surface stone artefacts (AMC 2014)	No. surface stone artefacts (2015)	No. of subsurface stone artefacts recorded (2015)	Subsurface Site Pit no.	Type of ground surface exposure	Max dimensions of surface artefact distribution (1996) (m)	Dimensions of ground surface exposure(s) (1996) (m)	Dimensions of ground surface exposure (2015)	Arch'l subsurface potential (NOHC1997 and this assessment)	GDA Easting *removed from this report version*	GDA Northing *removed from this report version*
B131		ssao				1	TL26/27 pit 11					confirmed		
B132		ssao				2	TL32 pits 3&4					confirmed		
B133		ssao				5	TL32 pits 9&10					confirmed		
B134		ssao				6	TL37 pits 1,2,4 & 5					confirmed		
B135		ssao				1	TL4 pit 5					confirmed		
B136		sao		1 (initially attributed by AMC as site B5)				Vehicle track		20 x 7		moderate		

Appendix 3

Landform variables recorded for each test pit

Landform variables recorded for each test pit

Test Locn	Pit no.	Map page	GPS refer. point	Broad scale landform category	Fine scale landform category	Watershed/ spurline order	Slope category	within 100 m of <1st order drainage line	Highest drainage line order within 100m	Elevation (AHD)	Elevation above nearest <1st order drainage line (m)	Order of closest drainage line	Aspect	Overall valley context
26/27	1	3	4	Valley floor	Alluvial flats	-	flat	yes	3	52	1	4	O	Lower
26/27	2	3	5	Valley floor	Alluvial flats	-	flat	yes	3	52	1	4	O	Lower
26/27	3	3	6	Valley floor	Alluvial flats	-	flat	yes	3	52	1	4	O	Lower
26/27	4	3	7	Valley floor	Alluvial flats	-	flat	yes	3	52	1	4	O	Lower
26/27	5	3	8	Valley floor	Alluvial flats	-	flat	yes	3	52	1	4	O	Lower
26/27	6	3	9	Valley floor	Alluvial flats	-	flat	yes	3	52	1	4	O	Lower
26/27	7	3	10	Valley floor	Alluvial flats	-	flat	yes	3	52	1	4	O	Lower
26/27	8	3	11	Valley floor	Alluvial flats	-	flat	yes	3	52	1	4	O	Lower
26/27	9	3	12	Basal slopes	slope	-	low	no	3	55	4	4	S	Lower
26/27	10	3	13	Basal slopes	slope	-	low	no	3	56	5	4	S	Lower
26/27	11	3	14	Upper slopes	slope	2	low	no	3	57	6	4	SW	Lower
26/27	12	3	15	Upper slopes	slope	2	low	no	3	57.5	6.5	4	SW	Lower
26/27	13	3	17	Secondary Spurline crest	Saddle	2	flat	no	3	58	7	4	O	Lower
26/27	14	3	16	Secondary Spurline crest	Saddle	2	flat	no	3	58	7	4	SW	Lower
14	1	1	18	Mid slopes	minor spur crest	1	low	yes	2	67.5	1.5	2	NW	Lower
14	2	1	19	Basal slopes	minor spur crest	1	low	yes	2	66.5	1	2	NW	lower



Test Locn	Pit no.	Map page	GPS refer. point	Broad scale landform category	Fine scale landform category	Watershed/ spurline order	Slope category	within 100 m of <1st order drainage line	Highest drainage line order within 100m	Elevation (AHD)	Elevation above nearest <1st order drainage line (m)	Order of closest drainage line	Aspect	Overall valley context
14	3	1	20	Basal slopes	minor spur crest	1	low	yes	2	65.5	1	2	NW	lower
14	4	1	21	Basal slopes	minor spur crest	1	low	yes	2	65	1	2	O	lower
14	5	1	22	Basal slopes	minor spur crest	1	flat	yes	2	64.5	0.5	2	O	lower
14	6	1	23	Valley floor	elevated rise	1	flat	yes	2	64.5	0.5	2	O	lower
14	7	1	24	Valley floor	elevated rise	1	flat	yes	4	64	0.5	2	O	lower
14	8	1	25	valley floor	elevated rise	1	flat	yes	4	64	0.5	2	O	lower
14	9	1	26	valley floor	elevated rise	1	flat	yes	4	63.5	1.5	4	O	lower
14	10	1	27	valley floor	elevated rise	1	flat	yes	4	63	1	4	O	lower
13	1	7	29	Secondary Spurline crest	knoll	2	low	no	1	86	5	1	O	middle
13	2	7	28	Secondary Spurline crest	crest	2	flat	no	1	85	5	1	E	middle
13	3	7	30	Secondary Spurline crest	crest	2	low	no	-	83.5	5.5	1	E	middle
13	4	7	31	Secondary Spurline crest	crest	2	low	no	-	82.5	4	1	E	Middle
13	5	7	32	Secondary Spurline crest	shoulder	2	flat	no	-	81.5	4	1	O	Middle
13	6	7	33	Secondary Spurline crest	shoulder	2	flat	no	-	81	5	1	O	Middle
13	7	7	34	Secondary Spurline crest	shoulder	2	flat	no	-	81	5	1	O	Middle



Test Locn	Pit no.	Map page	GPS refer. point	Broad scale landform category	Fine scale landform category	Watershed/ spurline order	Slope category	within 100 m of <1st order drainage line	Highest drainage line order within 100m	Elevation (AHD)	Elevation above nearest <1st order drainage line (m)	Order of closest drainage line	Aspect	Overall valley context
13	8	7	35	Secondary Spurline crest	shoulder	2	flat	no	-	80.5	5.5	1	O	Middle
13	9	7	36	Secondary spurline crest	shoulder	2	flat	no	-	80	6	1	O	Middle
13	10	7	37	minor spurline crest	shoulder	1	flat	no	-	79	5.5	1	O	Middle
23	1	14	38	Upper slopes	break-of-slope	3	moderate	no	1	86	27	1	S	middle
23	2	14	39	Upper slopes	slope	3	moderate	no	1	83	24	1	S	middle
23	3	14	40	Upper slopes	slope	3	moderate	yes	5	78	19	1	S	middle
23	4	14	41	Mid slopes	bench	3	low to moderate	yes	5	76	17	1	S	middle
23	5	14	42	Mid slopes	minor spurline crest	1	low to moderate	yes	5	75	16	1	W	lower
23	6	14	43	Mid slopes	minor spurline crest	1	low to moderate	yes	5	73	14	1	W	lower
23	7	14	44	Mid slopes	minor spurline crest	1	moderate	yes	5	71	12	1	W	lower
23	8	14	45	mid slopes	fan	-	low to moderate	yes	5	67	8	5	SW	lower
23	9	14	46	Basal slopes	fan	-	low to moderate	yes	5	63.5	4.5	5	SW	lower
23	10	14	47	Basal slopes	fan	-	low	yes	5	62	3	5	S	lower
37	1	6&7	48	Valley floor	elevated rise/terrace	-	flat	yes	3	70.5	1	3	O	middle



Test Locn	Pit no.	Map page	GPS refer. point	Broad scale landform category	Fine scale landform category	Watershed/ spurline order	Slope category	within 100 m of <1st order drainage line	Highest drainage line order within 100m	Elevation (AHD)	Elevation above nearest <1st order drainage line (m)	Order of closest drainage line	Aspect	Overall valley context
37	2	7	49	Valley floor	elevated rise/terrace	-	flat	yes	3	71	1	3	O	middle
37	3	7	50	Valley floor	elevated rise/terrace	-	flat	yes	3	71.5	1.5	3	NW	middle
37	4	6&7	51	Valley floor	elevated rise/terrace	-	flat	yes	3	71.5	1.5	1	NW	middle
37	5	6	52	Valley floor	elevated rise/terrace	-	flat	yes	3	71.5	1.5	1	O	middle
37	6	6	53	Valley floor	elevated rise/terrace	-	flat	yes	3	72	1	1	O	middle
37	7	6	54	Valley floor	elevated rise/terrace	-	flat	yes	3	72.5	1.5	3	O	middle
37	8	6	55	Valley floor	elevated rise/terrace	-	flat	yes	3	73	2	3	O	middle
37	9	6	56	Valley floor	elevated rise/terrace	-	flat	yes	3	73	2	3	O	middle
37	10	6	57	Basal slopes	minor spurline crest	-	low	yes	3	73.5	2.5	3	O	middle
6	1	12	58	mid slopes	minor spurline crest	1	low	no		79.5	5.5	3	S	Lower
6	2	12	59	mid slopes	minor spurline crest	1	low	yes	3	78	4	3	S	Lower
6	3	12	60	basal slopes	slope	-	low	yes	3	76	2	3	SW	Lower
6	4	12	61	basal slopes	slope	-	low	yes	4	75	1	3	SW	Lower
6	5	12	62	Valley floor	alluvial flats	-	flat	yes	4	74	0.5	3	O	Lower

Test Locn	Pit no.	Map page	GPS refer. point	Broad scale landform category	Fine scale landform category	Watershed/ spurline order	Slope category	within 100 m of <1st order drainage line	Highest drainage line order within 100m	Elevation (AHD)	Elevation above nearest <1st order drainage line (m)	Order of closest drainage line	Aspect	Overall valley context
6	6	12	63	Valley floor	alluvial flats	-	flat	yes	4	74	0.5	4	O	Lower
6	7	12	64	Valley floor	alluvial flats	-	flat	yes	4	73.5	0.5	4	O	Lower
6	8	12	65	Valley floor	alluvial flats	-	flat	yes	4	73	0.5	4	O	Lower
6	9	12	66	Valley floor	alluvial flats	-	flat	yes	4	72.5	0.5	4	O	Lower
6	10	12	67	Valley floor	alluvial flats	-	flat	yes	5	72	0.5	4	O	Lower
4	1	12	68	2ndy Watershed ridgeline	crest	4	flat	no	1	115	22	1	O	Upper
4	2	12	69	2ndy Watershed ridgeline	crest	4	flat	no	1	115	22	1	O	Upper
4	3	12	70	2ndy Watershed ridgeline	crest	4	flat	no	1	115	22	1	O	upper
4	4	12	71	2ndy Watershed ridgeline	crest	4	flat	no	1	115	22	1	O	upper
4	5	12	72	2ndy Watershed ridgeline	crest	4	flat	no	1	115	22	1	O	upper
4	6	12	73	2ndy Watershed ridgeline	upper slopes	4	moderate	no	1	114	21	1	SW	upper
4	7	12	74	2ndy Watershed ridgeline	crest	4	Low to moderate	no	1	114	21	1	NE	upper



Test Locn	Pit no.	Map page	GPS refer. point	Broad scale landform category	Fine scale landform category	Watershed/ spurline order	Slope category	within 100 m of <1st order drainage line	Highest drainage line order within 100m	Elevation (AHD)	Elevation above nearest <1st order drainage line (m)	Order of closest drainage line	Aspect	Overall valley context
4	8	12	75	2ndy Watershed ridgeline	crest	4	Low to moderate	no	1	113	20	1	NE	upper
4	9	12	76	2ndy Watershed ridgeline	crest	4	Low to moderate	no	1	111	18	1	NE	upper
4	10	12	77	2ndy Watershed ridgeline	crest	4	Low to moderate	no	1	109	16	1	NE	upper
1	1	12	78	Major Watershed ridgeline	crest	5	flat	no	1	99.5	8.5	1	O	upper
1	2	12	79	Major Watershed ridgeline	crest	5	flat	no	1	100	9	1	O	upper
1	3	12	80	Major Watershed ridgeline	crest	5	flat	no	1	100	9	1	O	upper
1	4	12	81	Major Watershed ridgeline	crest	5	flat	no	1	100.5	9.5	1	O	upper
1	5	12	82	Major Watershed ridgeline	crest	5	flat	no	1	100.5	9.5	1	O	upper
1	6	12	83	Major Watershed ridgeline	crest	5	flat	no	1	100.5	9.5	1	O	upper

Test Locn	Pit no.	Map page	GPS refer. point	Broad scale landform category	Fine scale landform category	Watershed/ spurline order	Slope category	within 100 m of <1st order drainage line	Highest drainage line order within 100m	Elevation (AHD)	Elevation above nearest <1st order drainage line (m)	Order of closest drainage line	Aspect	Overall valley context
1	7	12	84	Major Watershed ridgeline	crest	5	flat	no	1	101	10	1	O	upper
1	8	12	85	Major Watershed ridgeline	crest	5	flat	no	1	101	10	1	O	upper
1	9	12	86	Major Watershed ridgeline	upper slopes	5	low	no	1	101	10	1	SW	upper
1	10	12	87	Major Watershed ridgeline	upper slopes	5	low	no	1	101.5	10.5	1	SW	upper
32	1	13	88	Mid slopes	minor spurline crest	1	low	no	1	75.5	3	1	E	lower
32	2	13	89	Mid slopes	minor spurline crest	1	low	no	1	74	3	1	E	lower
32	3	13	90	Basal slopes	minor spurline crest	1	flat	no	1	73	3	1	SE	lower
32	4	13	91	Basal slopes	minor spurline crest	1	flat	no	1	72	2	1	SE	lower
32	5	13	92	Basal slopes	minor spurline crest	1	low	yes	5	71	5	1	S	lower
32	6	13	93	Valley floor	alluvial flats	-	flat	yes	5	68.5	2.5	1	O	lower
32	7	13	94	Valley floor	alluvial terrace	-	flat	yes	5	68	2	1	O	lower
32	8	13	95	Valley floor	alluvial terrace	-	flat	yes	5	68	2	5	O	lower

Test Locn	Pit no.	Map page	GPS refer. point	Broad scale landform category	Fine scale landform category	Watershed/ spurline order	Slope category	within 100 m of <1st order drainage line	Highest drainage line order within 100m	Elevation (AHD)	Elevation above nearest <1st order drainage line (m)	Order of closest drainage line	Aspect	Overall valley context
32	9	13	96	Valley floor	alluvial terrace	-	flat	yes	5	68	2	5	O	lower
32	10	13	97	Valley floor	alluvial terrace	-	flat	yes	5	68	2	5	O	lower
8/10	1	10	98	mid slopes	minor spurline crest	1	flat	yes	2	68.5	9	2	O	middle
8/10	2	10	99	mid slope	minor spurline crest	1	low	yes	2	67	7.5	2	O	middle
8/10	3	10	100	mid slopes	minor spurline crest	1	flat	yes	2	65.5	5	2	NW	lower
8/10	4	10	101	mid slopes	minor spurline crest	1	low	yes	2	64.5	4.5	2	NW	lower
8/10	5	10	102	mid slopes	minor spurline crest	1	low	yes	2	62	3.5	2	NW	lower
8/10	6	10	103	basal slopes	minor spurline crest	1	low	yes	5	58	2.5	2	NW	lower
8/10	7	10	104	valley floor	alluvial flats	-	flat	yes	5	57	1	2	O	lower
8/10	8	10	105	valley floor	alluvial flats	-	flat	yes	5	57	3	5	O	lower
8/10	9	10	106	valley floor	alluvial flats	-	flat	yes	5	57.5	4,5	5	O	lower
8/10	10	10	107	valley floor	elevated rise	-	low	yes	5	58.5	5.5	5	O	lower
9	1	9	108	basal slopes	slope	-	low	yes	5	50.5	4.5	5	O	lower
9	2	9	109	basal slopes	slope	-	low	yes	5	50	4	5	O	lower
9	3	9	110	valley floor	alluvial flats	-	flat	yes	5	49.5	3.5	5	O	lower
9	4	9	111	valley floor	alluvial flats	-	flat	yes	5	49.5	3.5	5	O	lower

Test Locn	Pit no.	Map page	GPS refer. point	Broad scale landform category	Fine scale landform category	Watershed/ spurline order	Slope category	within 100 m of <1st order drainage line	Highest drainage line order within 100m	Elevation (AHD)	Elevation above nearest <1st order drainage line (m)	Order of closest drainage line	Aspect	Overall valley context
9	5	9	112	valley floor	alluvial flats	-	flat	yes	5	49.5	3.5	5	O	lower
9	6	3	113	valley floor	alluvial flats	-	flat	yes	5	48	2	5	O	lower
9	7	3	114	valley floor	alluvial flats	-	flat	yes	5	48	2	5	O	lower
9	8	3	115	valley floor	alluvial flats	-	flat	yes	5	48	2	5	O	lower
9	9	3	116	valley floor	alluvial flats	-	flat	yes	5	48	2	5	O	lower
9	10	3	117	valley floor	alluvial flats	-	flat	yes	5	48	2	5	O	lower

Appendix 4

Glossary of technical terms

Term	Definition
Aboriginal site	A place or location which relates to past or contemporary Aboriginal occupation. Sites can be divided into those identified from archaeological evidence (archaeological sites), and those related to intangible cultural values, such as revealed by oral tradition and lore, or from the historical record. An Aboriginal site may have both archaeological and intangible values.
aggradation	(i) The building up of the Earth's surface by deposition; specifically the upbuilding performed by a stream in order to establish or maintain uniformity of grade or slope. (ii) A synonym of accretion, as in the development of a beach.
alluvial	pertaining to alluvium and fluvial processes.
alluvium	unconsolidated deposit of gravel, sand, mud etc., formed by water flowing in identifiable channels. Commonly well-sorted and stratified.
archaeological deposit	a ground deposit with the confirmed presence of archaeological evidence of Aboriginal occupation, where the context of that evidence can be reliably related to the Aboriginal actions which produced the evidence.
Archaeological sensitivity	A term used to describe an area or zone within which sites and/or potential archaeological deposits are known or predicted to occur at a scale or frequency which necessitates careful management action in the future.
archaeological site	a place or location with the confirmed presence of archaeological evidence of Aboriginal occupation, where the context of that evidence can be reliably related to the Aboriginal actions which produced the evidence.
archaeologically sensitive landform (asl)	an area within which sites and/or potential archaeological deposits are known or reliably predicted to occur at a scale or frequency which necessitates careful management action in the future.
artefact	an object, normally portable, made or modified by human hand (see 'stone artefact').
artefact occurrence	a term usually applied to site recordings comprising stone artefacts and which refers to one or more stone artefacts situated within a specified surface area or subsurface deposit. Various measures are used for defining the boundaries of such recordings. Refer also to 'surface' and 'subsurface artefact occurrence'.
artefact scatter	a formerly used open site-type classification defined as two or more stone artefacts situated no more than a specified distance (such as 60m) away from any other included artefact. Typically this category did not include isolated finds. The use of the term *scatter* was intended only to be descriptive and did not infer the original human behaviour which formed the site. The term *open camp site* has been used extensively in the past to describe open artefact scatters.
assemblage	see lithic assemblage.
background discard or scatter	There is no single concept for background discard or 'scatter', and therefore no agreed definition. The definitions in current use are based on the postulated nature of prehistoric activity, and often they are phrased in general terms and do not include quantitative criteria. Commonly agreed is that background discard occurs in the absence of 'focused' activity involving the production or discard of stone artefacts in a particular location. An example of unfocussed activity is occasional isolated discard of artefacts during travel along a route or pathway. Examples of 'focussed activity' are camping, knapping and heat-treating stone, cooking in a hearth, and processing food with stone tools. In practical terms, over a period of thousands of years an accumulation of 'unfocussed' discard may result in an archaeological concentration that may be identified as a 'site'. Definitions of background discard comprising only qualitative criteria do not specify the numbers (numerical flux) or 'density' of artefacts required to discriminate site areas from background discard.
background lithic material	natural stone (in the form of pebbles and/or fragments) of types used by Aborigines to make artefacts (such as quartz, tuff, silcrete, chalcedony and quartzite) and occurring in or near a prehistoric archaeological site.
background scatter	can be generally defined as manuport and artefactual material which is *insufficient either in number or in association* with other material to suggest focused activity in a particular location or context.

Term	Definition
backing (retouch)	abruptly angled flaking (retouch) which has shaped a thick back part to an implement such as an elouera or microlith. The process of flaking varies from bipolar impact (on some eloueras) to delicate application of pressure with a small stone ('chimbling' used to make microliths).
bending initiation	the commencement of a fracture by the application of a bending load or force, as in breaking a bar of chocolate, where the load is applied away from the point at which the object breaks. Bending initiation is common in the fracture of a tool's cutting edge during its use, and is commonly caused by human treadage at a site. It normally occurs on thin edges (see also 'snap fractures or flakes').
bioturbation	the process of mixing soil materials or sediments by living organisms.
bipolar core	A core (nucleus) that is supported on a stone anvil surface and struck repeatedly with a hammerstone from above. Diagnostic attributes of bipolar fracture damage are point or sinuous ridge type initiation platforms, crushing, cracks, and concentrated overlapping step fractures emanating from areas of hammer impact.
bipolar flake	(and broken bipolar flake) -a flake retaining evidence of bipolar fracture damage on at least one end. Some of these are 'compression flakes' formed by substantial compressive force. A broken bipolar flake has a transversely oriented breakage.
bipolar flaking	a method of making flakes or retouched flake tools by smashing a piece of stone, often a quartz pebble, rested on a stone surface and repeatedly striking the core from above with a stone hammer.
BP	Before present, a convention adopted in the publication of radiometric age determinations whereby the present is deemed to be 1950 AD.
broken bipolar flake	Transversely broken flake from a bipolar core.
broken flake	A flake with two or more breakages but retaining its area of flake initiation.
Cenozoic	is the current and most recent of the three Phanerozoic geological eras, following the Mesozoic Era and covering the period from 65 million years ago to present day.
chalcedony	a compact variety of silica, formed of quartz crystallites, often fibrous in form and with sub-microscopic pores which contain water (about 1% of weight). Coloured varieties include carnelian (yellow brown), sard (brown), agate (varicoloured) and jasper (red). Chalcedony can form veins or can occur as pseudomorphs, resulting from silica-charged solution infiltrating voids or cavities in rock, sometimes by gradually replacing decaying organic matter. Chalcedony, like fine quality chert, was a valued stone tool material. Mohs hardness always registers within half a point of 7. Chalcedony appears very fine-grained to the naked eye and can be translucent, banded and include a wide variety of colours. This rock type breaks by the process of conchoidal (shell-like) fracture and provides flakes that have sharp durable edges.
chert	a highly siliceous rock type formed biogenically from the compaction and precipitation of the silica skeletons of diatoms. Normally there is a high percentage of cryptocrystalline quartz. This rock type breaks by the process of conchoidal (shell-like) fracture and provides flakes that have sharp durable edges.
chronosequence	a sequence of soils developed under similar soil-forming conditions, but at different times
clast	a grain or crystal with a finer grained matrix (usual in silcrete).
cobble	waterworn stones of diameter greater than 64 mm (about the size of a tennis ball) and less than 256 mm (about the size of a basketball). Archaeologists often refer to cobbles as pebbles (see also 'pebble').
colluvium	an unconsolidated deposit of gravel, sand, mud etc., formed by water flowing across a hillslope surface (slope wash, sheetwash, rain wash) and/or by mass movement. Commonly poorly sorted and stratified.
conchoidal flake	a flake created by Hertzian initiation (a cone crack). This is the most common type of flake produced by tool making, but occasionally also occurs in nature. It is distinguished by a partial or complete cone crack and a bulb of force; other fracture surface features are éraillure scar, lances and undulations (see these other glossary entries, and Cotterell and Kamminga 1987, 1992). The inside fracture surface of a well-formed conchoidal flake is similar to that of a bivalve shell, hence the term 'conchoidal'. 'Conchoidal fracture' refers to the process of this flake formation.

Term	Definition
conchoidal fracture	describes the way that brittle materials break or fracture when they do not follow any natural planes of separation. Materials that break in this way include quartz, flint, quartzite, and other fine-grained or amorphous materials with a composition of pure silica, such as obsidian and window glass.
concretion and nodules	a mineral forming in isolated aggregates, sometimes as spherical or ellipsoidal forms. Concretions display a concentric zonation of matrix components, whereas nodules display an undifferentiated internal fabric.
cone crack initiation	a Hertzian cone initiation which leads to the formation of a conchoidal flake. A Hertzian cone is similar in shape to the neck of a milk bottle with the top of this cone being the initiation of the circular fracture. On a flake surface the cone is not fully formed and is represented by one side, because the fracture-initiating force was applied from above at an angle of about forty-five degrees, not ninety degrees. Other terms in current usage are 'focussed initiation' and 'split cone'.
conjoin analysis	piecing together or 'conjoining' artefacts helps in reconstructing prehistoric 'events' (such as tool manufacture, tool use activities and cutting-edge rejuvenation), determining chronology and assessing site integrity.
contact	A relative chronological term used loosely to refer to the initial period of contact between Aboriginal and European peoples. This period occurred at different times within the eighteenth and nineteenth centuries, depending on the nature and timing of European exploration and settlement.
Core (synonymous with nucleus)	a piece of stone, often a pebble or cobble but also quarried stone, from which flakes have been struck for the purpose of making stone tools. (see also 'tabular nucleus'). The core (or core fragment) is generally amorphous in shape. Flakes removed from a core are called 'primary flakes' and may be further shaped by finer flaking, called 'retouch'. The term 'nucleus' refers to cores and flakes or cores that have been retouched.
core rotation	rotation of a core so that another surface is presented from which to initiate fractures that create flakes or blades. Usually this occurs when the previously flaked part of the core because unsuitable for further flake removals. Core rotation may be in any direction. The process may be opportunistic or planned, and is aimed at maximising the number of suitable flakes detached from the core.
cortex	cortex is the weathered exterior of rocks formed by long periods of exposure to chemical and physical weathering. The percentage of cortex remaining on either the dorsal (if limited to the dorsal), the platform (if limited to the platform) or both dorsal and platform (if occurring on both) is recorded in 10% increments. On flaked pieces, cortex is recorded as an estimation of the total surface area covered
cortex type	cortex type varies according to the environment in which it formed and the subsequent processes by which it came to be transported to its current position. Three types of cortex are recorded for all artefacts preserving a cortical remnant. These are angular, rounded and irregular.
Cretaceous	is defined as the period between 145.5 and 65.5 million years ago,* the last period of the Mesozoic Era, following the Jurassic
cutan	a skin, generally thin, on the natural surfaces in soil, that is, on the walls of the voids, the surfaces of skeleton grains and aggregates (e.g., pisoliths) or associated structures (e.g., glaebules), or the boundaries of other associated structures. Cutans have a composition and/or fabric different from the objects they coat. Cutans may be, e.g., argillans (clay), ferrans (iron oxide hydroxide), mangans (manganese oxide/hydroxide), calcans (or calcitans) (calcite).
debitage	commonly used French word for the stone refuse from flaking activity. Usually there is a large quantity of flaking debitage for every finished stone implement.
discard	when referring to lithic scatters the term discard means the incidental, intended and unintended scatter of artefacts on the ground surface or directly into a sediment.
distal portion or end	the end of a flake or microblade (the opposite end to that of the point of fracture origin on the ventral (or inside) surface. Tabular cortex is the weathered surface of a tabular shaped nucleus (core).

Term	Definition
dorsal face/facet	the outside surface(s) of a flake, the inside surface of the flake being one side of the fracture created during the formation of the flake. The speed at which these fracture formed ranges from about 200 m to over one kilometres a second (see also 'ventral face').
edge-ground axe	Implement shaped on at least one margin by grinding against another surface. Such implements are often shaped by flaking, pecking, flaking and pecking or grinding and/or burnishing around much of their exterior.
end scraper	A flake with a flat ventral surface and steeply retouched distal end.
Éraillure flake	a secondary flake, always very thin in cross-section that usually remains attached by a fine bridge of stone to the bulbar surface of a conchoidal negative flake scar. The fine attachment is easily removed by applying a very small force. A negative éraillure scar is left on one side of the bulb of force, which is in the upper part of the ventral surface of the primary flake from which it was detached, and is often referred to as 'bulbar scar'. This flake type has no initiation platform, is round or ovoid in plan view, and is always very thin. This flake type is not significant for the purposes of analysis other than to indicate conchoidal flaking.
facies	a body of rock with specified characteristics. Ideally, a facies is a distinctive rock unit that forms under certain conditions of sedimentation, reflecting a particular process or environment.
ferricrete	an indurated material formed by the in-situ cementation of regolith by iron oxyhydroxides, mainly goethite and/or hematite. The fabric, mineralogy and composition of the cemented materials may reflect those of the parent (regolith) material. Some authors restrict the term to the ferruginous horizon of lateritic regolith (and therefore synonymous with cuirasse, lateritic duricrust) but the more general definition is preferred. [Anand1] Original definition: A conglomerate of surficial sands and gravels cemented by Fe “salts”.
flake	(General) a piece of stone detached from a nucleus such as a core. A complete or substantially complete flake of lithic material usually with evidence of hard indenter initiation, or occasionally bending initiation. A general category for substantially complete conchoidal flakes, and rarely bending-initiated flakes. The most common type of flake is called 'conchoidal flake'. In certain circumstances flakes (especially conchoidal flakes) may be the result of natural fracture of stone. The flake's primary fracture surface (the ventral or inside surface) exhibits features such as fracture initiation, bulb of force, and undulations and lances that indicate the direction of the fracture front. Very occasionally a conchoidal flake comprises only a bulb of force (see also 'core', 'fracture initiation', 'bulb or force', 'lances' and 'undulations', and specific flake types).
flake fragment	A category comprising flake fragments without areas of fracture initiation but which display sufficient fracture surface attributes (normally conchoidal markings) for identification as a lithic artefact fragment.
flake from bipolar core	A flake retaining evidence of bipolar fracture damage on at least one end. Some of these are 'compression flakes' formed by substantial compressive force.
flake portion	terminated flake'. This variety of flake sustains a breakage at its distal end either because it was detached from the nucleus by a bending force that created a second, transverse break or was broken transversely by a bending force after it was detached (such as when it struck the ground during knapping or subsequently by treadage at the site).
flake portion	a proximal portion retains the area of flake initiation, a distal portion exhibits a flake termination. Longitudinally broken flakes and ones with an oblique break are also recognised.
flake rotation contact damage	the fine flake scars damage on the distal end of a flake (such as a microlith backing flake) a fraction of a second after it has been created and before it separates fully from the nucleus. This fracturing is caused by the continued application of load or force to the flake as its upper part moves outwards and away from the nucleus.
flaked piece	A flaked piece is defined as any piece of rock clearly derived from the process of conchoidal fracture, but for which no attributes exist to identify it as a core, a flake or any other identifiable technological category.

Term	Definition
flat	a landform element which is planar or near horizontal; creek flat -flat adjacent to a creek usually a floodplain.
floodplain	valley floor flat adjacent to a stream which is flooded by the 'annual' flood (often considered to be the flood with a recurrence interval of about 1.6 years).
fluvial	pertaining to a stream or river.
fluvial	of or pertaining to a river or rivers.
fracture or flake initiation	the point or area defining the beginning of a flake-forming fracture (always found at the top of the top of the flake scar or ventral (inside) surface of the flake (see also 'initiation surface').
fresh breakage or fracture	fracturing of a lithic item during archaeological excavation or sieving. Such fracture, which has no adhering sediment or sediment stain, may be caused by trowel, pick, shovel or earth moving machinery.
hammerstone /anvil	A piece of stone with such evidence of use in the form of diagnostic abrasion and other fracture damage.
heat fracture	fractures cause by heating the stone, either from natural causes, a campfire, or intentional heat treatment. Generally, these are undesirable effects though larger pieces of stone fractured by heat sometimes are used as cores or made into implements because of their convenient shape or size. Attributes indicating heat fracture include colour change, cracking, crazing, potlidding and creation of highly irregular fracture surface topography (often referred to as 'crenation' or 'crenulation'.
heat treatment	the intentional slow heating of stone, such as silcrete, above 300°C to improve its flaking properties.
hinge termination	when the end of the flake or fracture continuously turns at ninety degrees to the surface of the nucleus or outside surface of the flake (see also 'retroflexed hinge termination').
Holocene	is the geological epoch that began at the end of the Pleistocene (at 11,700 calendar years BP) and continues to the present.
implement (of stone)	synonym for a stone tool, usually denoting a tool that has been shaped by flaking (retouch).
Indeterminate retouched piece	an artefact or piece of an artefact with retouch along at least one margin. The purpose of this retouch cannot be determined, though some items are probably fragments of microlithic items, scrapers or utilised flakes listed above
initiation	see 'fracture or flake initiation'.
initiation platform	see 'initiation surface'.
initiation surface	the surface of a stone (sometimes called a platform) that is struck with a hammerstone at low angle for the purpose of detaching a flake. This surface is where a flake-forming crack commences; commonly part of it is retained on the flake. The load applied to this surface may be delivered by a hammerstone or by continuous increasing pressure with a length of dense wood or bone (a pressor or pressure flaking tool).
interfluve	the area between rivers; especially the relatively un-dissected upland or ridge between two adjacent drainage basins.
isolated find	a single stone artefact, not located within a rock shelter, and which occurs without any associated evidence of Aboriginal occupation within a specified radius, such as 60 metres (depending on which archaeological convention is used). Isolated finds may represent single discard events, be constituent components of background scatter, or be indicative of larger obscured, remnant and disturbed sites.
knapping episode	a series of flaking events (see also 'knapping event')
knapping event	a single act of flaking a piece of stone resulting in the *in-situ* deposition of stone flaking debris. Such an event may occur as part of a series of events
knick point	any interruption or break of slope in the longitudinal profile of a stream or of its valley, especially a point of abrupt change or inflection, resulting from rejuvenation, glacial erosion, or the outcropping of a resistant bed.
lamination	a fine layer within the matrix of a lithic material. This layer is less than 2 mm thick.
lateral margin (of a flake)	the edge along the side of a flake, running from the flake's initiation surface to its termination.

Term	Definition
laterite	generally, regolith exhibiting the characters of all, or at least the upper part, of a laterite profile. Laterite, or lateritic regolith, commonly has a hard, more or less prominent, ferruginous surface expression, with some degree of chemical and mineralogical differentiation below, characterized by varying colour reflecting varying iron and silicate distribution. Laterite is the product of weathering.
lateritization	the process of transformation of a (near) surface layer (rock or soil) into lateritic regolith.
lithic	in an archaeological context, items of a hard, usually siliceous, stone of a type selected by Aborigines for tool making. These items are often nondescript fragments but some also finely shaped implements.
lithic assemblage (of stone)	a collection of whole and fragmentary stone artefacts and manuports obtained from an archaeological site, either by collecting items scattered on the present ground surface (see lithic scatter) or by controlled excavation (see also 'stone artefact').
lithic fragment	a nondescript lithic item that does not have sufficient morphological attributes to identify it as a complete artefact or a portion of an artefact. The lithic fragment category comprises items which are identified only to the level of manuport fragments, even though it contains nondescript flaking shatter and fragments of flakes not individually identifiable as such. Some fragments exhibit attributes characteristic of heat stress, such as occurs during bushfire, hearth fire or intentional heat treatment. Evidence of heat fracture on lithic fragments (and identifiable artefacts) has been recorded in the comments for each entry. Depending on the nature of the cultural sediment and non-Aboriginal land-use practices this group may also contain a small number of non-artefactual fragments exhibiting fresh fracture surfaces.
lithic item	a piece of stone exhibiting fracture surfaces and not identified as a natural piece of stone.
lithofacies	a mappable subdivision of a designated stratigraphic unit, distinguished from adjacent subdivisions on the basis of lithology; a facies characterized by particular lithologic features. The rock record of any particular sedimentary environment, including both physical and organic characteristics.
lithology	the lithology of a rock unit is a description of its physical characteristics visible at outcrop, in hand or core samples or with low magnification microscopy, such as colour, texture, grain size, or composition
manuport	an object or fragment of an object (called item in this report) carried by human agency to the locality in which it is found.
margin	the surface immediately adjacent to an edge, the letter being the intersection of two margins.
microdebitage	flaking waste or debris (debitage) up to 10 mm in maximum size. There is no uniform metrical definition of micro-debitage and some archaeologists specify a maximum size of 5 mm.
microlith (synonym 'backed blade')	a variety of small, delicately retouched implements of various shapes such as asymmetric (bondi) point, segment, crescent, triangle, trapeze, rectangle and oblique ended. These implements are commonly thought to have been spear barbs.
microlith preform	a microblade with some degree of initial backing retouch, often along the distal end. Recognised portions are proximal, distal and fragment.
modified tree	an Aboriginal archaeological site type classification which includes all trees considered to have been modified by an Aboriginal action. Most modified tree recordings are of *scarred trees*, which display scarring that resulted from the removal of bark or wood. Rarer types include trees with evidence of carved motifs and designs, foot and hand holds, extraction of animals, or deliberate manipulation of growth form.
mottles (in soil/sediment)	masses or blotches of subdominant colours within a soil mass. Often evidence of poor drainage or extensive bioturbation.
mottles (on stone surface)	masses or blotches of subdominant colours in an area of stone surface.

Term	Definition
Neogene	is a geologic period and system in the International Commission on Stratigraphy (ICS) Geologic Timescale starting 23.03 million years ago and ending 2.58 million years ago. The second period in the Cenozoic Era, it follows the Paleogene Period and is succeeded by the Quaternary Period. The Neogene is subdivided into two epochs, the earlier Miocene and the later Pliocene
nondescript core or core fragment	A core (or core fragment) of generally amorphous shape.
nucleus	see 'core', 'polyhedral core', 'tabular nucleus'.
open camp site	a formerly used site type classification defined as an open context stone artefact occurrence (or artefact scatter), containing two or more artefacts situated no more than a specified arbitrary distance (such as 60 metres) away from any other included artefact. The term *open camp site* was based on ethnographic modelling suggesting that most artefact occurrences resulted from activities at camp sites. However, in order to separate the description from the interpretation of field evidence, both open camp sites and isolated finds are now referred to as *artefact occurrences.*
open site	an Aboriginal site which does not occur within a rock shelter or cave.
outrépasse termination	a flake ending that turns inwards within the nucleus taking off part of its base. This occurs when the fracture front approaches the bottom of a nucleus and must turn in one direction or the other, as the stresses on either side of the fracture front cannot be equal. If the fracture front turns sharply towards in the other direction the flake will terminate in a hinge. A modest to pronounced outrépasse termination is common on microlith backing flakes and occasionally is seen on microblades.
palaeochannel	is a remnant of an inactive river or stream channel that has been either filled or buried by younger sediment.
palaeosol	soil formed under environmental conditions different from those of the present. May be buried.
palaeovalley	re geologically ancient, buried river valleys which no longer function as active surface water systems.
Paleogene	is a geologic period and system that began 66 and ended 23.03 million years ago and comprises the first part of the Cenozoic Era.
pebble	by geological definition, a waterworn stone less than 64 mm in diameter (about the size of a tennis ball). Archaeologists often refer to waterworn stones larger than this as pebbles though technically they are cobbles.
pedogenesis	soil formation. Adjective: pedogenetic, pedogenic.
pH	acidity or alkalinity of soil or water. Expressed in logarithmic units either side of 7 which is neutral, <7 = acid, >7 = alkaline.
pit	a below ground level ('subsurface') testing location, either excavated by hand and sometimes referred to as a *spade pit* or *shovel pit*, or excavated by machine, such as with a backhoe or machine auger and sometimes referred to as a *trench*.
porphyry	An igneous rock rich in phenocrysts. The term 'porphyritic' refers to ones in which relatively large crystals are set in a fine-grained or glassy groundmass.
potential archaeological deposit (pad)	A discrete location or area, defined spatially either by geomorphological, disturbance or administrative criteria, within which there is a predicted likelihood that subsurface archaeological material is present, and that this material would warrant archaeological investigation in order to determine its' scientific, cultural, or statutory value and status.
potential archaeological sensitive landform (pasl)	an area within which sites and/or potential archaeological deposits are predicted to occur at a scale or frequency which necessitates careful management action in the future. The 'potential' prefix of this classification is necessary where there are no locally applicable results or model available to support the predicted occurrence.
potlid	A piece of lithic material that has a generally convex or dome-shaped ventral surface, often with evidence of fracture initiation from a location within the surface and not from the edge.
preform	a flake or blade selected for shaping by retouch into an implement. For inclusion in this category an artefact must have some degree of retouch (see also 'retouch' and 'blank').

Term	Definition
primary fracture surface	One of the two conjoining fracture surfaces created on a nucleus and flake after the flake has detached. The primary fracture surface on the flake is called the ventral surface.
proximal	the top part of a flake beginning with the initiation surface or ridge. It is the same for an implement (or tool). The opposite end of flake is called the distal end.
quarry	a site where stone was obtained by excavation from bedrock with extraction tools of simple design (see also Stone procurement site or place).
quartz	a mineral composed of crystalline silica SiO^2. Quartz is a very stable mineral that does not alter chemically during weathering or metamorphism. It is hard, usually colourless or white ('milky'). In its massive form quartz occurs as geodes or veins, from which pebbles are formed by weathering. Despite the often unpredictable nature of fracture in quartz the flakes often have sharp cutting edges. Quartz is common and abundant, and the Aborigines used it throughout Australia to make convenient light-duty cutting tools.
quartzite	A hard, silica rich stone formed from a sandstone that has been recrystallised by heat (meta-quartzite) or strengthened by slow infilling of silica in the voids between sand grains (orthoquartzite). The essential difference between sandstone and quartzite is that major fracture will propagate around the larger grains in sandstone and through the grains in quartzite.
quartzose	relating to or made of quartz
Quaternary	The most recent geological time period. Divided into the Holocene and the Pleistocene. Began 1.8 million years ago.
Quaternary	the most recent geological time period. Divided into the Holocene and the Pleistocene. Began 1.8 million years ago
reduction process	the process of removing flakes from a core, or of manufacturing an implement by flaking and/or grinding, or progressively rejuvenating a tool's working edge.
reduction strategy	strategy of flaking and/or grinding a piece of stone in predetermined stages to produce an implement.
regolith	all materials stored over bedrock on the earth`s surface
residues on stone tools	residue analysis concerns the identification of tool use activities from preserved organic and inorganic residues of worked materials. These residues may be compacted into small flake scars on the edges of utilised artefacts or adhere strongly to their surfaces. Routine examination of residues is aided by low-magnification microscopy.
retouch or retouching	an area of flake scars on an artefact resulting from intentional shaping, resharpening, or rejuvenation after wear or breakage. In resharpening a cutting edge the retouch is invariably found only on one side (see also 'indeterminate retouched piece', retouch flake' etc).
rockhead	the surface of the bedrock beneath soil cover, uppermost occurrence of unweather bedrock
sandstone	a cemented or compacted rock consisting of detrital grains which range in size from 2 mm. Because of its chemical stability quartz often comprises the majority of the grains. The nature of the cement is denoted by terms such as argillaceous (clayey), calcareous, ferruginous and tuffaceous sandstone.
saprock	compact, slightly weathered rock with low porosity; defined as having less than 20% of weatherable minerals altered but generally requiring a hammer blow to break.
saprolite	weathered bedrock in which the fabric of the parent rock, originally expressed by the arrangement of the primary mineral constituents of the rock (e.g., crystal, grains), is retained. Compared to saprock, saprolite has more than 20% of weatherable minerals altered, and generally collapses under a light blow.
scarred tree	A tree with a scar or scars of assessed Aboriginal origin. Most such scars are the result of the removal of bark or wood. The identification of a scar as Aboriginal in origin is dependent on a set of inter-related interpretive criteria, and is often associated with varying degrees of recorder confidence or surety. For this reason classifications are often prefixed as possible, probable or most likely. The credibility of alternative causal explanations such as natural traumas and other types of human scarring must be tested for each scar. Scarred trees are now included in the more inclusive site type classification of *modified tree*.

Term	Definition
siderite	is a mineral composed of iron(II) carbonate (FeCO3).
sieve damage	fracture damage on lithic items caused by abrasive contact with the sieve mesh during the process of sieving. This occurs more commonly with wet sieving of clayey sediment.
silcrete	(also known as 'porcellanite' and 'grey billy') A hard, fine grained siliceous stone flaking properties similar to quartzite and chert. It is formed by the cementation and/or replacement of bedrock, weathering deposits, unconsolidated sediments, soil or other material by a low temperature physico-chemical process. Silcrete is essentially composed of quartz grains cemented by microcrystalline silica (SiO^2). Mineral composition is highly variable, but it comprises more than 85% silica, and includes aluminium, iron and titanium in small but significant amounts. The bonding matrix is often composed of microcrystalline quartz or chalcedony. Clasts are most often quartz grains but may also include chert or chalcedony or some other hard mineral particle. Mechanical properties and texture are equivalent to the range exhibited by chert at the fine-grained end of the scale to silcrete at the coarse-grained end. Silcrete has been used by Aborigines for stone tool manufacture throughout most of Australia.
site	refer *Aboriginal site*
site integrity	the degree of post-depositional disturbance to a site.
spit	an arbitrary interval of excavated depth in an archaeological excavation, such as in: spit 2 was the layer of deposit excavated between 10 and 20 cm below ground level.
stone artefact	a piece or fragment of stone showing evidence of intentional human creation or modification.
stone layer	a sheet or layer of gravel sized materials found within a body of soil material. Commonly formed at the lower limit of bioturbation and often contains a concentration of artefacts.
stone material	(synonymous with 'lithic material', 'stone type' and 'raw material' which is a less specific but commonly used term).
stone procurement place (or site)	a place where stone is obtained for making into artefacts. As a prehistoric site type in Australia, stone procurement places range on a continuum, from pebble beds in watercourses (where there may be little or no archaeological evidence of human activity) to extensively quarried outcrops of bedrock where there is clear evidence of procurement activity, such as quarry pits, discarded hammerstones and large consolidated cultural deposits of primary flaking debris. (See also quarry)
stone tool	a piece of flaked or ground stone used in an activity or fashioned for use as a tool. A synonym of stone tool is implement, which is more often used by archaeologists to describe a flake tool fashioned by more delicate flaking (retouch).
subsurface artefact occurrence	One or more stone artefacts which occur within a specified deposit, and which have been revealed as a result of natural or human excavation. The boundaries of a recording may be strictly tied to known artefacts (such as test pits or erosion scarps) or consist of an interpretation base on topographic or disturbance variables. Subsurface artefact occurrences can also be described as archaeological deposits
superficial	at the surface, especially the surface of the Earth
surface artefact occurrence	One or more stone artefacts which occur within a specified surface area, and which are distinguished from other recordings by defined criteria, such as the boundary of ground surface exposures, landform type, or an arbitrary separation distance
technological attributes analysis	methods of reconstructing reduction sequences in stone technology (see reduction sequence). Discrete and metrical attributes of artefacts are identified, recorded and examined mathematically.
termination (of a flake)	the distal end
tuff	a stone type consisting of consolidated volcanic ash. Fine grained and highly siliceous forms of tuff were often exploited by Aboriginal people for the manufacture of flaked stone tools.
unconformable	consisting of a series of younger strata that do not succeed the underlying older rocks in age or in parallel position, as a result of a long period of erosion or non-deposition.
use fractures	breakages on the edges of stone tools resulting from tool use (see also 'use-wear').

Term	Definition
use-wear	microscopic and macroscopic damage to the surfaces of stone implements resulting from its use. Routine examination for use-wear is aided by low-magnification microscopy. Major use-wear forms are edge fractures, use-polish and smoothing, abrasion, and edge rounding and bevelling.
ventral face	the inside surface of a flake created during the flake's formation. The speed of the fracture ranges from about 200 metres to over one kilometres per second (see also 'dorsal face').
volcanic stone	rock types formed by volcanic activity display a wide range of mechanical and flaking properties. Freshly fractured volcanic stone tends not to have fine, durable edges suitable for cutting. Only a few types are utilised for making stone tools, often ones that are shaped by grinding.
working edge	the edge of a tool in contact with the worked substance or material during its usage.

Appendix 5

Mapping of landforms and test locations

A5.1 Landform mapping

Key to landform mapping

Drainage lines

First order — *not delineated*

Second order

Third order

Fourth order

Fifth order



Crests

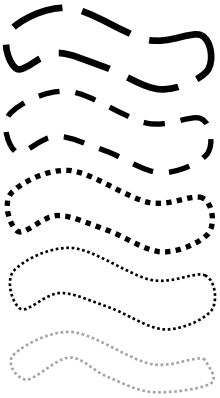
(5) Major watershed (Nepean R – South Creek)

(4) Secondary watershed (Cosgroves Creek – Badgerys Creek)

(3) Tributary watershed (eg Oaky Creek)

(2) Secondary spurline

(1) Minor spurline or locally elevated ground



Valley Context

Valley Floor Flats/infill sediments

Basal valley slopes

Upper and mid valley slopes

Riparian zone

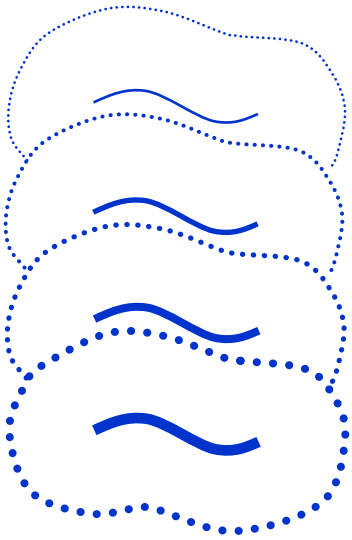
100 m radius around:

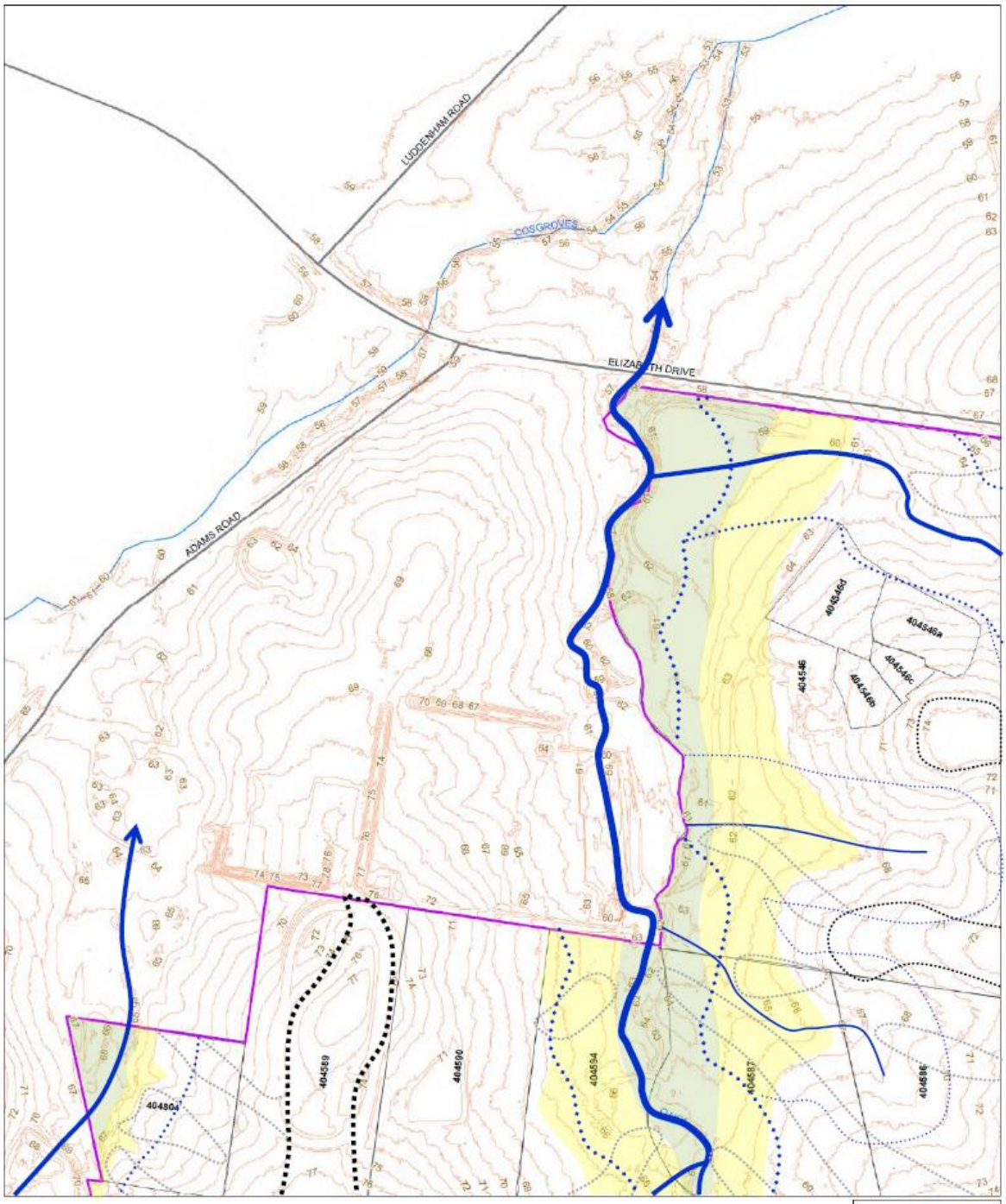
Second order drainage line

Third order drainage line

Fourth order drainage line

Fifth order drainage line

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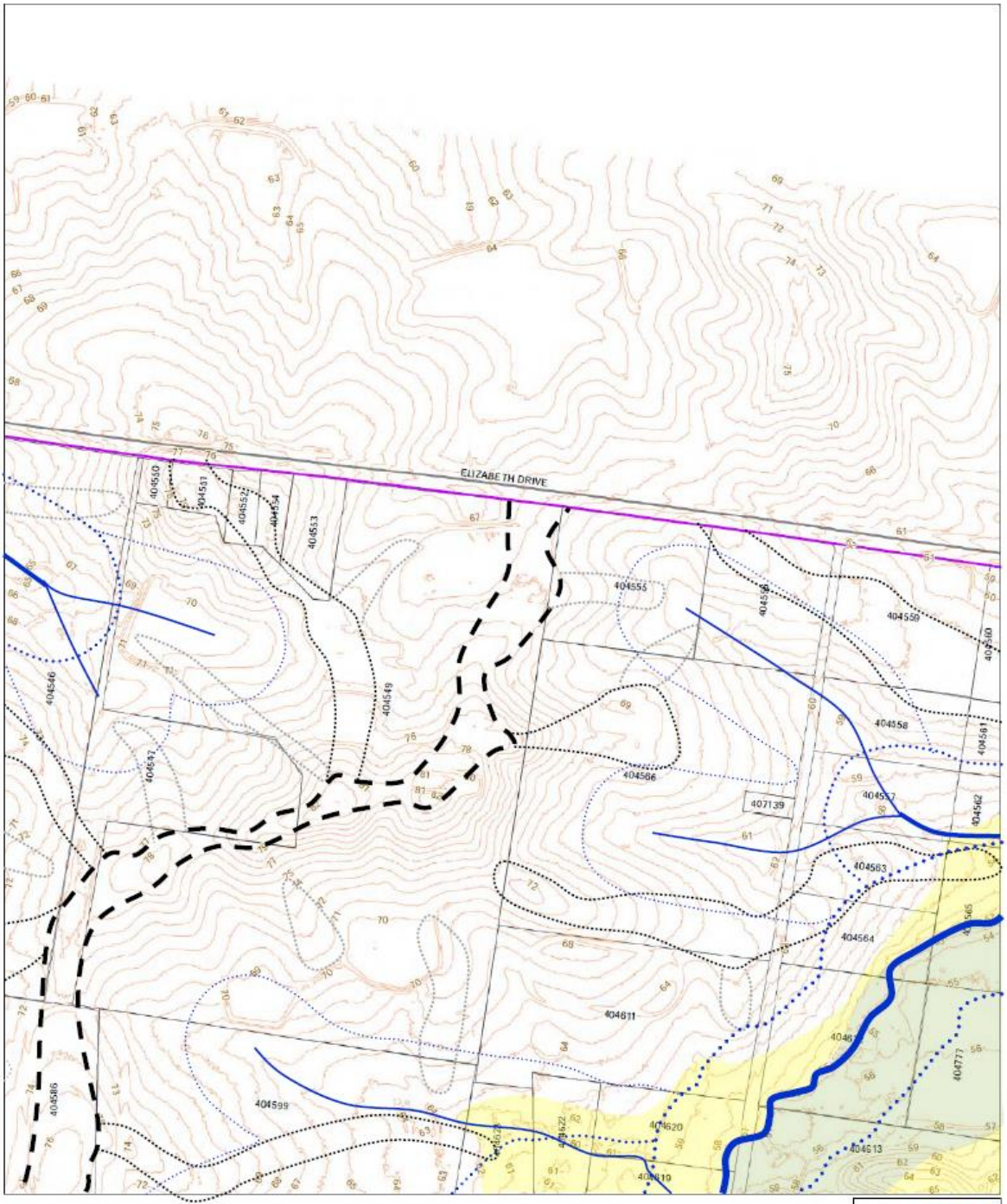

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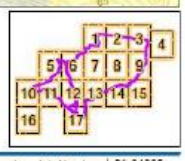

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Environmental Assessment of Commonwealth-owned Land at Badgerys Creek.

Job Number 21-24265
Revision A
Date 26 Feb 2015

Site layout

Page: 2

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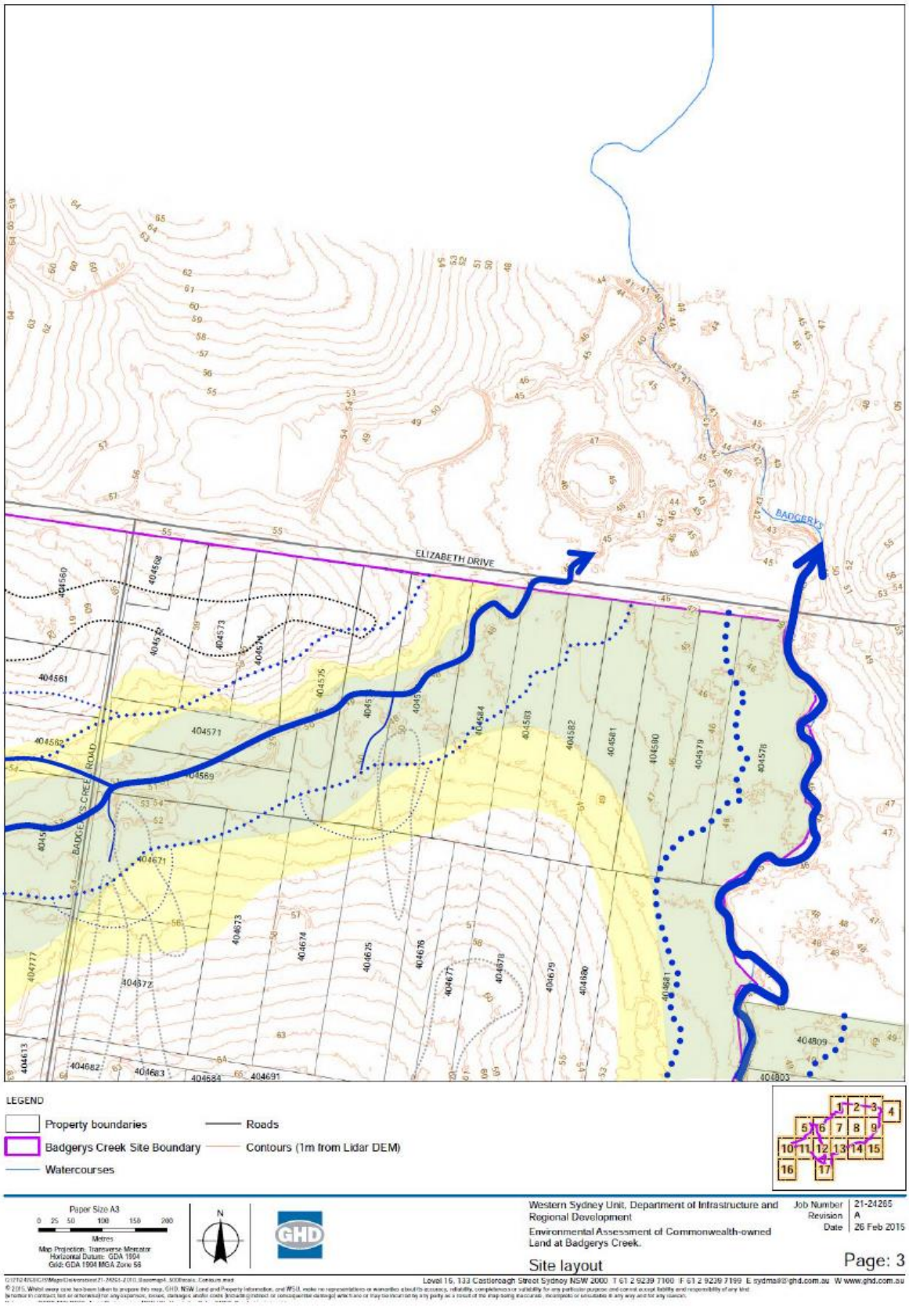
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Western Sydney Unit, Department of Infrastructure and Regional Development
Environmental Assessment of Commonwealth-owned Land at Badgerys Creek.
Site layout
Job Number 21-24266
Revision A
Date 26 Feb 2015
Page: 3
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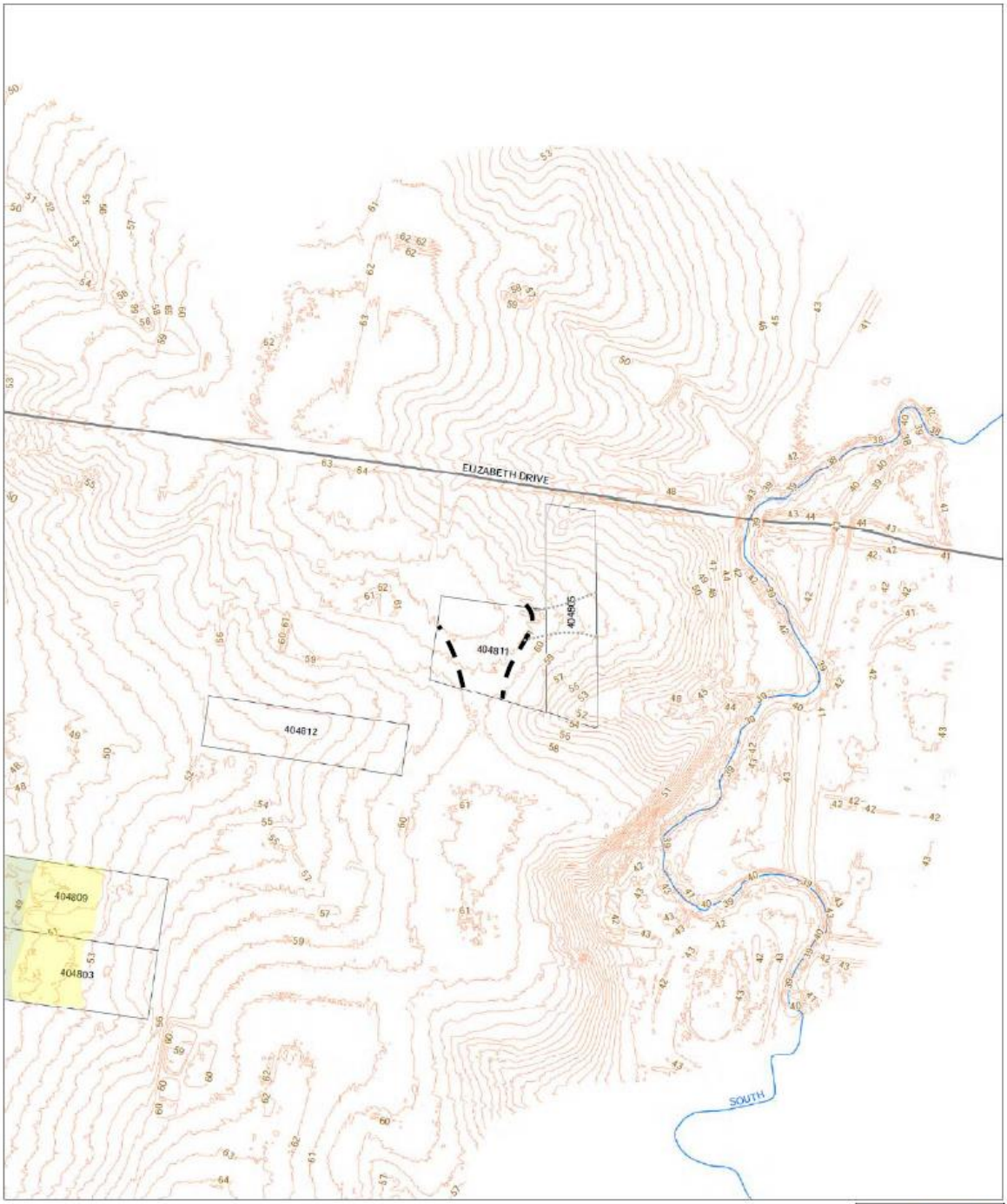

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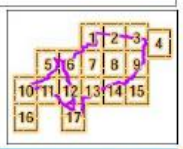

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Job Number 21-24265
Revision A
Date 26 Feb 2015

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Site layout
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Revision A
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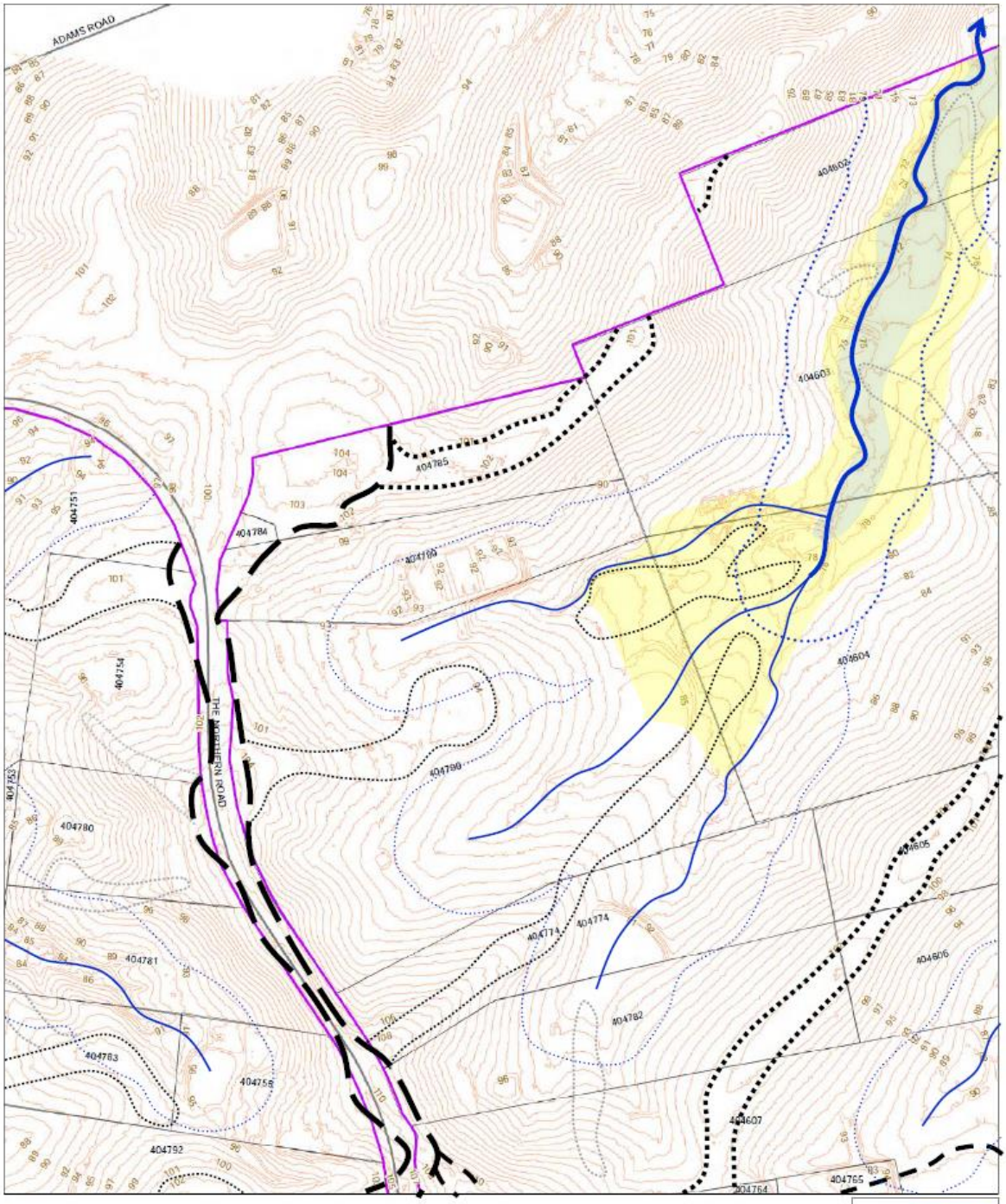

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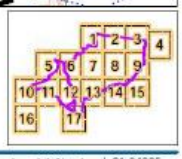

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Environmental Assessment of Commonwealth-owned Land at Badgerys Creek.

Job Number 21-24265
Revision A
Date 26 Feb 2015

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Page: 6

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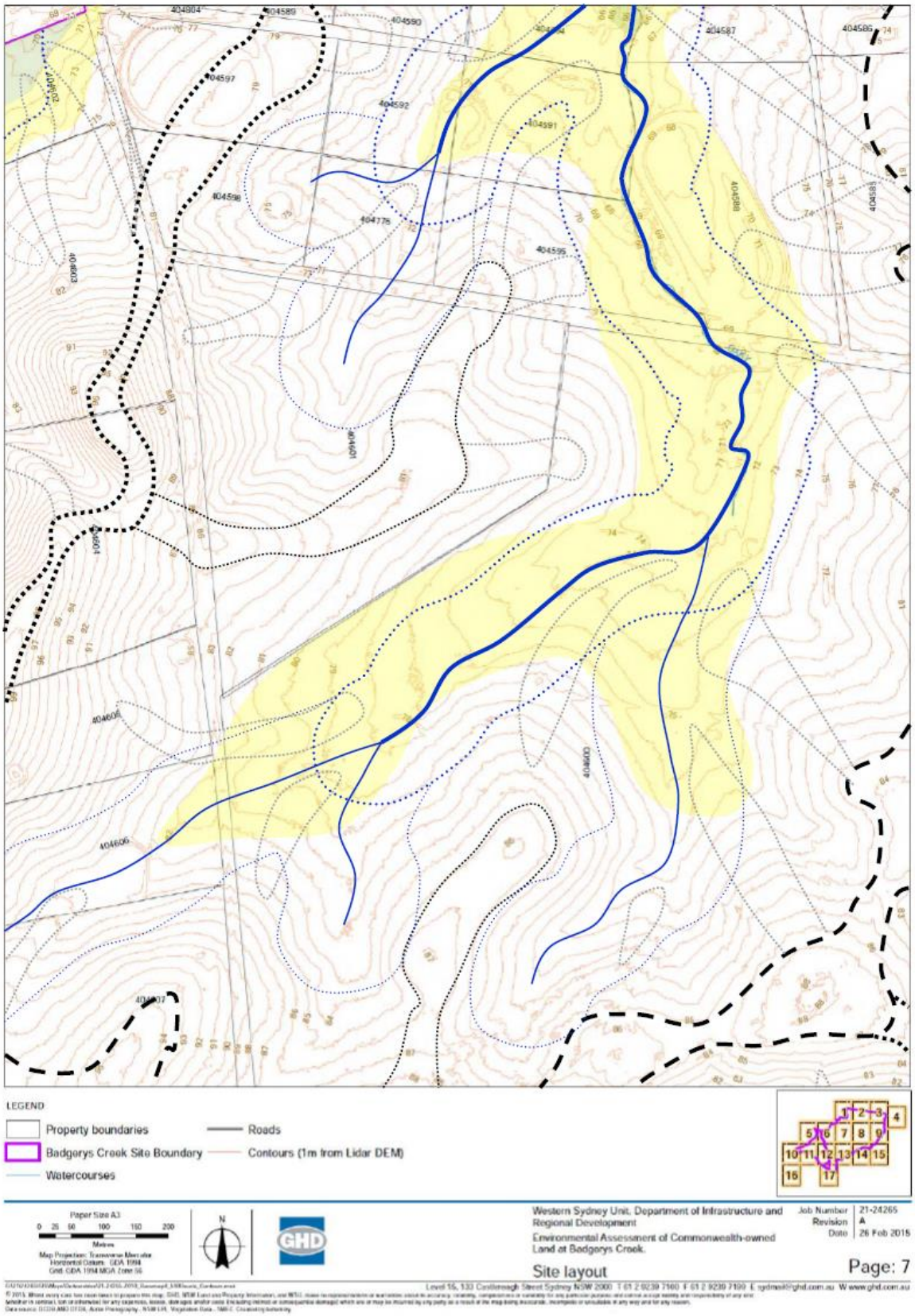
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Site layout
Job Number 21-24265
Revision A
Date 26 Feb 2015
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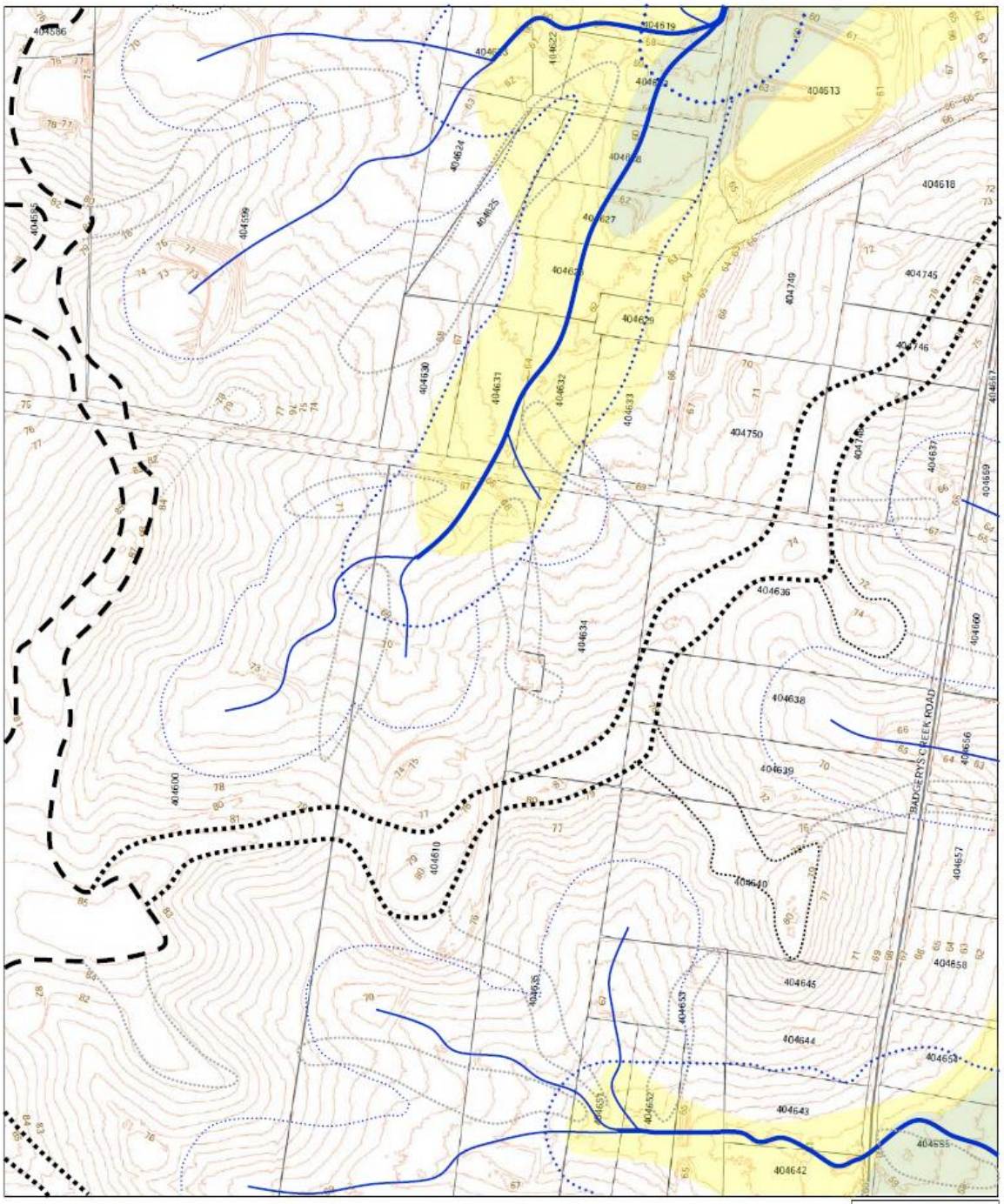

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Job Number 21-24265
Revision A
Date 26 Feb 2015

Site layout

Page: 8

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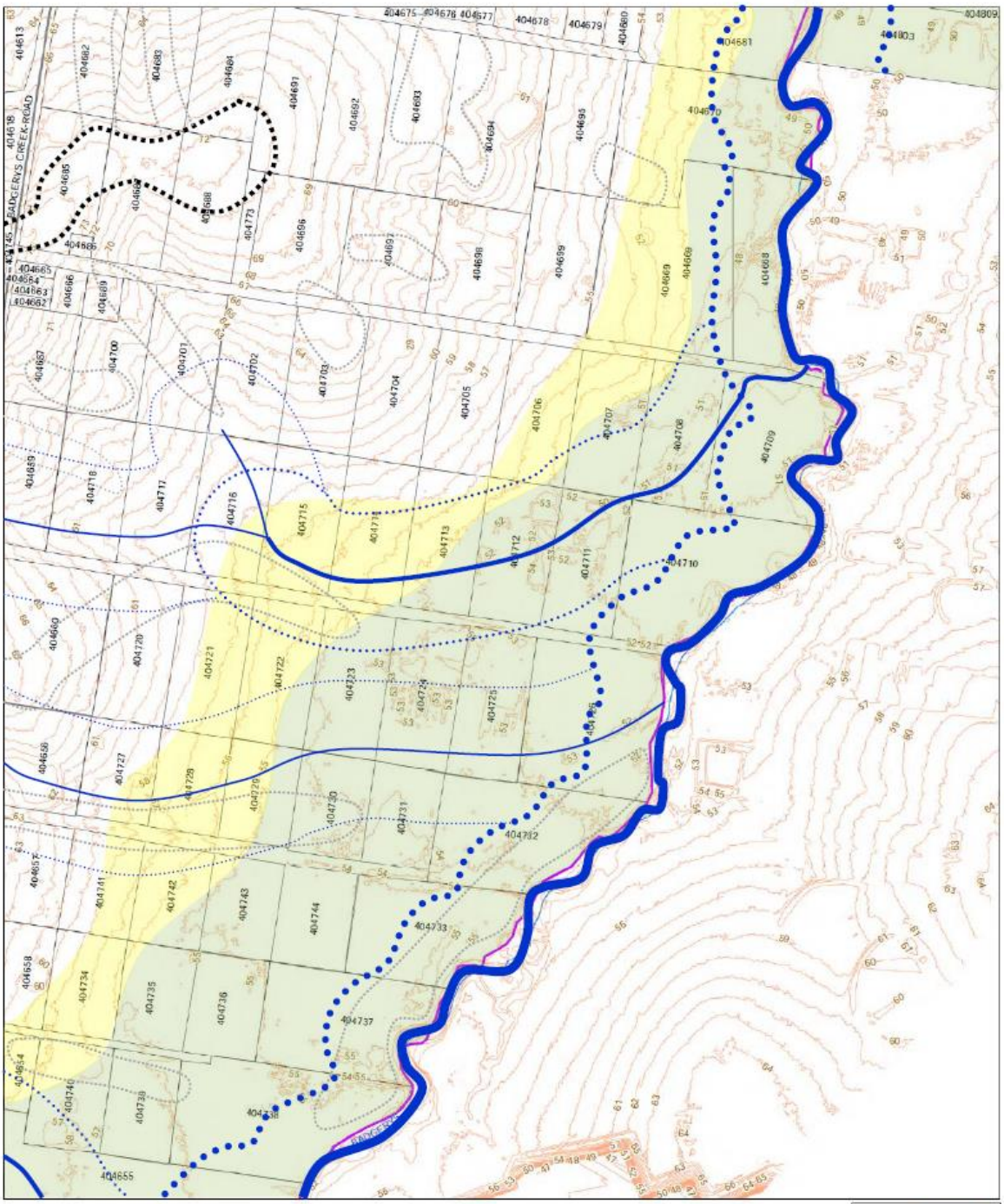

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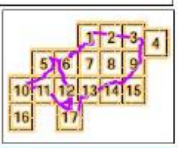

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Job Number 21-24265
Revision A
Date 26 Feb 2015

Site layout

Page: 9

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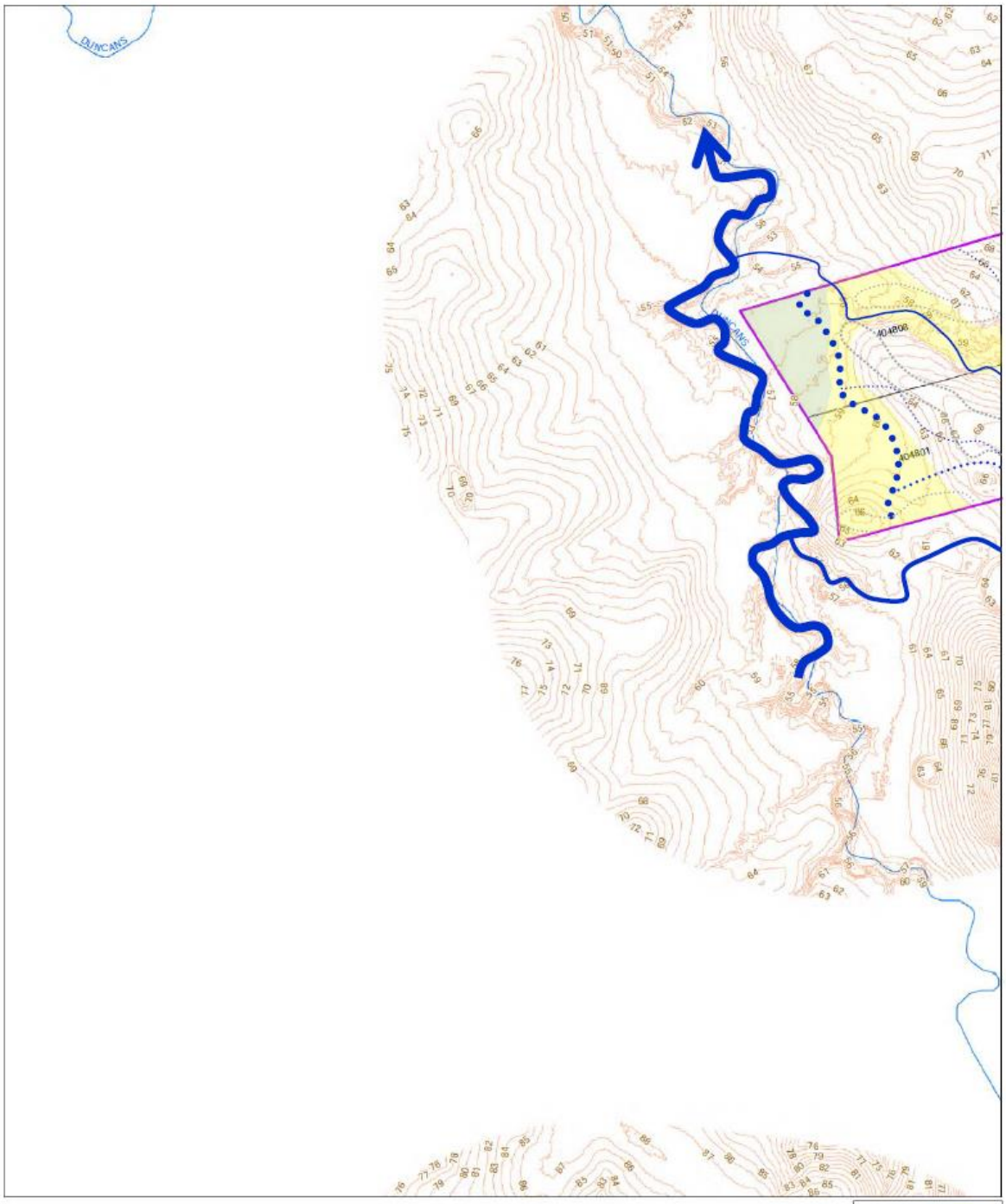
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Western Sydney Unit, Department of Infrastructure and Regional Development
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Site layout
Job Number 21-24265
Revision A
Date 26 Feb 2015
Page: 10
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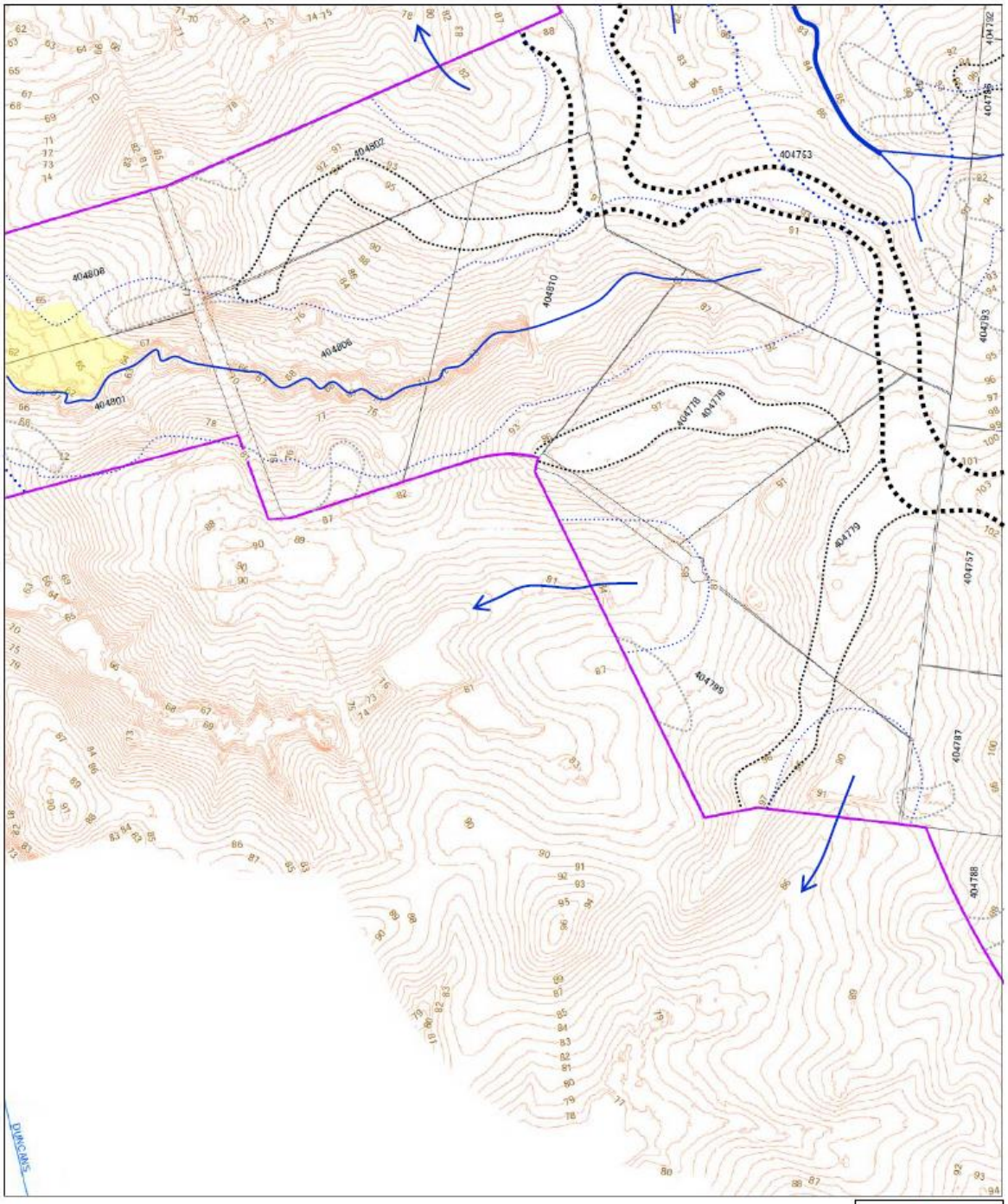

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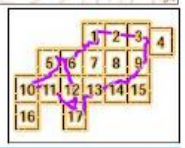

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Western Sydney Unit, Department of Infrastructure and Regional Development

Environmental Assessment of Commonwealth-owned Land at Badgerys Creek.

Job Number 21-24265
Revision A
Date 26 Feb 2015

Site layout

Page: 11

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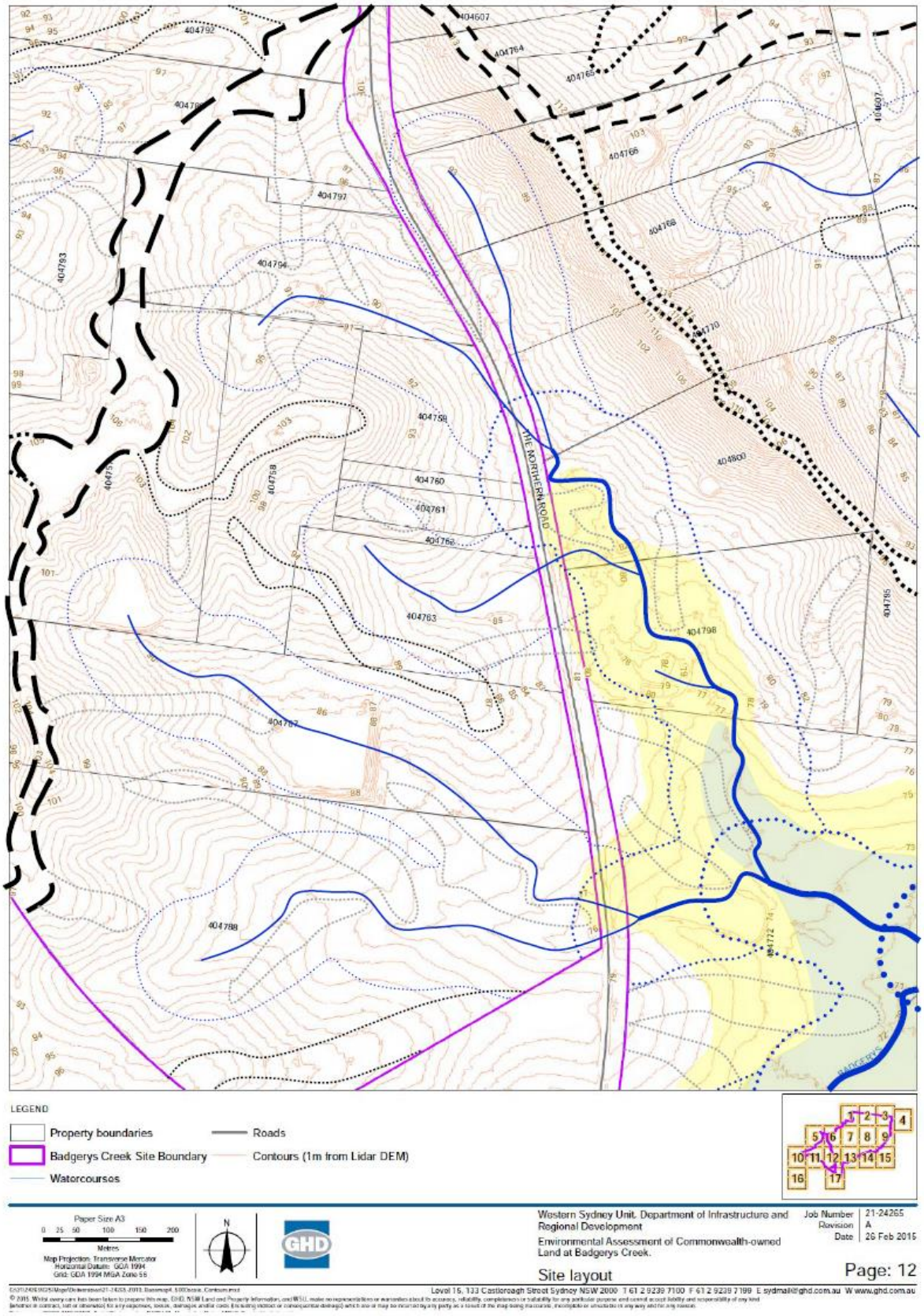
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Western Sydney Unit, Department of Infrastructure and Regional Development
Environmental Assessment of Commonwealth-owned Land at Badgerys Creek.
Site layout
Job Number 21-24265
Revision A
Date 26 Feb 2015
Page: 12
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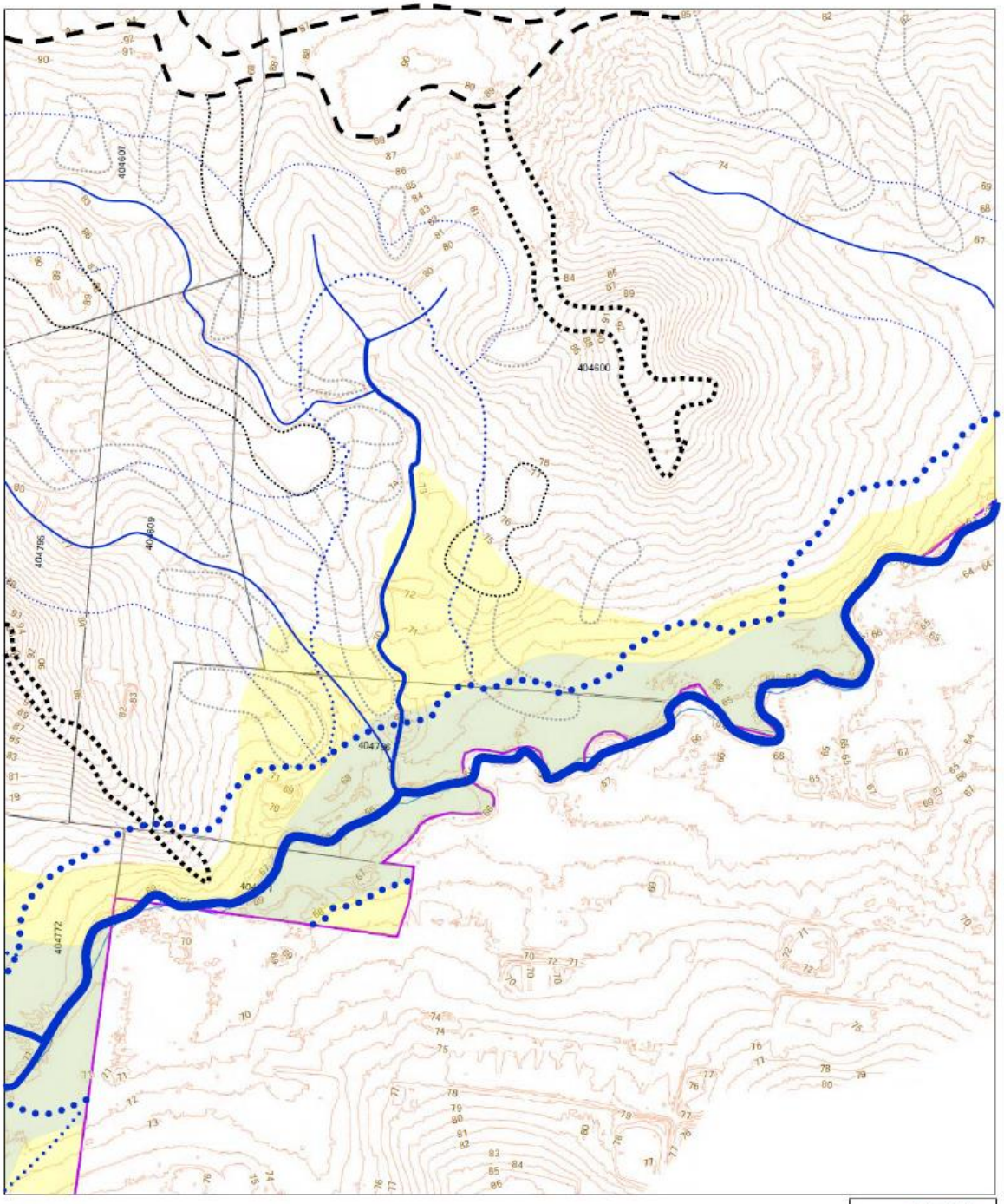

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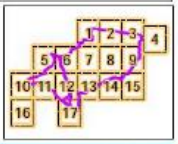

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Western Sydney Unit, Department of Infrastructure and Regional Development

Environmental Assessment of Commonwealth-owned Land at Badgerys Creek.

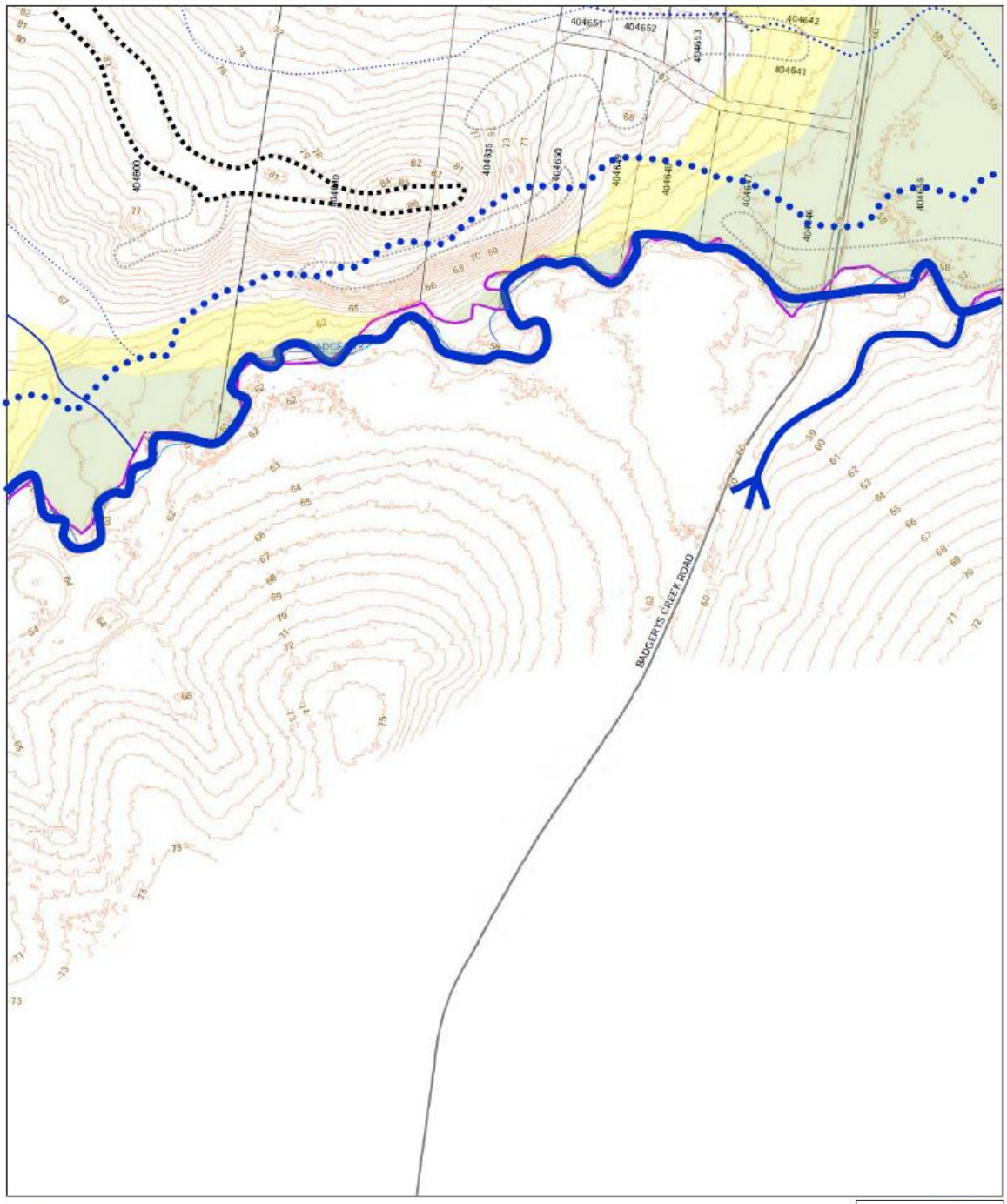
Job Number 21-24265
Revision A
Date 26 Feb 2015

Site layout

Page: 13

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Western Sydney Airport – Aboriginal Cultural Heritage Assessment *274*
Navin Officer Heritage Consultants Pty Ltd *October 2015*



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GHD

Western Sydney Unit, Department of Infrastructure and Regional Development

Environmental Assessment of Commonwealth-owned Land at Badgerys Creek.

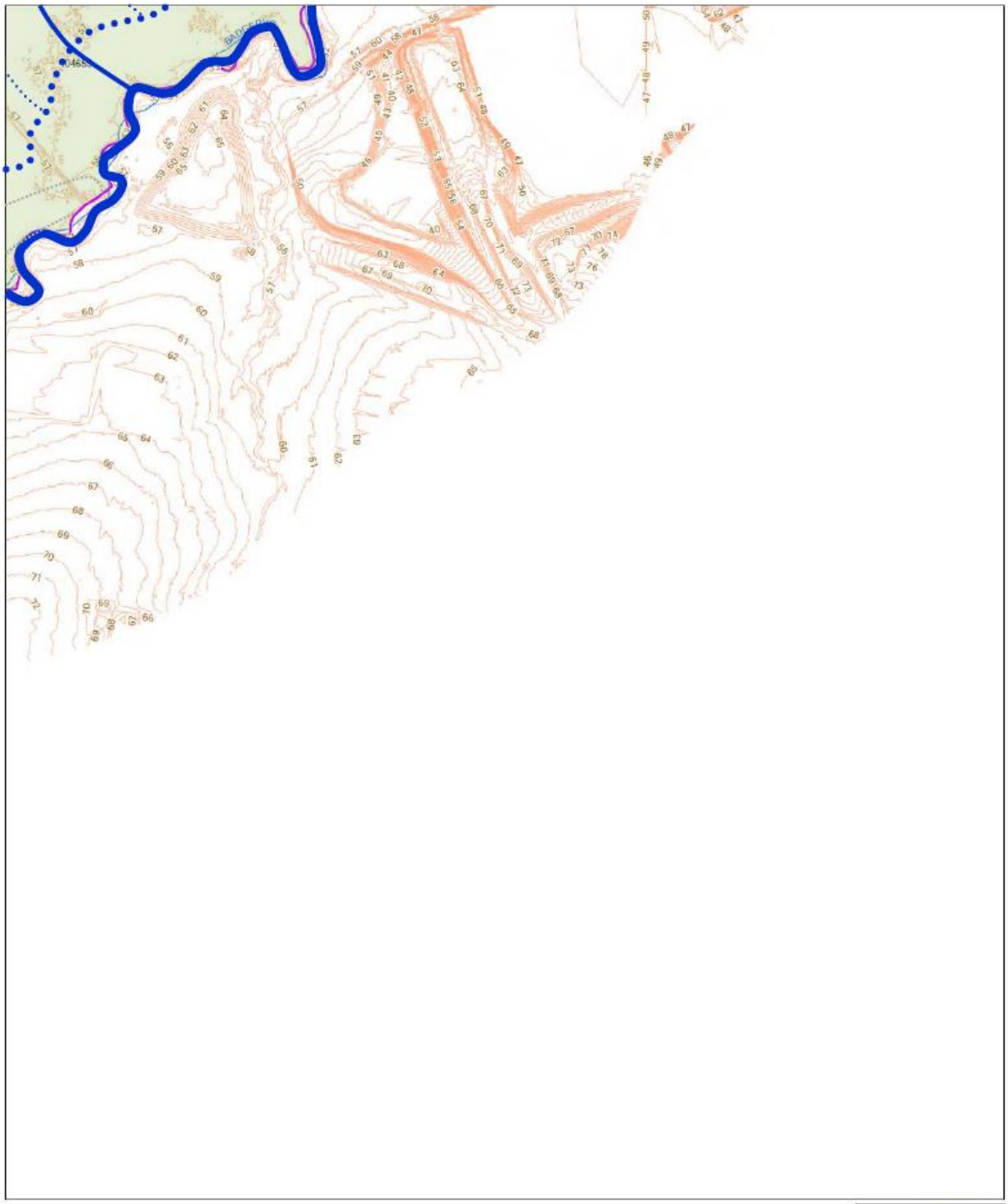
Job Number 21-24265
Revision A
Date 26 Feb 2015

Site layout

Page: 14

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

Western Sydney Airport – Aboriginal Cultural Heritage Assessment 275
Navin Officer Heritage Consultants Pty Ltd October 2015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Western Sydney Unit, Department of Infrastructure and Regional Development
Environmental Assessment of Commonwealth-owned Land at Badgerys Creek.
Site layout
Job Number 21-24265
Revision A
Date 26 Feb 2015
Page: 15
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au


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Western Sydney Unit, Department of Infrastructure and Regional Development
Environmental Assessment of Commonwealth-owned Land at Badgerys Creek.
Site layout
Job Number 21-24265
Revision A
Date 26 Feb 2015
Page: 16
Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au



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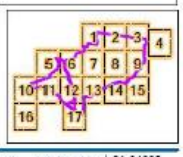

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GHD

Western Sydney Unit, Department of Infrastructure and Regional Development

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Job Number 21-24266
Revision A
Date 26 Feb 2015

Site layout

Page: 17

Level 15, 133 Castlereagh Street Sydney NSW 2000 T 61 2 9239 7100 F 61 2 9239 7199 E sydmail@ghd.com.au W www.ghd.com.au

A5.2 Test pit locations

Maps from this section have been removed for the unrestricted access version of this report

Appendix 6

Geoarchaeological overview of the historical borehole data, Western Sydney Airport

Specialist report by Anthony Barham
Navin Officer Heritage Consultants

A6.1 Introduction

This report examines the potential value of borehole data for improving understanding of the known and potential archaeological resource at the airport site. The desktop study reviews data from historic geotechnical investigations across the Commonwealth owned lands at Badgerys Creek. Data reviewed comprise borehole and test pit records, mapping and geotechnical reports supplied by GHD to Navin Officer Heritage Consultants.

This review was restricted to historic geotechnical data, acquired during the late 1980s and 1990s. Because of time constraints, the data provided were sampled.

The core aim was to establish whether borehole and test pit geotechnical data might be used to improve understanding of the archaeological resource across the planned impact areas of the airport site, as part of the conditions of any development approval.

The review briefly examines the landform history across the area. An interim conclusion was that the geologically ancient nature of weathering across the airport site, coupled with tectonic warping, does create a geographic context across the airport site in which near surface modification of regolith may have occurred through ancient fluvial activity, and subsequent drainage diversions. This may lead to significant uncertainties regarding deposit ages and depths occurring across the area, mainly in regolith within 5 m of surface. Some older regolith may have archaeological significance. This particularly relates to remnants of past weathered land surfaces, surviving as thin cappings (e.g. lateritized deposits possibly including silcretes) and traces of former high level alluvial “palaeochannel” deposits. These deposits are “palaeosols” in the broadest geological sense. Such deposits (being geologically ancient) predate human occupation of the Australian continent by millions of years. The archaeological potential significance of such deposits lies in their potential as procurement source deposits - areas of near-surface raw material which Aboriginal people may exploit to make stone artefacts.

The geotechnical data provided were then sampled. The aim was to test whether any boreholes and test pits log stratigraphy of the “residual types” anticipated in the review, and in particular if evidence for palaeosols and other chronostratigraphy of potential archaeological significance may exist in the data sets.

It was assumed geotechnical investigations would preference particular areas. The historic data will not randomly sample the land surface across the scheme footprint as now defined. Also the geotechnical data variably included maps, and when mapped were set to varying scales. The scope of the review did not allow full geo-referencing of the historic data to a common modern mapping base, or evaluate it with respect to:

a) the spatial map of the archaeological test pit assessment outcomes undertaken by NOHC for the current investigation, or

b) the mapping of geotechnical investigations conducted for the current investigation.

The drivers of the short review were forming preliminary answers to the following questions:

- Might borehole and test pit (geotechnical) data assist in reducing uncertainties regarding the depth and spatial extent of archaeological deposits across the area?
- Is there evidence in the historic geotechnical data pointing to locations, areas or stratigraphic sequences which might be archaeologically significant?
- Can palaeosols, stratified deposits or chronostratigraphic potential be seen in the data?
- Can geotechnical data guide and prioritise areas for further phases of archaeological mitigation, especially as conditions of the EIS?

- If there is potential – what methodologies and strategies can best utilise both historic geotechnical data, and new geotechnical data now being acquired across the development footprint?

The initial review of sampled data suggests there will be considerable value in integrating a model of the near-surface geometry of unconsolidated deposits over bedrock (a regolith model based on geotechnical data) with requirements set for post-EIS archaeological salvage. The geotechnical data are sufficiently detailed to permit direct comparison with archaeological field results from subsurface testing (e.g. as depths of topsoil; recorded depths to subsoil; evidence or not of saprolite or bedrock rockhead near surface. In areas where shallow archaeological excavation have been completed (often to 0.3-0.5 m metres to "clay") geotechnical data can provide broad cross-checks of the stratigraphy likely to lie below the depths investigated. However, as spatial variation in near surface regolith depths is high, such cross-checking will only provide broad areal information.

However, the historic geotechnical data have neither sufficient spatial coverage, nor the consistency of investigative methods, to profitably drive a full geoarchaeological model applicable to the archaeological assessment stage, such as that conducted for the current investigation. In particular, field verification of historic data would be needed ahead of investigating deeper regolith for archaeological purposes.

In addition, the historic data do not provide sufficient coverage to drive deep archaeological investigations, especially in "high risk" landforms such as upper (1st order) tributary floors and slope margins.

A more efficient approach will be to marry the historic geotechnical data, with the array of new borehole and test pit data recently acquired for this EIS and for future post EIS investigations. The combined data will generate a geospatial "net" and mode:

a) with much improved coverage of the geometry of shallow regolith cover over bedrock (superficial deposits) and

b) a specific relationship to scheme "cut and fill" geometry.

The larger data set model can then be used to verify and cross-check outcomes from archaeological assessment testing conducted for the EIS assessment. In particular, areas of "uncertainty" can be refined where combined archaeological testing and geotechnical sources of data show either:

a) high archaeological potential at depth or

b) areas and zones of "high uncertainty and risk" predicted from geotechnical data - which justify deeper archaeological investigations at specific "known" points in the landscape.

Building and applying this geometry model using a geoarchaeological methodology could form one part of the archaeological salvage strategy to be conducted in the event of development approval. The methodology would require specific stipulations of geoarchaeological criteria used for interpreting geotechnical data. A common Digital Terrain Model (DTM) and geo-referencing system would be required to integrate data.

A6.2 Methodology of this study

The methodology of this review is based on the concept of a "regolith". Regolith is a term which describes all materials stored over bedrock on the earth`s surface (Eggleton 2004). Conceptually the approach has advantages as it does not require differentiation of soils from sediments. The concept is inclusive of all materials and as such includes archaeological artefacts, plants materials, biological organisms, soil properties, and fluids and gases. The regolith concept is especially useful when assessing profiles in boreholes where sediments, soils and various forms of weathered bedrock may all be present. For terminology and definitions used in this review please refer to the specialist glossary provided in Section A6.12.

A full analysis of the historic borehole data was outside of the scope of this review. Also, the spatial sampling patterns represented in the historic data are highly skewed to particular areas. The sets of raw data are currently "tuned" to landforms, (such as the landform model used for the NOHC archaeological test pitting program), making it difficult to provide a reliable "test" of improving subsurface archaeological understanding across the scheme. Considerable amounts of georectification, standardization and checking of the historic geotechnical data would be required to make the historic data reliable for predictive archaeological purposes.

Instead, this study sampled the data provided and sought to identify whether the types of data gathered in boreholes and test pits can, with further work and remapping, assist in identifying tasks for archaeological salvage post-EIS.

At this stage it is assumed "best practice" would be incorporated in the required archaeological management strategies which form part of any development approval.

The aim – with respect to subsurface uncertainty regarding Potential Archaeological Deposits – would be to refine surface investigations by splicing with geoarchaeologically interpreted geotechnical borehole/test pit information. Key tasks would be to:

a) initially integrate the full set of historical archived boreholes for the area to a common geospatial data set

b) incorporate the results of the NOHC surface archaeological assessment and mapped soil landscape layers into the common geospatial data set

c) subsequently incorporate newly acquired borehole and test pit data, as the data are generated.

A model would then be available in which archaeological salvage could be undertaken, tuned to both the airport impact (especially "cut" and "cover" geometry) and also to areas of uncertainty regarding subsurface archaeological significance.

A particular set of uncertainties apply to the extent of fills (colluvium and alluvium) situated within the contemporary valley tributary systems associated with slope base/valley floor landforms. Such regolith zones are likely to be small in area relative to overall scheme footprint. The likely landform locations are mostly not sampled by the historical borehole set. The majority of boreholes are located on plateau/interfluve sites. Upper tributary fills are a particular set of unknowns.

A second set of uncertainties exist with respect to depth of regolith associated with ancient palaeo-drainage lines across the area. Ancient rivers crossed this area and have left remnant deposits, typically lag gravels. The deposits will not map onto the present drainage network pattern. Deposits of this type can be provisionally identified in the historic data set. These deposits have potential significance in two ways a) as deposits influencing water flow and possible spring sources in the landscape and b) as possible sources /outcrops of lithic materials suitable for use in making stone artefacts. Mapping from boreholes may assist in identifying stone procurement sites.

The initial review suggests that borehole loggers are sufficiently familiar with both Bringelly Shale bedrock facies variations, and variability in Bringelly Shale saprolite and weathered subsoils, that most logs do pick up subsurface deposit anomalies that could signify archaeological potential. Logged observations of thin beds of near surface gravels and records of clast composition (e.g. quartz gravel lags) indicate valuable data exist in the historic data.

Identified benefits of modelling subsurface deposits according to geoarchaeological criteria all involve reducing uncertainty with respect to the possibility of archaeological deposits being present at depth across the scheme area. Using existing geotechnical data sources is cost-effective.

For modelling (as part of the salvage and management actions required in the event of development approval) key aims would be to:

- Determining areas where the regolith sequence is so shallow over bedrock that no further archaeological concerns exist regarding stratigraphy (for regolith depths below the depths already tested by subsurface archaeological test pitting)

- Identifying areas of landform/regolith conjunction where palaeosols and/or deeper stratified deposits of archaeological potential may exist at depth

- Mapping the relationship of regolith over bedrock in relation to terrain surfaces such that possible palaeovalleys and areas of natural sediment storage which could contain Potential Archaeological Deposits at depth are identified.

Key objectives of this review were to assess the qualitative value of extant geotechnical records and in particular assess:

- The potential of available geotechnical data to assist with archaeological evaluation of the terrain, soils and sediments forming regolith across the airport site?

- To specifically address whether geotechnical data may assist in establishing whether palaeosols or buried soils may exist within the airport site?

- Examine whether geotechnical data may assist in establishing the potential for archaeological assemblages to occur at depth, associated with palaeosols or potentially stratified beneath deposits of alluvium or colluvium?

A6.3 Data sources reviewed

The sources reviewed are a series of reports and geotechnical studies completed mainly in the 1990s. All data sources provided were briefly examined.

The following sets were then examined in more detail however the following actions fell outside of the scope of this review:

- assessment of the adequacy or the spatial coverage in relation to the proposed airport footprint.

- assessment of “representivity” of historical geotechnical data locations according to landform segment or type; soil landscape units or AHD elevation.

Table A6.1 Data sources examined in this study

Study	Date	Authorship	Data	Method
Geotechnical Investigation – Appendix C	1994	SMEC	56 test Pits	Mechanical Excavator
Badgerys Creek Airport Geotechnical Studies Inception Report – Report No S9222/1-AE and Appendix A	May 1990	Gutteridge Haskins & Davey Pty Ltd	2 BH and 1 TP	Truck rig and excavator
Badgerys Creek Airport – Soil and Rock Test Results – report No S9222/1-AS	Oct 1990	Gutteridge Haskins & Davey Pty Ltd	Lab results	N/A
Badgerys Creek Airport – Geotechnical Investigation Draft Borehole Logs D36 to D55 report No S9222/1-AU	Oct 1990	Gutteridge Haskins & Davey Pty Ltd		Fully cored BHs D36, D37, D38 and D39 (4) and Pengo Drill (D40-D55)
Attachment A - Borehole Logs from 1999 EIS - Vol 4 – Appendices to supplement (A to E5)	Nov 1998	PPK Environment and Infrastructure		Pioneer P160 Rig

A6.4 Geology across the airport site

The area of investigation is underlain by the Bringelly Shales of the Wianamatta Group.

Structurally the geology of the area sits within part of the Sydney Basin. Rocks at outcrop represent the upper parts of very thick sequences of fine grain lithologies originally laid down in a foreland basin through late Permian and Triassic time (Herbert 1997). The Cumberland Plain represents a subset of the inner Sydney Basin. The Wianamatta Group lithologies represent the uppermost Triassic lithofacies which were laid down during marine regression as prograding epimarine, intertidal, back-swamp and alluvial sediments (Jones and Clarke 1991; Smith 1979).

The Wianamatta Group consists, in order of deposition up-sequence:

- The Ashfield Shales Formation grading from sideritic shales to fine sandstones and siltstones laminates (Smith 1979) laid down in shallow marine and lacustrine conditions. Outcrop is very limited on the Cumberland Plain.
- The Minchinbury Sandstone Formation - a quartz lithic sandstone normally up to 6 metres thick. The lithofacies exhibit low angle cross-bedding indicative of a prograding bar barrier or beach system
- The Bringelly Shales - predominantly consisting of claystone and siltstones with thin laminate layers and locally discontinuous, thin and often sinuous sandier units (former channel lithofacies).

The implications for both surface drainage, topography and the nature of near surface regolith is that subtle variations from siltstone to sandstones (and occasionally laminates) exist in the nearsurface outcrop Bringelly Shale outcrops across the airport site. This makes detailed correlation, both in unweathered rockhead and saprolite, difficult between adjacent boreholes/test pits. There is considerable subtle heterogeneity in bedding and fine-grain rock composition in the Bringelly Shales. This reflects the channel, channel-marginal and back-barrier lagoonal facies environments in which Triassic sedimentation originally occurred.

The consequence is that bedrock outcrop, saprolite and saprock, and derived regolith across the airport site will be inherently (and subtly) variable. Subtle textural variability in sediments, weathered clasts and lags will be expected in boreholes, test pits and the base of archaeological excavations.

This will reflect:

- underlying bedrock (facies) variability in the Bringelly Shales;
- differential Tertiary laterization and survival of laterized weathering lags and products of the underlying bedrock;
- variations due to lateral mass movement (including sorting) of regolith across and downslope;
- ancient (pre-Quaternary) and recent Quaternary lag formation; and
- late Quaternary and Holocene reworkings of those lags in relation to modern slope topography, stream tributary systems, catenary soil profile development and pedogenesis.

A6.5 Post-Triassic and Quaternary geology and deposits

The Triassic Wianamatta Group sediments, laid down across broad low angle plains, represent the last major phases of sedimentation across the Cumberland Plain. Alluvial channel and gravel aggradational deposits were unconformably laid across the Plain from the ancestral Hawkesbury-Nepean river systems during the Cretaceous and Paleogene/Neogene, leading to unconformable deposition of SW-NE aligned paleochannel and gravel floodplain/terrace units mapped as the Rickabys Creek Gravel (Bishop and Hunter 1990; Jensen 1911; Smith 1979).

These deposits pre-date the Cenozoic uplift of the Blue Mountains and rapid valley incisions of that structural block and the downcutting of the Hawkesbury River into its contemporary west-east alignment at the Hornsby Warp (Bishop et al. 1982; Carter 2011; Fergusson et al 2010); Graham et al 2010).

The Rickabys Creek Gravels formed within high energy braided stream networks with clasts up to 0.5 m in size, and a wide range of clast lithologies reflecting sources in the Lachlan Fold Belt (Bishop and Hunter 1990; Hall 1926; Herbert 1997; Hickin 1970).

The units are locally overlain by the finer grain Londonderry Clay (within a Palaeogene age basin developed on the erosional surface of Triassic rocks). Deposition of the Londonderry Clay was low energy and either in a lacustrine environment (Hall 1926) or (more probably) as a fluvial fining upwards floodplain aggradational stack relating to episodic blocking/damming at the downstream knick point of the developing Hawkesbury-Nepean system relating to incision timings at the Hornsby Warp (Carter 2011).

Recent reviews of the diverse evidence for timings of uplift and tectonics (Bishop and Hunter 1990; Bishop et al 1982; Graham et al 2010) suggest uplift of the Hornsby Plateau at around 45-55 Ma (million years) and the Hawkesbury River maintaining its course through the Hornsby Warp at that time. Initiation of faulting/movements at the Lapstone Structural Complex, around 45 Ma led to depression and flooding around the Richmond area and consequent deposition of the Londonderry Clay. Erosion and gorge formation through the Hornsby Gap re-initiated effective fluvial drainage across the northern Cumberland Plain south of the Hornsby Plateau.

Ages of the Hornsby Warp activity are constrained by K-Ar (Potassium – Argon) dating of the Maroota Basalt capping the uplifted Maroota Sand which indicates eruption/basalt flow deposition prior to uplift dating to c. 45Ma (Graham et al 2010). Eruptive events in the Blue Mountains where basalt flow architectures sit within pre-existing deeply incised palaeovalleys (Van der Beek et al. 2001) indicate substantial palaeovalley incision/uplift prior to eruptions around 20.1-14.5 Ma.

Development of Quaternary terraces marginal to the present inset stream course of the Hawkesbury-Nepean indicates the main drainage alignments were well developed by the early Quaternary (Nanson et al 2003). Moreover, the surviving Paleogene/Neogene river terrace was the primary locus for deposition of the Rickabys Creek Gravel, while Londonderry Clay also overlies Bringelly Shale in the south. Both units outcrop on the uplifted Lapstone Monocline (Carter 2011).

The overall implication of these histories is that drainage across the airport site has developed over a long (>40 Ma) timescale, with the watersheds and plateau areas being progressively decoupled from the ancestral and Quaternary courses of the Hawkesbury-Nepean as it incised to the west.

Present tributaries across the airport site reflect multiple periods of drainage diversion, river capture and shifts in catchment boundaries. Deposits relating to the ancestral abandoned courses of palaeo-rivers probably preserve in patches and reworked lags across the airport site.

A6.6 Landform and regolith relationship across the airport site

This brief review of literature confirms that the airport site is located in an area of the Cumberland Plain which is primarily associated and underlain by Bringelly Shale bedrock and associated regoliths. Regolith sequences across the area are primarily weathered residual products and soils developed on Bringelly Shales, which exhibit variable sandstone, laminate and shale/mudstone facies.

The airport site locates well south of the area on the Cumberland Plain where old river aggradational lithofacies dating to paleoeoflow regimes of the proto-Hawkesbury, align SW-NE, preserved on interfluves and as residual geology overlying Wianamatta Group rocks. These units include the Londonderry Clay, and the Rickabys Creek Gravels. Both these units show laterization at outcrop.

While these deposits appear to be largely unmapped or absent from the airport site, the airport site locates in the upstream catchment area of the SW-NE streams which produced the Rickabys Creek Gravels. Remnants of those older palaeovalleys and deposits may therefore exist across the airport site, or may be cryptically present as residual lags of the original deposits in younger regoliths.

A6.7 Geoarchaeological review of historic borehole and test pit data sources

All of the historic data made available from GHD were briefly reviewed as part of a desk top study, and then more detailed analysis of individual boreholes was undertaken as a sampling exercise.

The principle aims were:

- To gauge the utility of this data as an interpretive data set against which preliminary stratigraphic observations from archaeological field assessment/testing can be compared or contextualised
- To assess whether borehole and test pit data may inform the broader question of the depths and nature of the regolith sequence (near surface) which is likely to preserve archaeological materials
- To seek trends in near surface deposit - landform relationships across the study site. Such trends, if found, may inform where potential archaeological deposits are more likely (or not) to occur/survive across the landscape[1].

[1] For example, identification of stable lag deposits and overlying texture-contrast soils across parts of interfluve areas might indicate longer term residence times for near surface deposits. This in turn might indicate higher probability of a) long-term survival of archaeological evidence on that landform-regolith unit and b) more likely concatenation of numerous discreet archaeological discard events into an archaeological palimpsest across that landscape unit.

- To define depth envelopes to bedrock/saprolite – this provides:

  a) a measure of "maximum potential storage" of Quaternary sediments which might contain archaeology, and

  b) indications of areas of regolith accumulation/stripping and storage

- To address whether the presence /absence of archaeologically indicative stratigraphy can be seen in borehole/test pits
- Specifically address if the presence /absence of buried soils/palaeosols across the landscape can be seen in the borehole/test pit data.

A6.8 Interpretation of borehole data

The quality of the borehole data examined was high. Descriptive terminologies are comparable across different data sets. The nature of the drilling method determines presence/absence of measured data (e.g. Standard Penetrometer Test (SPT) results). Where available such data were examined to assess and confirm written visual descriptions of rockhead/saprolite depths.

For this exercise observed trends and attributes which assist in determining presence/absence of palaeosols might occur include:

- Depths of topsoils as logged. These observations in geotechnical boreholes and test pits provide sources directly comparable with stratigraphy (and deposit depths) investigated by archaeologists in subsurface testing.
- Depth to weakly weathered/unweathered rockhead (it was assumed any archaeological significant horizons will be stratified above rockhead[2])
- The reference to laminations in unweathered grey to dark grey shales (taken to indicate *in situ* Bringelly Shales Bedrock and/or rockhead).
- Reference to cutans/cutan coatings in clayey soils and on clasts (taken as inferring horizon is part of a soil, or subsoil profile, palaeosol or intrusive in uppermost saprolite level).
- Plasticity (medium to high) – taken to *more probably* indicate a soil, subsoil or saprolite level
- Evidence of well-defined stratification with sharp contacts /interfaces and up- or down profile textural changes or sorting in unconsolidated deposits (possibly indicating alluvium and colluvium in which soils/palaeosols might occur)
- Evidence of clastic gravels in the described sequence (unlikely in the *in situ* Bringelly Shales)

In the analysis no assumptions were made regarding the maximum depths at which soils and palaeosols can occur.

Generally it was thought that cryptic "soil" properties at depths >5 m *were less likely to be archaeologically significant* where located on higher plateau areas, interfluves and slopes. In tributaries and larger valley floors no assumptions are made regarding maximum depths for palaeosols/archaeological significance.

[2] This does not equate to lithified units in a simple way. In this review if the terms "indurated" or weakly cemented were present, or co-associate with references to ferricrete or silcrete, those stratigraphies were deemed to be potentially of interest. Properties of induration can indicate "palaeosols" and can be of diverse ages in the Australian landscape. Weak lithification (induration) can be acquired quickly in some soils, so the term induration does not preclude a recent eg Holocene age or archaeological significance.

A6.9 Review of data – specific "archaeologically significant" examples

A number of boreholes were identified which show quite specific records and descriptions which might drive further subsurface investigations aimed at improving the archaeological understanding of the scheme impact subsurface.

The data below are examples which show the value of the approach. No complete review of all data was possible in the time available. These logs show a sub-sample of what may exist in larger data sets.

Attachment A - Borehole Logs from 1999 EIS - Vol 4 – Appendices to supplement (A to E5)

These logs describe deep (e.g. 25 m) and shallow (e.g. 5 m) drill results. The small sample (16 BHs some shallow + deep duplicates at single locations) covers a representative range of elevations across the airport site. All logs clearly identify transitions into relatively unweathered grey shales (or siltstones), reporting laminate structures and limonite staining in upper bedrock. Transitions to rockhead are typically identified between 3.0 - 5.5 m below surface and occasionally as deep as 7.0 m (BH "F"). There is a tendency for the transition into bedrock at shallow depth (eg 3.0 metres below surface) to be sharp. Shallow depths to bedrock can occur at both high elevations (105 m AHD in BH "D") and lower elevations (e.g. 66.5 m AHD in BH).

Most logs describe thin topsoils (<0.3 m) which are locally silty or sandy and generally red-brown. These grade into generally silty or sandy silty clays which vary from yellow-brown, pale grey, red-brown and show limonite and haematite staining at many locations. These subsoils are variably 3.0 to >7.0 metres in depth and grade into weathered shales at depth. The logs frequently record gradational trends from weathered red-brown and yellow-brown low plasticity clays into moderately weathered dark grey shale bedrock. This indicates saprolite over bedrock has variable thickness, is discontinuous, and locally has been reworked in the geological past to yield gravelly lags.

No boreholes in this set show deep topsoils. Most topsoils are reported to be about 0.2-0.3 m deep.

Two boreholes (Table 2) indicate sources of gravels at depth which may represent residual deposits from older land surfaces or landforms. The presence of ferricrete and silcrete in these gravels indicate a possible near-surface weathering origin. These deposits might be either *in situ* (a residual ancient palaeosol capping) or a reworked or re-transported residual gravel.

Table 2 Borehole evidence for sources of gravels at depth which may represent residual deposits from older land surfaces or landforms

BH ID	Easting	Northing	AHD BH surface (m)	Depth below surface	Deposit attributes	Potential Archaeological Significance
BH "C"	270473	1248025	66.59	Band at 3.5 - 4.0 m depth	Ferricrete - "dark brown iron indurated siltstone; some silcrete with conchoidal fracture". Deposit is overlain by silty clay subsoils and underlain by extremely weathered shale /saprolite. Rockhead at 5.0m. Could be *in situ* ancient palaeosol "capping" or reworked gravel lag from older land surfaces.	Indicates natural occurrence of rock materials suitable for making artefacts within airport site. Assist in interpreting artefact occurrence as local versus distant potential sources. Indicates silcrete/ferricrete sources may outcrop now/ have outcropped in the past within airport site.

BH ID	Easting	Northing	AHD BH surface (m)	Depth below surface	Deposit attributes	Potential Archaeological Significance
BH "E"	272676	1245812	78.25	Ferricrete band 1.1 to 1.3 depth. Clayey sand (1.3 -2.8m) within which moderately indurated silcrete horizon at 2.3m depth	Ferricrete "dark brown indurated siltstone" overlying clayey sand – brown to yellow brown fine grain well sorted. At 2.3m moderately indurated silcrete horizon. Water at 2.6m.	Indicates natural occurrence of rock materials suitable for making artefacts within airport site. Assist in interpreting artefact occurrence as local versus distant potential sources. Indicates silcrete/ferricrete sources may outcrop now/ have outcropped in the past within airport site

Three boreholes record shallow thin units of gravel that are either quartz or quartzose in composition. These deposits are most unlikely to be derived from weathering of the Bringelly Shales. This evidence points again to the occurrence of lag gravels derived from ancient paleolandsurfaces across the airport site. These may be remnants of ancient river gravels from the "palaeo-Hawkesbury" and most probably up-catchment remnants of the same alluvial valley fills and ancestral rivers which deposited the Rickabys Creek Gravels to the north and east.

Table A6.3 Borehole record of shallow thin units of gravel which may be lag gravels derived from ancient paleolandsurfaces across the airport site.

BH ID	Easting	Northing	AHD BH surface (m)	Depth below surface	Deposit attributes	Potential Archaeological Significance
BH "G"	275626	1247625	58.79	4.0-5.0 m	Gravelly clay – "yellow-brown surrounded to sub-angular red-brown quartz gravel	Potential source of quartz in landscape – possible procurement source for artefact manufacture. Possible river gravel lag and/or alluvial or colluvial deposit. Weathered alluvial or colluvial gravel? Gravel lag in valley floor?
BH "I"	275067	1246075	72.35	2.0-2.5m	Gravelly clay – "red-brown sticky with red-brown quartzose sub-angular gravel" (overlain by red clay subsoil and underlain by yellow clay)	Potential source of quartz in landscape – possible suitable for artefact manufacture. Possible river gravel lag and/or alluvial or colluvial deposit. Note: "angular quartz" makes *in situ* alluvial origin less likely. Colluvial reworked ancient gravels?

BH ID	Easting	Northing	AHD BH surface (m)	Depth below surface	Deposit attributes	Potential Archaeological Significance
BH "J"	274824	1243803	70.90	2.0-3.5m	Orange brown sub-angular quartz + iron oxide stained ferricrete fragments and minor organic fragments	Potential source of quartz in landscape – possible suitable for artefact manufacture. Possible river gravel lag and/or alluvial or colluvial deposit. Note: "angular quartz" unlikely far-travelled fluvial gravels. Significance of "minor organics" not known.

A6.10 Discussion

The sampled sets of data are sufficiently standardised to be suitable for building a general geoarchaeologically predictive model of subsurface deposits over bedrock across the impact areas of the scheme.

This is expected. Geotechnical data has to be evaluated against strictly defined and professionally agreed standards for design purposes. We can now address the questions posed earlier.

Might borehole and test pit (geotechnical) data assist in reducing uncertainties regarding the depth and spatial extent of archaeological deposits across the scheme area?

Simple parameters such as depth to unweathered rockhead can be readily and reliably mapped from the historic data. New data would be as high quality or better. Mapping simple parameters like "depth to rockhead" quickly identifies areas where shallow archaeological testing has approached the maximum depth necessary, and conversely, areas where deeper unknown superficials occur and "uncertainty" might exist. Almost all logs viewed record data in sufficient detail to map depths to bedrock and/or or saprolite to +/- 0.5 m and many to a precision of +/-0.2 m depth.

All data viewed would be adequate to this type of mapping, and most data viewed would provide a higher level of detail which would resolve saprolite and /or saprock depths overlying unweathered bedrock, and thus allow a refined general model of "maximum depth of archaeological potential" - which would equate to the depth of deposit over saprolite.

Stratification within upper unconsolidated deposits could be seen in some boreholes suggesting the possibility of colluvial and/or alluvial sequences stratified above the saprolite. Logs have "potential" but do not provide sufficient information to model a chronosequence. Examination of stored core or resampling would normally be needed to move to establishing "possible age significance" from an archaeological perspective.

The historic data thus provide pointers to where in the landscape further investigations might be required. They will not normally be sufficient to determine the equivalent of subsurface "potential archaeological deposit" in a precise chronological sense.

Most data show quite shallow depths to bedrock. As the majority of data points are on interfluves/plateau areas this does not help resolve whether, for example, small narrow areas of significant archaeological deposit might exist at the edge of small tributary valley floors, or under small colluvial fans.

The general limitation of the data viewed is therefore adequacy of spatial coverage across all landforms, and sub-landform (landform elements).

With incorporation of all geotechnical data (historic and new data being acquired), improvement would be expected. However, as potential archaeological deposits are inherently "patchy"– some purposive drilling or machine test pitting will always be required to check micro-landforms, and areas of high potential (eg at the base of slopes to examine fans; within areas of linear alluvial fill (especially "chains of ponds type fills) in upper tributary valleys.

Is there evidence in the historic geotechnical data pointing to locations, areas or stratigraphic sequences which might be archaeologically significant?

A small number of individual locations were seen where stratified unconsolidated deposits, some showing grading, or fining upwards trends could be inferred from the logs. Most sequences of this type relate to observations of "gravel" some of which is quite specifically described as "silcrete" or quartzose or quartz. In all cases the deposits are clearly superficial and not directly associated with the underlying Bringelly Shales.

Such deposits are clearly described as stratifying above saprolite and are often within 2-3 m of the present land surface.

The records thus pinpoint locations where useful additional supplementary archaeological investigations might take place.

They do not map units or areas. More data points and much more detailed analysis of elevation/topography/deposit relationships would be needed to assign "archaeological significance" unequivocally.

Can palaeosols, stratified deposits or chronostratigraphic potential be seen in the data?

As indicated above the broad answer is affirmative. But while there is clear evidence of weathering, possible stratification and locations worth testing, evidence of age is weak. Such units need not relate to the period of human occupation of Australia – broadly the last 50,000 +/-5000 years BP.

Gravels, where logged near surface have potential, but could be millions of years old and represent minor unmapped upstream remnants (or age-equivalents) of the "Rickabys Creek Gravels".

No palaeosols were seen in logged data which suggest unequivocally recent (late Pleistocene or Holocene) ages. No records were observed which document wood, or peat, tufa or other types of clearly recent sediments with unequivocal dating potential, despite waterlogging and high tables within 5 m of surface in many logs.

Can geotechnical data guide and prioritise areas for further phases of archaeological mitigation, especially as conditions of the EIS?

Here the answer is unequivocally affirmative. If all the historic geotechnical data were geo-rectified to modern DTM and then interpreted to well-defined criteria a model would quickly emerge which could relate subsurface depths of potential deposits to landforms at surface.

Some specific localities would emerge which might warrant specific investigations – especially those described as being silcrete gravels.

More importantly, zones of uncertainty would also be mappable – where depths to Bringelly Shale are unusually deep (possibly indicating palaeochannels) or where stratified unconsolidated deposits clearly overlie saprolite.

If there is potential – what methodologies and strategies can best utilise both historic geotechnical data, and new geotechnical data now being acquired across the development footprint?

There is potential. The data examined indicate what can be achieved, but did not indicate that the NOHC test pit investigations would have been substantially improved had their distribution been

guided by meshing with subsurface data from historic sources. This is because of significant skew in patterns chosen for borehole transects, preference for interfluve/plateau locations for geotechnical testing in the past (and present) investigations.

The optimum approaches would now be stepwise and involve:

- Georectifying data on position of historic boreholes/test pits to overlay mapping layers which include scheme design “cut and fill”; the results of the current program of NOHC archaeological surface testing; high quality DTM and in particular predicted areas of sediment storage (e.g. in upper tributaries and valley slope lower margins).

- Setting clear criteria for interpreting borehole/test pit data and also for creating ranked categories of potential archaeological significance subsurface.

- Mapping out subsurface predicted geoarchaeological “potential” and then identifying locations being sampled as part of ongoing geotechnical sampling where observations/core will permit testing archaeological potential without additional investigations.

- Identifying areas where archaeological salvage is anticipated from NOHC’s recent assessment which overlap with possible areas for possible deeper investigation as predicted from boreholes/test pit geotechnical data.

- Setting out protocols and methods to be incorporated into development approval conditions sufficient to drive the above tasks.

A6.11 References

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Appendix 7

Summary of previous heritage investigations, and Outline of changes in archaeological approach since 1997

A7.1 Outline of changes in archaeological approach since the 1997 EIS

A7.1.1 A paradigm shift from surface to subsurface archaeological evidence

Following an increase in the systematic conduct of archaeological test excavation as part of environmental impact assessments across the Cumberland Plain, advances in our knowledge of the archaeological resource have presented a number of challenges to analysts. It is now established that Aboriginal stone artefacts within subsurface contexts are distributed across the full spectrum of landscape variation. The areal incidence of this distribution is discontinuous and uneven, but broad and relative categories of artefact incidence can be reliably predicted according to landform types and variables. These categories are related to the past accessibility of resources, notably permanent fresh water, food and exploitable sources of stone (refer to Chapter 5). Localised and small-scale areas of higher artefact incidence may relate to single large occupation events, or to multiple smaller events.

Based on this understanding of the archaeological resource, the identification and information value of individual site classifications has been reviewed. Most site recordings from the Cumberland Plain are a consequence of a recorder's recognition of stone artefacts visible on the ground surface. With few exceptions, the exposure of surface artefacts is dependent on low vegetation cover, and the erosion of the soil profile, either from natural processes or human land-use impacts. Once it is acknowledged that the subsurface incidence of stone artefacts occurs throughout the landscape, it becomes clear that the location and boundaries of recorded surface sites relate more directly to patterns of erosion and land-use, factors which determine ground surface exposures, than to patterns in Aboriginal occupation.

The past methodological reliance on surface archaeological survey, and as a consequence, exposure dependent site recordings, has encouraged the establishment of an archaeological assessment paradigm which is both site focused and site dependent. Assessments were generated for finite units of archaeological material, bounded either by surface incidence, or a bounded area of assessed archaeological potential. A dependence on bounded discrete entities now runs contrary to the evidence from test excavation programs which reveal subsurface artefact occurrences to be widespread, with diffuse boundaries, and to be largely unrelated to surface distributions or exposure boundaries. Current predictive modelling now allows the extrapolation of subsurface artefact incidence data to untested landforms of the same type. The nature of the predicted archaeological resource can now be mapped in terms of broad area landforms and topographic variables. This has introduced a new paradigm in which the measures generated by the site-based paradigm, such as site frequency, density (areal incidence), and even the identification of discrete potential archaeological deposits, have reduced relevance.

The 1997 EIS assessment determined that the average surface site density for the surveyed portion of the Badgerys Creek study area was 7.7 sites per square kilometre. It then extrapolated these results to predict that if a 100 per cent survey had been conducted, 260 surface sites would have been recorded, in the whole area, and 131 within Option A (which is roughly equivalent to the airport site in the current assessment) (NOHC 1997:5-8 - 5-10). This measure provided a useful relative comparison at the time, but is of limited value to any future resource management because it replicated biases inherent in exposure distribution. Although this calculation remained within the parameters of surface evidence, it illustrates the limitation of the site-based paradigm, and how predictive landform mapping based on excavation results, can more effectively characterise the resource and provide an effective framework for management.

A7.1.2 Terminology used for the predicted archaeological resource

The definition of a site as a location with the confirmed presence of evidence of past Aboriginal occupation remains a useful recording and management tool. However, it is now understood to have limited value as an indicator of spatial patterning or actual rates of artefact discard during past Aboriginal occupation. It is now useful to further qualify recordings of artefact occurrences to identify if the record is based on surface or subsurface evidence. The latter provide an indicator that this information is free from biases caused by erosion and ground surface disturbance.

A wider range of terminology is now used for the identification of the predicted archaeological resource. The category of 'potential archaeological deposit' (pad) is a well-established cornerstone of the site-based paradigm. This category is typically applied to a relatively small and discrete location, defined spatially either by geomorphological, disturbance, or administrative criteria. Within such an area, there is a predicted likelihood that subsurface archaeological material is present, and that this material would warrant archaeological investigation in order to determine its scientific, cultural, or statutory value and status. The latter qualification is a recent methodological refinement intended to avoid the inclusion of predicted low or very low subsurface artefact incidences which, based on more recent modelling, can now be predicted across a majority of assessed landscapes.

Although the pad category is an effective tool when applied at a local level and on a small scale, it has become impractical and inaccurate when applied to larger scales of predicted potential. For example, within small or linear study areas, it remains feasible to systematically identify the resource at a fine scale and at specific locales. However, large and broad area assessments often necessitate a coarser level of resource identification, such as at the level of a landform type or combination of topographic variables. To define such areas as a potential archaeological deposit would be inaccurate. This is because of the expected discontinuous distribution of archaeological material across the defined zone and the very low incidence within some included small-scale landforms. In such cases the concept of 'archaeological sensitivity' is now considered to be more effective. This terminology can be used to indicate an area within which sites and/or pad's are known or predicted to occur at a scale or frequency which necessitates careful management action in the future. This is the basis for the use of the term 'archaeologically sensitive landform' (asl) in this assessment.

Both the categories: archaeological deposit, and archaeologically sensitive landform, can be used on their own where there is evidence of archaeological material, or with the prefix 'potential', where there is a lesser degree of certainty or supporting evidence. The strength and nature of the evidence differs across the respective categories. The basis for identifying an archaeologically sensitive landform is likely to be the interpretation of the results of an applicable program of test excavation, which may or may not have been conducted within a subject study area. Where there are no locally applicable results or model available, identifications must be limited to 'potential' classifications (an example is the use of 'potentially archaeological sensitive areas' (pasa's) in NOHC 2012). For a specific deposit, direct evidence of archaeological material would be needed to remove a 'potential' prefix, such as from a visible soil profile section or test pit.

The basis for the identification of archaeologically sensitive landforms in this assessment is the conduct and results of the test excavation program. Only locales with direct evidence of archaeological material are classified as sites.

A7.1.3 Implications for the assessment of significance

Older approaches to the significance assessment of Aboriginal archaeological sites have typically employed the category of 'site' as a primary unit of analysis, with the assessment of collective values enabled by the grouping of sites into complexes according to spatial, functional and chronological criteria. The expanding knowledge of the interrelation between surface and subsurface evidence has provided a basis for revising the methodology for the assessment of that portion of archaeological resource resident within open context deposits. It is acknowledged that site recordings based on surface-only evidence are unlikely to provide a reliable basis for an assessment of the subsurface resource from which the site is derived. In almost all cases the surface record comprises a residue, the result of erosional processes and land-use impact. An unknown proportion of material is missing, as is contextual information. As such, surface archaeological material is now typically considered to have substantially less significance than any associated subsurface deposit. Some assessments address this issue by including a predictive evaluation of any identified and locally associated subsurface potential.

The paradigm shift in the analysis of artefact occurrences from surface to subsurface evidence has introduced a parallel shift from sites to landscapes. The generation and application of test excavation data is made possible by the building and refinement of models. These models use the close interrelation of past Aboriginal occupation and resource exploitation with landform variables to create a framework for ordering the archaeological resource and its landscape context. It follows then that this framework, when substantiated by locally applicable and excavation derived datasets, can

provide a basis for making significance assessments and an effective alternative or complement to the site-based approach. The advantages of this approach are that assessments can be directed at the full predicted scope of the archaeological resource, and include consideration of evidentiary interrelations across landforms and landscapes. This approach avoids surface –based biases introduced by the incidence, frequency and nature of ground surface exposures.

The assessment conducted for this investigation of the significance of the subsurface archaeological resource within the airport site has adopted a landscape approach based on the predictive value of the test excavation program. This is has been combined with a reassessment of the results of the 1997-1999 EIS assessment which employed a site based approach.

A7.2 Summary of previous heritage investigations conducted within the local district of the airport site

Report Author/ Date	Location	Investigation type	Results	Approximate distance from airport site
Haglund (1979)	Kemps Creek	Archaeological survey for proposed substation	No Aboriginal sites identified.	4.26 km east
Koettig (1981)	South St Marys Second Stage Release Area, Erskine Park	Archaeological survey of proposed land release area	No Aboriginal sites identified.	8.0 km northeast
McIntyre (1984)	Portion 7785, Erskine Park	Archaeological survey for proposed quarry extension	1 artefact scatter identified in a disturbed context adjacent to a road, comprising five pieces of flaked silcrete, one chert flake and one piece of broken quartz.	6.2 km northeast
Dallas (1988a)	Luddenham Equestrian Centre, Luddenham Road, Erskine Park	Archaeological survey for proposed recreational and residential development	12 artefact scatters identified; 8 along the bank and flats of Cosgroves Creek, 3 on a ridge near the confluences of Kemps Creek and Badgerys Creek with South Creek, and 1 in disturbed deposits on South Creek. The presence of subsurface fine grained silcrete cobbles and nodules on the ridge was noted. Artefacts were predominantly manufactured from silcrete; other stone types included chert and quartz.	2.18 km north
Dallas (1988b)	Corner Samuel Marsden and Landsdowne Roads, Orchard Hills	Archaeological site inspection for Kindalin School annexe	No Aboriginal sites identified.	8.81 km north
Brayshaw (1989)	Orchard Hills	Archaeological survey for proposed urban subdivision	No Aboriginal sites identified.	7.94 km north
Dallas (1989a)	Lots 1 and 2 DPS217319 & 547057, Luddenham Road, Orchard Hills	Archaeological survey for proposed canine showground	No Aboriginal sites identified.	6.46 km north
Nicholson (1989)	Lot 2, Elizabeth Drive, Kemps Creek	Archaeological survey for proposed quarry	No Aboriginal sites identified.	0.59km north
Dean-Jones (1991)	Lot 3 DP623799, Adams Road, Luddenham	Archaeological survey for proposed clay/shale extraction	1 artefact scatter was identified around the margin of a dam on the edge of the Oaky Creek floodplain, comprising 22 artefacts made of indurated fine sandstone, chert/tuff, and mudstone.	Adjacent to airport site (north west)

Report Author/ Date	Location	Investigation type	Results	Approximate distance from airport site
Kohen (1991)	Lot 2, Elizabeth Drive, Kemps Creek	Archaeological survey for proposed landfill development	1 artefact scatter identified adjacent to Badgerys Creek, comprising 22 artefacts manufactured from silcrete (18 artefacts), chert (2), and quartz (2).	0.59 km north
Brayshaw McDonald (1992)	Herbert Street, Kemps Creek to Bringelly sub-station	Archaeological survey of proposed 33kV transmission line	1 artefact scatter was identified on a low spur 80-150 m from South Creek, comprising 11 artefacts of indurated mudstone, silcrete and chert.	2.47 km southeast
Brayshaw McDonald Pty Ltd (1995)	Cowpasture Road, West Hoxton	Archaeological salvage excavation, residential subdivision	2 previously identified sites were excavated; one on a remnant alluvial terrace overlying Bringelly shale, approximately 40 m from an unnamed tributary of Cabramatta Creek, and the second on the heavily disturbed footslope of a spur with very little topsoil (WH4). 3,672 artefacts were recovered from the terrace, with 90% obtained from two silcrete knapping floors. Artefacts were predominantly manufactured from silcrete (96.6%), with smaller quantities of indurated mudstone/chert (2.1%), quartz (1.1%), and igneous stone (0.1%). No artefacts were recovered from the footslope.	8.61 km east
HLA-Envirosciences Pty Ltd (1995)	Farnsworth Avenue, Warragamba to The Northern Road, Luddenham	Archaeological survey for proposed haulage roads	Ten sites identified in Wallacia, including 7 PADs on Farnsworth Avenue near Megarritys Creek, 1 artefact scatter near the corner of Park Road and Montelimar Place, 1 isolated artefact (stone axe) to the south of Park Road.	1.0 km west

Report Author/ Date	Location	Investigation type	Results	Approximate distance from airport site
NOHC (1997)	Badgerys Creek, an enlarged airport study area of 34 km^2 , 17 of which occurred outside of Commonwealth owned land	EIS investigation of Second Sydney Airport proposal at Badgerys Creek or Holsworthy	Assessment based on surface archaeological survey and predictive assessment of the subsurface resource. The assessment documented 111 known surface archaeological sites, of these 58 were open artefact scatters, 8 scarred trees, 44 isolated finds, and nine sites were associated with potentially substantial archaeological deposits. Survey coverage of thirty-seven percent of the total study area was achieved. Potential archaeological deposits were identified within valley floor alluvium and basal slope landforms associated with higher order streamlines. The number of surface artefacts recorded per site ranged from one to 31. 46% of sites with more than one recorded artefact included between three and five artefacts. Twenty two percent contained only two artefacts. The maximum surface artefact incidence was one per square metre.	Included the airport site, and lands extending up to 4km to the southeast.
Steele (1999)	Luddenham & Mamre Roads, Luddenham	Archaeological survey for proposed rural residential subdivision and golf course	5 artefacts scatters, 1 isolated artefact and 1 potential scarred tree were identified. The locations of 5 previously identified sites were confirmed, 7 previously identified sites could not be relocated. Sites on the Cosgrove Creek flat were generally dispersed along the watercourse and had low artefact densities. This area was assessed as having moderate archaeological sensitivity. Sites near the confluences of Kemps Creek and Badgerys Creek with South Creek, in the vicinity of a low gradient spur, are situated closer together. A number of these sites produced large quantities of artefacts. This area was assessed as having high archaeological sensitivity.	2.18 km north
JMCHM (2000)	“Austral Site”, Mamre Road, Erskine Park	Archaeological survey for proposed light industrial subdivision	5 artefact scatters and 3 isolated artefacts were identified on areas with ground surface exposure on unsealed vehicle tracks, cattle tracks and areas of sheetwash erosion. 7 sites were identified on lower hillslopes, 2 on creek banks, and 1 on floodplain.	5.54 km northeast

Report Author/ Date	Location	Investigation type	Results	Approximate distance from airport site
JMCHM (2001a)	1503 Elizabeth Drive, Kemps Creek	Archaeological survey for proposed redevelopment of Nolans Quarry	1 PAD with 1 quartz flake identified on a ridgeline on Bringelly shale, near a headwater tributary of Kemps Creek. Due to poor ground visibility, it was recommended that archaeological test excavation be undertaken prior to development to determine if sub-surface artefacts are present.	2.5 km east
Steele (2001)	Luddenham & Mamre Roads, Luddenham	Archaeological test excavation, rural residential subdivision and golf course	3 geomorphological zones were investigated: the floodplain, slope and a ridgeline spur. A very low density of artefacts was found in alluvial deposits on the floodplain and aggrading lower slope. The highest density of artefacts, as well as naturally occurring silcrete gravels, was found on the ridgeline spur. The artefact assemblage was dominated by silcrete (93.7%), followed by quartz (4.4%) and tuff (1.8%), with a minor amount of other raw materials including volcanics, petrified wood and quartzite (0.1%).	2.18 km north
White (2001)	Lot 70 DP260492, McCann Road and Bringelly Road, Leppington	Archaeological survey for proposed subdivision	Six isolated stone artefacts and one area of PAD were identified on a ridge between South Creek and Kemps Creek.	6.09 km southeast
McIntyre-Tamwoy (2003)	Junction of Mamre Road and Erskine Park Road, Erskine Park	Archaeological survey for proposed road works	4 sites identified, including 1 artefact scatter and 3 isolated finds. The location of 2 previously identified sites were confirmed	5.54 km northeast
NOHC (2003)	Erskine Park to West Sydney sub-station	Archaeological survey of proposed 132kV transmission line	2 sites were identified on basal slopes adjacent to minor drainage lines; one scatter of 4 silcrete and 3 mudstone artefacts, and one scatter of 8 silcrete artefacts. 1 PAD was identified on alluvial soils on a terrace near the junction of Ropes Creek with an unnamed tributary.	7.58 km northeast
Archaeological & Heritage Management Solutions (AHMS) (2005a)	85 Bakers Lane, Kemps Creek	Archaeological survey of proposed development area in Emmaus Village	4 sites identified, including 1 artefact scatter and 2 isolated artefacts on low-lying flats/footslopes, and 1 artefact scatter on a drainage line. All sites were within the Blacktown soil landscape.	5.18 km northeast

Report Author/ Date	Location	Investigation type	Results	Approximate distance from airport site
AHMS (2005b)	85 Bakers Lane, Kemps Creek	Archaeological test excavation, proposed development area in Emmaus Village	11 artefacts and probable artefacts were recovered from 15 test trenches. The artefacts were manufactured from silcrete (7) and tuff (4). The density of artefacts present was considered to be low compared to other sites in the local area (Luddenham), partially attributed to disturbance from erosion and mixing of remnant soils arising from vegetation clearance, ploughing and grazing, and bioturbation.	5.18 km northeast
Brayshaw (2005)	Mamre Road/Erskine Park Road, Erskine Park	Archaeological survey for proposed intersection upgrade	1 artefact scatter, comprising one silcrete flake and one silcrete flaked fragment, was identified on a very gentle slope beside Mamre Road, approximately 60-140 m from an unnamed tributary of South Creek. Three other small fragments of unmodified silcrete were also noted in this area.	6.28 km northeast
Kayandel Archaeological Services (2005)	Lot 330 DP2475, 15th Avenue, West Hoxton	Archaeological survey for proposed residential subdivision	1 artefact scatter comprising 2 silcrete flakes, one probable milky quartz flake, and one milky quartz flaked piece/core fragment, was identified on a spurline.	8.82 km east
NOHC (2005a)	CSR lands, Lenore Lane, Erskine Park	Archaeological test excavation, proposed industrial development	49 artefacts were recovered from 20 of 38 test pits. The lithic assemblage was dominated by silcrete (55.1%, 27 artefacts) and rhyolitic tuff (24.5%, 12 artefacts), with minor quantities of chert, chalcedony, quartz and unidentified stone (20.3%, 10 artefacts). The greatest density of artefacts occurred on locally elevated and relatively level ground adjacent to an unnamed creek line. Lower densities of artefacts were recorded on low gradient slopes along a spurline.	6.2 km northeast
NOHC (2005b)	CSR lands, Lenore Lane, Erskine Park	Archaeological test excavation, proposed industrial development	285 artefacts were recovered from 88 of 256 test pits. Low densities of artefacts were found on all landform units tested, including a ridgeline, spurline, valley floor, and locally elevated and relatively level ground adjacent to a watercourse. The greatest quantity of artefacts was recovered from valley floor contexts, which were assessed as having moderate to high archaeological potential. All other landform units were assessed as having moderate archaeological potential.	6.2 km northeast

Report Author/ Date	Location	Investigation type	Results	Approximate distance from airport site
NOHC (2005c)	Crown road reserve near Mamre Road, Erskine Park	Archaeological test excavation, proposed access road	172 artefacts were recovered from 21 of 24 test pits on a low spurline, previously identified as an area of archaeological potential. The artefact density was considered to be low, with 29.48 artefacts per square metre. The assemblage was dominated by silcrete (72.67%, 96 lithic items) and tuff (17.44%, 30 items), with smaller quantities of milky quartz (2.33%, 4 items), quartzite (2.33%, 4 items), rhyolitic tuff (1.745%, 3 items), unidentified stone (1.745%, 3 items), chert (1.16%, 2 items), and chalcedony (0.58%, 1 item). Some lithic items were heat affected, mostly silcrete and tuff, although it could not be determined if the heat fracturing was from anthropogenic or natural causes.	6.14 km northeast
NOHC (2005d)	Ropes Creek to Erskine Park Road, Erskine Park	Archaeological survey for proposed gas main	1 previously identified site, an artefact scatter with shell (freshwater mussel), was relocated on the elevated eastern bank of Ropes Creek. More than 40 artefacts manufactured from silcrete, tuff/chert, and quartz were noted; however, no shell material was visible.	9.92 km northeast
Kayandel (2006)	Lot 1978 DP792932, 17th and 2nd Avenues, West Hoxton	Archaeological survey for proposed residential subdivision	No Aboriginal sites identified.	8.12 km east
NOHC (2006)	Lot 13 DP707337, between Camden Valley Way and Cowpasture Road, Leppington	Archaeological survey for proposed redevelopment of caravan park	1 stone artefact, a silcrete flaked piece, was identified on a low gradient slope.	9.76 km southeast
NOHC (2007)	Erskine Park Employment Area, Ropes Creek	Archaeological test excavation, proposed industrial development	261 artefacts were recovered from 112 test pits. The lithic assemblage was dominated by silcrete (70%), with smaller quantities of tuff (21.3%), quartz (3.9%), chert (2.6%), volcanics (1.6%), and quartzite (0.6%). The highest concentration of artefacts occurred on the basal slopes, midslopes and crest of a spurline.	6.86 km north

Report Author/ Date	Location	Investigation type	Results	Approximate distance from airport site
Steele (2007)	Twin Creeks Estate, Luddenham Road, Luddenham	Archaeological salvage excavation and monitoring, rural residential subdivision and golf course	120 flaked stone artefacts were recovered from 16 test trenches in shallow colluvial soils. The assemblage was dominated by silcrete (90%, 108 artefacts), with smaller quantities of silicified tuff (6.67%, 8 artefacts), petrified wood (1.67%, 2 artefacts), quartzite (0.83%, 1 artefact), and indurated mudstone (0.83%, 1 artefact). No artefacts showed evidence of h eat treatment. The artefact density was considered to be low, with approximately 7.5 artefacts per square metre. 90-95% of stone material recovered from the salvage excavation and surface collection was amorphous naturally fractured rock. Flakeable quality silcrete cobbles were noted to be present across the surface of the study area.	2.18 km north
Total Earth Care Pty Ltd (2007)	Lenore Lane, Erskine Park	Archaeological salvage excavation, Erskine Centre Industrial Park	1 previously identified artefact scatter of 15 flaked pieces and surrounding area was investigated. The largest number of artefacts were recovered from hilltop excavation areas (81.8% of total assemblage), and from a knoll below the hilltop (15.6%), with relatively few artefacts found mid-slope (2.7%). 1,014 artefacts were recovered, with the distribution of artefact concentrations suggesting the presence of knapping floors around the top of the hill as well as discrete knapping events. The assemblage was dominated by silcrete (87.6%, 888 artefacts), with smaller quantities of quartz (10.7%, 108 artefacts), indurated mudstone (1.0%, 10 artefacts), and silicified tuff (0.8%, 8 artefacts).	7.2 km northeast
Archaeological Surveys & Reports Pty Ltd (2009)	Lot 40, DP738126, Patons Lane, Orchard Hills	Archaeological survey for proposed waste and resource management facility	2 isolated artefacts identified, 1 mudstone/tuff broken flake and 1 quartzite backed blade, identified 100 m and 350 m from Blaxland Creek, respectively	6.26 km north

Report Author/ Date	Location	Investigation type	Results	Approximate distance from airport site
JMCHM (2009)	Mamre Road Biodiversity Lot, Erskine Park	Aboriginal Heritage Management Plan	9 sites previously identified; 5 artefact scatters and 2 isolated finds in the vicinity of minor, first order tributaries of South Creek, and 2 artefact scatters in the vicinity of a second order stream channel. All sites are within 300 m of the closest water source, with most sites between 50-200m. Sites were recorded on lower hillslope landform units (67% of total sites), the interface of lower hillslope and creek bank (22%), and floodplain-creek bank (11%).	5.81 km northeast
AMBS (2013)	Leppington Precinct, South West Growth Centre	Archaeological survey for precinct planning	16 sites identified including11 artefact sites on slopes, 1 artefact site on a slope/crest, and 2 PADs and 2 artefacts sites on creek flats associated with Kemps Creek and unnamed, minor tributaries.	7.36 km southeast
Artefact Heritage (2012)	The Northern Road between The Old Northern Road, Narellan to Mersey Road, Bringelly	Archaeological survey for proposed road upgrade	32 sites identified; including 29 artefact sites, 2 scarred trees and 1 PAD. Landform units on which sites occurred include flats (4 artefact sites and 2 scarred trees), lower hillslope (12 artefact sites), lower hillslope/terrace (1 artefact site), hillslope (4 artefact sites), creek flat/terrace (1 PAD), creek flat (1 artefact site), upper hillslope (4 artefact sites), and low ridgeline (2 artefact sites). In addition, 4 previously recorded sites had been destroyed; including 2 artefact sites and 2 PADs.	Adjacent to airport site (south)
Australian Museum Business Services (AMBS) (2012)	Austral & Leppington North Precincts, South West Growth Centre	Archaeological survey for precinct planning	7 sites identified; including 2 artefact sites on slopes, 4 artefact sites and 1 artefact site/PAD on creek flats associated with Kemps Creek, Bonds Creek, and unnamed, minor tributaries.	4.22 km east

Appendix 8

Protocols to follow in the event of unanticipated discovery of Aboriginal sites

Notes:

- The following protocols are applicable to actions conducted within the airport site prior to the adoption of a project specific conservation management plan (CMP).
- A CMP could be expected to revise some of the provisions of the unanticipated discovery protocol so that required actions are consistent with approved management strategies.

A8.1 Protocol to follow if Aboriginal object(s), other than human remains, are encountered

In the event that object(s) which are suspected of being Aboriginal in origin are encountered during works conducted within the airport site, then the following protocol will be followed:

1. Cease any further excavation or ground disturbance, in the area of the find(s);

    a. The discoverer of the find(s) will notify machinery operators in the immediate vicinity of the find(s) so that work can be temporarily halted; and

    b. The site supervisor and the Principal/Project manager will be informed of the find(s).

2. Do not remove any find(s) or unnecessarily disturb the area of the find(s);

3. Ensure that the area of the find(s) is adequately marked as a no-go area for machinery or further disturbance, and that the potential for accidental impact is avoided;

4. Note the location and nature of the finds, and report the find to:

    a. Relevant personnel responsible for the worksite and project;

    b. The Dept of Infrastructure and Regional Development (DIRD);

    c. The Department of the Environment (DoE);

    d. The NSW Office of Environment and Heritage (OEH); and

    e. The project archaeologist (if appointed).

5. Where feasible, ensure that any excavation remains open so that the finds can be recorded and verified. An excavation may be backfilled if this is necessary to comply with work safety requirements, *and* where this action has been approved by WSU. An excavation that remains open should only be left unattended if it is safe and adequate protective fencing is installed around it.

6. Following consultation with DIRD and DoE, and where advised, any other relevant stakeholder groups, such as key Aboriginal stakeholders, the significance of the finds should be assessed and an appropriate management strategy formulated and followed. Depending on project resources and the nature of the find(s), this process may require input from a consulting heritage specialist.

7. No impact may occur to the object until approval is gained from DIRD and DoE, or relevant authority with delegated authority.

8. If human skeletal material is encountered, the protocol for the discovery of human remains should be followed.

A8.2 Protocol to follow in the event of the discovery of suspected human remains

The following protocol will be actioned if suspected human material is revealed during ground disturbance, excavations or other works within the airport site:

1. All works must halt in the immediate area of the find(s) and any further disturbance to the area of the find(s) prevented.

    a. The discoverer of the find(s) will notify machinery operators in the immediate vicinity of the find(s) so that work can be halted; and

    b. The site supervisor and the Principal/Project manager will be informed of the find(s).

2. If there is substantial doubt regarding a human origin for the remains, then consider if it is possible to gain a qualified opinion within a short period of time. If feasible, gain a qualified opinion (this can circumvent proceeding further along the protocol for remains which are not human). If conducted, this opinion must be gained without further disturbance to the find(s) or the immediate area of the find(s). (Be aware that the site may be considered a crime scene that retains forensic evidence). If a quick opinion cannot be gained, or the identification is positive, then proceed to the next step.

3. Immediately notify the following of the discovery:

    a. The local Police (this is required by law);

    b. The Department of Infrastructure and Regional Development (DIRD) and/or their representative;

    c. The Department of the Environment;

    d. The NSW Office of Environment and Heritage (OEH); and

    e. The project archaeologist (if appointed).

4. Co-operate and be advised by the Police and/or coroner with regard to further actions and requirements concerning the find area. If required, facilitate the definitive identification of the material by a qualified person (if not already completed).

5. In the event that the Police or coroner instigate an investigation, any disturbance to the area of the find(s) are not to resume until approval in writing is gained from the NSW Police.

6. In the event that the Police and/or Coroner advise that they do not have a continuing or statutory role in the management of the finds then proceed with the following steps:

7. If the finds are not human remains but are considered to be archaeological material relating to Aboriginal occupation then proceed with an archaeological assessment methodology as appropriate.

8. If the finds are human remains and Aboriginal or probably Aboriginal in origin, then ascertain the requirements of DoE, OEH, DIRD, the Project Manager (if not DIRD), and the views of Registered Aboriginal Stakeholders, and the project archaeologist.

    Based on the above, determine and conduct an appropriate course of action. Possible strategies could include one or more of the following:

        i. Avoiding further disturbance to the find and conserving the remains *in situ*

        i. Conducting archaeological salvage of the finds following receipt of any required statutory approvals;

ii. Scientific description (including excavation where necessary), and possibly also analysis of the remains prior to reburial;

iii. Recovering samples for dating and other analyses; and/or

iv. Subsequent reburial at another place and in an appropriate manner determined by the Aboriginal Stakeholders.

9. If the finds are non-Aboriginal in origin:

a. Ascertain the requirements of DoE, OEH, DIRD and the Project Manager (if not DIRD), and the views of any relevant community stakeholders and the project archaeologist.

b. Based on the above, determine and conduct an appropriate course of action. Possible strategies could include one or more of the following:

ii. Avoiding further disturbance to the find and conserving the remains *in situ*;

iii. Conducting archaeological salvage of the finds following receipt of any required statutory approvals;

iv. Scientific description (including excavation where necessary), and possibly also analysis of the remains prior to reburial;

v. Recovering samples for dating and other analyses; and/or

vi. Subsequent reburial at another place and in an appropriate manner determined in consultation with relevant stakeholders.

10. Any disturbance to the area of the find(s) may not resume until written approval is received from the relevant statutory authority, or authority with delegated authority. This may be the Police or Coroner in the event of an investigation, or the DoE and/or OEH in the case of remains outside of the jurisdiction of the Police or Coroner.

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VOLUME 4

Appendix M2 European and other heritage

Western Sydney Airport EIS

European and other heritage technical report

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APPROVAL FOR ISSUE

Name	Signature	Date
Nick van Bronswijk		07/10/2015

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Executive summary

The Commonwealth Department of Infrastructure and Regional Development is undertaking the detailed planning for a new greenfield airport at Badgerys Creek. The Western Sydney Airport project (the project) would service both domestic and international air traffic, with development staged in response to passenger demand. The initial development of the airport would include a single, 3.7 kilometre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million domestic and international passengers per year. In the longer term, approximately 40 years after the airport has been constructed and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and rail transport facilities for around 82 million passenger movements per year.

This assessment addresses the Australian Government environmental assessment requirements for the project for European and other heritage. Advice on the environmental assessment requirements from the Heritage Division of the NSW Office of Environment and Heritage (OEH) is also addressed in this assessment.

The assessment involved the identification of heritage items within and adjacent to the airport site through a review of previous studies, heritage registers, historical research, and by undertaking field survey and archaeological test excavation.

A thematic contextual history of the airport site was developed and key historical themes identified. A predictive model of the types of European and other heritage places was developed from the thematic history, historical research, known site distribution, and past land use.

A total of 19 European and other heritage items were identified as being within the airport site, with 22 identified outside of the airport site but within the study area adopted for this study. The significance of each heritage item within the airport site was assessed against the Commonwealth heritage list criteria (Department of the Environment and Water Resources n.d) and NSW state heritage register criteria (NSW Heritage Office 2001). Significance assessment of these items identified 18 items of Commonwealth heritage significance, and one with undetermined heritage significance within the airport site. It should be noted that Commonwealth heritage values relate to the significant values of places on land owned or controlled by the Australian Government. The threshold for consideration for inclusion on the Commonwealth heritage list is local heritage significance.

Of those identified European and other heritage items, all but one within the airport site will be directly impacted by the initial development, and all 19 will ultimately be directly impacted by the airport development. One item beyond the airport site but within the study area will be subject to direct impact, however, a range of indirect impacts would result at these places as a result of the initial and longer term development at the airport site.

Mitigation and management recommendations

Potential mitigation measures for those items within the airport site involve the realisation of the information and research potential associated with each site, and with the airport site as a whole, through a range of methods, as described in the table below.

General management measures have been recommended, including the development and implementation of a European heritage management plan including a procedure for unexpected finds, a procedure for the

identification of human remains, and the provision of heritage induction training for contractors working on demolition or earthworks at the site.

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
	Airport site	Commonwealth	Direct, initial airport development	Oral history, interpretation, archive and keeping place
AS1	Pennell's property 2170 Elizabeth Drive, Badgerys Creek	Commonwealth	Direct, initial airport development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations
AS2	Gardiner Road farm complex 5 Gardiner Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Removal of all structures and destruction of any archaeological evidence associated with this site as a result of earthworks.	Archival recording, inventory of moveable heritage items, staged demolition, archaeological investigations, cultural plantings, relocation of structures
AS3	Badgerys Creek Public School Corner of Pitt Street and Badgerys Creek Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Removal of all structures associated with this site as a result of earthworks.	Archival recording, inventory of moveable heritage items, staged demolition, relocation of structures
AS4	Badgerys Creek butchery Lot 51A Badgerys Creek Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations
AS5	Badgerys Creek post office Lot 52 Badgerys Creek Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations
AS6	Saw pit 61 Badgerys Creek Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
AS7	Badgerys Creek Uniting Church and cemetery 15 Pitt Street, Badgerys Creek	Commonwealth	Direct, initial airport development: Removal of all graves and destruction of any archaeological evidence associated with this site as a result of earthworks.	Archival recording, relocation of remains interred at cemetery site
AS8	St John's Anglican Church and cemetery 30 Pitt Street, Badgerys Creek	Commonwealth	Direct, initial airport development: Removal of all graves and destruction of any archaeological evidence associated with this site as a result of earthworks.	Archival recording, relocation of remains interred at cemetery site
AS9	Braeburn homestead 55 Longleys Road, Badgerys Creek	Commonwealth	Direct, longer term development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations, cultural plantings
AS10	Orange Hill homestead 5 Jagelman Street, Badgerys Creek	Commonwealth	Direct, initial airport development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations, cultural plantings
AS11	Vicary's Winery 1935 The Northern Road, Luddenham	Commonwealth	Direct, initial airport development: Removal of all structures and destruction of any archaeological evidence associated with this site as a result of earthworks.	Archival recording, inventory of moveable heritage items, staged demolition, archaeological investigations, cultural plantings, relocation of structures
AS12	Well 1972 The Northern Road, Luddenham	Commonwealth	Direct, initial airport development: Removal of well and destruction of any archaeological evidence associated with this site as a result of earthworks.	Archival recording, staged demolition, archaeological investigations

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
AS13	The Northern Road alignment within the airport site	Commonwealth	Direct, initial airport development t: Removal of all evidence of The Northern Road alignment through the airport site as a result of earthworks.	Archaeological investigations
AS14	Anschau Vineyard, Steinberg and grave(s) 1845-1875 The Northern Road, Luddenham	Commonwealth	Direct, initial airport development: Removal of all graves and destruction of any archaeological evidence associated with this site as a result of earthworks.	Relocation of remains interred at cemetery site, archaeological investigations, cultural plantings
AS15	St Francis Xavier Church and cemetery 1966 The Northern Road, Luddenham	Commonwealth	Direct, initial airport development: Removal of all graves and destruction of any archaeological evidence associated with this site as a result of earthworks.	Relocation of remains interred at cemetery site, archaeological investigations, cultural plantings
AS16	Jackson Road cottage Lot 2 Jackson Road, Luddenham	Commonwealth	Direct, initial airport development: Removal of all structures associated with this site as a result of earthworks.	Archival recording, staged demolition, archaeological investigations
AS17	Badgerys Creek Road alignment within the airport site	Commonwealth	Direct, initial airport development: Removal of all evidence of the Badgerys Creek Road alignment through the airport site. The southern section of Badgerys Creek Road is proposed to be retained but is expected to be removed to enable construction of the second runway when required.	Archaeological investigations

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
AS18	Spredenberg 55 Longleys Road, Badgerys	Unknown	Direct, initial airport development: Removal of any archaeological evidence associated with the site.	Archaeological investigations
AS19	Howe residence Corner of Badgerys Creek Road and Longleys Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Removal of all archaeological evidence associated with the site.	Archaeological investigations
SA1	Former Overseas Telecommunications Commission site group Badgerys Creek Road, Bringelly	Local	Indirect, initial airport development: Visual impact.	None required
SA2	Kelvin 30 The Retreat, Bringelly	State	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA3	Two RAAF water tanks Badgerys Creek Road, Bringelly	Local	Indirect, initial airport development: Visual impact.	None required
SA4	Mount Pleasant homestead 3 Shannon Road, Bringelly	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA5	Bringelly Public School group 1205 The Northern Road, Bringelly	Local	None	None required
SA6	Willmington Reserve 17 Jamison Street, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site	None required
SA7	Luddenham Public School The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA8	Lawson's Inn Lot 2 DP 623457, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
SA9	McGarvie Smith University Farm 124 Elizabeth Drive, Badgerys Creek	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA10	Brick cottage 21-55 Campbell Street, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA11	Luddenham Road alignment	Local	Indirect, direct, initial airport development: Visual impact, impact to southern alignment of Luddenham Road following Elizabeth Drive realignment	None required
SA12	Weatherboard cottage 3065-3067 The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA13	Weatherboard cottage 3075 The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA14	Luddenham Progress Hall 3091-3095 The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA15	Luddenham Uniting Church and cemetery 3097-3099 The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA16	St James Anglican Church and cemetery 3101-3125 The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA17	Showground 428-452 Park Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site	None required
SA18	Shadforth Monument Greendale Road, Greendale	Local	None	None required

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
SA19	Private dwelling (former St Marks) Greendale Road, Greendale	Local	None	None required
SA20	Greendale Roman Catholic Cemetery Greendale Road, Greendale	Local	None	None required
SA21	Vertical slab dairy Lot 10, Adams Road, Badgerys Creek	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA22	Evergreen homestead Off Derwent Road, Bringelly	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required

Note: AS and SA in the above table refers to airport site and study area respectively

Contents

EXECUTIVE SUMMARY IV
TERMS AND ABBREVIATIONS 1
1 INTRODUCTION 3
1.2 Background 3
1.3 Previous studies 4
1.4 Scope and content of this report 5
2 METHODOLOGY 7
2.1 Assessment approach 8
2.2 Approach to heritage values of Badgerys Creek 8
2.3 Archival research 9
2.4 Historic heritage register searches 9
2.5 Predictive model 9
2.6 Field survey 10
2.7 Archaeological assessment 12
2.8 Assessment of significance 13
2.9 Definition of impacts 14
2.10 Consultation informing this assessment 15
2.11 Relevant legislation and guidelines 15
3 EXISTING ENVIRONMENT 20
3.1 Historical context 20
3.2 Physical context 33
3.3 Predictive model for European and other heritage sites 43
3.4 Field survey 44
3.5 Test excavation 45
3.6 Effectiveness of the predictive model 56
3.7 Summary of historical and physical contexts 56
4 SIGNIFICANCE ASSESSMENT 59
4.1 Specific heritage items 59
4.2 Significance assessment of the airport site 65
4.3 Potential for nomination of places to the Commonwealth Heritage List 66
5 IMPACT ASSESSMENT 68
5.1 Initial airport development 68
5.2 Longer term development 68
6 MITIGATION AND MANAGEMENT 75
6.1 Specific measures 75
6.2 General measures 79

7 CONCLUSION 82
7.1 Key findings of the assessment 82
8 REFERENCES 83

Tables

Table 1 Commonwealth and New South Wales heritage criteria 13
Table 2 Heritage items or places within the study area on the Register of the National Estate 34
Table 3 Heritage items or places within the study area on the State Heritage Register 35
Table 4 Heritage items or places within the study area on Schedule 5 of the Liverpool LEP 2008. 35
Table 5 Heritage items or places within the study area on Schedule 5 of the Penrith LEP 2010. 37
Table 6 Heritage items or places identified in Godden Mackay 1997 *Technical Paper* and Australian Museum Consulting 2014 *Initial Environmental Survey* 39
Table 7 Australian historical themes of the European and other heritage items at the airport site 42
Table 8 Results of field survey and test excavation, 2015 45
Table 9 Summary of all European and other heritage sites identified within the airport site and the study area 56
Table 10 Summary of heritage significance of European and other heritage items within the airport site 59
Table 11 European and other heritage items impacted by the project 69

Figures

Figure 1 Airport site and study area 6
Figure 2 European and other heritage items within the study area 67

Plates

Plate 1 1835 map of Bringelly showing Blaxland's Luddenham property at the proposed airport site. (Source: National Library of Australia) 22
Plate 2 Photo of the substantial brick Exeter Farm house, originally constructed by James Badgery. Photography was taken in 1995 before the house was demolished. (Source: Liverpool City Library, Heritage Library Collection, 1776-12). 23
Plate 3 Members of the Lowe family outside the second Birling Gap, photograph taken in the 1880s. (Source: Liston 2009:41) 25
Plate 4 Plan of the Eastern Division of the Luddenham Estate, by Samuel Jackson, 1859, showing various sized allotments for sale and details of existing structures and property boundaries. (Source: State Library of NSW) 29
Plate 5 Undated advertisement for the sale of orchard and vineyard land on Nicholson's Luddenham Estate, between Cox's Road (now Badgerys Creek Road) and Badgerys Creek. (Source: Donald and Gulson 1996:15) 30
Plate 6 Ploughing on Nobbs' farm at Badgerys Creek in the 1940s. Note the hipped roof, bullnose veranda homestead, Exeter House, in the background. (Source: Liston 2009:46). 32

Appendices

Appendix A Significance assessments 87

Plate A1 Plan of the Eastern Division of the Luddenham Estate, 1859. (Source: State Library of NSW).....89

Plate A2 Part of the Plan of the Eastern Division of Luddenham Estate. Lot 32 is located centrally, bounded to the east by Badgerys Creek. (Source: National Library of Australia).....91

Plate A3 Deposited Plan 1451 showing Lots 30 and 31. (Source: NSW Land and Property Information) 92

Plate A4 Deposited Plan 1841 following the subdivision of Lots 30 and 31, showing Lot 10 extended through to Peter Neiss' property. (Source: NSW Land and Property Information).....92

Plate A5 Lesley Dorahy on the poultry farm in the 1940s. (Source: Donald and Gulson 1996:27).....93

Plate A6 Ralph Wiener's residence. (Source: Donald and Gulson 1996:31) 93

Plate A7 View north toward the cottage. (Source: RPS 2015) 95

Plate A8 Cistern behind Gardiner Road cottage. (Source: RPS 2015) 95

Plate A9 View west toward sleep-out and garage. (Source: RPS 2015).....96

Plate A10 View west towards shed and hopper. (Source: RPS 2015) 96

Plate A11 Lysaght silo. (Source: RPS 2015) 97

Plate A12 Water tank on stand; outbuildings behind. (Source: RPS 2015).....97

Plate A13 View west toward byre. (Source: RPS 2015) 98

Plate A14 One of several sets of poultry sheds on the site. (Source: RPS 2015).....98

Plate A15 View south toward outbuildings. (Source: RPS 2015) 99

Plate A16 View north east toward 1960s house. Sleep-out visible at rear. (Source: RPS 2015).....99

Plate A17 Badgerys Creek Public School, 1908. (Source: National Library of Australia) 102

Plate A18 View south east toward classroom block. (Source: RPS 2015).....103

Plate A19 View toward western wall of the staff room, note extensive fire damage. (Source: RPS 2015) ...104

Plate A20 View south east toward library. (Source: RPS 2015) 104

Plate A21 View north west toward wash room. (Source: RPS 2015) 105

Plate A22 View north toward hall. (Source: RPS 2015).....105

Plate A23 View south toward the old cottage. (Source: RPS 2015).....106

Plate A24 View west across former monument location to courts. (Source: RPS 2015) 107

Plate A25 Former butchers at Badgerys Creek. (Source: Godden Mackay 1997).....110

Plate A26 Aerial view of the Badgerys Creek butcher site, 1965. (Source: Land and Property Information)110

Plate A27 Badgerys Creek butchery site, viewed from Badgerys Creek Road. (Source: RPS 2015).....111

Plate A28 Badgerys Creek post office location, general store at the left. (Source: RPS 2015) 113

Plate A29 View of saw pit location from Longleys Road. (Source: RPS 2015) 115

Plate A30 Badgerys Creek Uniting Church and cemetery site, undated. Note hall building at rear. (Source: Donald and Gulson 1996).....118

Plate A31 Aerial photograph of Badgerys Creek Uniting Church and cemetery site, note hall building at rear of church, 1965. (Source: Land and Property Information) 118

Plate A32 Badgerys Creek Uniting Church and cemetery, view from Pitt Street. (Source: RPS 2015).....119

Plate A33 Badgerys Creek Uniting Church cemetery, view toward former Church site. (Source: RPS 2015)119

Plate A34 St John's Anglican Church, Badgerys Creek. (Source: Office of Environment and Heritage).....122

Plate A35 Rows of graves at St John's Anglican Church and cemetery site. (Source: RPS 2015) 123

Plate A36 Braeburn homestead, c.1991. (Source: Liverpool City Library) 126

Plate A37 1965 aerial photograph of Braeburn homestead site. (Source: Land and Property Information) .126
Plate A38 View of Braeburn homestead site, note plantings. (Source: RPS 2015) 127
Plate A39 Cape honeysuckle trees marking the location of Orange Hill homestead. (Source: RPS 2015) ..129
Plate A40 Sandstone flagging identified at Orange Hill homestead site. (Source: RPS 2015) 130
Plate A41 Advertisement for Vicary's "Vineyards". (Source: Nepean Times, 5 April 1951) 133
Plate A42 Vicary's Winery cellar door building. (Source: RPS 2015) 133
Plate A43 Vicary's Winery group ablutions and ancillary sheds. (Source: RPS 2015) 134
Plate A44 Vicary's Winery group, train carriage at right, extension to woolshed at left. (Source: RPS 2015)134
Plate A45 Vicary's Winery woolshed. (Source: RPS 2015) 135
Plate A46 Vicary's Winery group, cow bails outside the woolshed. (Source: RPS 2015) 135
Plate A47 Vicary's Winery front of c.1860 slab homestead. (Source: RPS 2015).....136
Plate A48 Vicary's Winery, rear of c.1860 slab homestead, fibro wing at right. (Source: RPS 2015).....136
Plate A49 House at 1972 The Northern Road. (Source: RPS 2015).....139
Plate A50 Internal sandstone lined well at 1972 The Northern Road, capped with fibro and timber. (Source: RPS 2015) 140
Plate A51 Cadastral plan of the Parish of Bringelly, 1834, note North Road. (Source: State Library of NSW) 142
Plate A52 1965 aerial photograph of Anschau Vineyard site, note furrows on western slope and structures on the site. (Source: Land and Property Information, NSW 1404 5166 Cumberland 1965 series, Run 22, 29/08.1965).....145
Plate A53 View toward Anschau Vineyard site from The Northern Road. (Source: RPS 2015) 146
Plate A54 View east to the ruin of Steinberg, thickly covered in vegetation. (Source: RPS 2015) 146
Plate A55 Collected iron thought to be evidence of a smithy near Steinberg. (Source: RPS 2015) 147
Plate A56 Undated photograph of St Francis Xavier Church. (Source: Wilmington 2013:35) 151
Plate A57 Open areas within St Francis Xavier Church and cemetery site. (Source: RPS 2015) 151
Plate A58 Ruins of unknown structure, St Francis Xavier Church and cemetery. (Source: RPS 2015) 152
Plate A59 St Francis Xavier Church Greendale, with relocated headstones from the original site. (Source: RPS 2014) 152
Plate A60 Plaque at St Francis Xavier Greendale. (Source: RPS 2015) 153
Plate A61 Undated photograph of house at Lot 2 Jackson Road. (Source: Donald and Gulson 1996).....155
Plate A62 Lot 2 Jackson Road house. (Source: RPS 2015) 156
Plate A63 Lot 2 Jackson Road farm shed with accretions. (Source: RPS 2015) 156
Plate A64 View west across the site of Spredenburg. (Source: RPS 2015).....160
Plate A65 View west across the site of the Howe residence. (Source: RPS 2015).....161
Plate A66 Circular, brick lined depression (well) at Howe's residence. (Source: RPS 2015) 162

Terms and abbreviations

Term	Definition
1985 EIS	*1985 Second Sydney Airport Site Selection Programme Environmental Impact Statement*. An environmental impact statement developed in 1985 to assess the economic, environmental and social impacts of developing an airport at Badgerys Creek. This was the first environmental impact statement prepared for an airport at Badgerys Creek.
1997 Draft EIS	*Draft Environmental Impact Statement: Second Sydney Airport Proposal*. A draft environmental impact statement developed in 1997 to assess the economic, environmental and social impacts of developing an airport at Badgerys Creek. This was the second environmental impact statement prepared for an airport at Badgerys Creek.
AHD	Australian height datum. A mean sea level used as a standard to measure elevation above sea level in Australia.
Aircraft movement	One landing or one take off by an aircraft.
C'th *Airports Act 1996*	Commonwealth legislation that establishes a system for regulating airports.
Airport site	The land declared under the *Airports Act 1996* as the site of the proposed Western Sydney Airport.
Ambient noise	The pre-existing noise levels in an environment prior to any given development.
Badgerys Creek	A suburb of Sydney about 50 kilometres west of the Sydney central business district. The general locality of the airport site.
Cut and fill	Earthworks and engineering term meaning an operation commonly used in road building and other rock and earthmoving operations in which the material excavated and removed from one location is used as fill material at another location. This is typically to reduce the gradient of a site on which it would otherwise be prohibitive or too costly to construct.
DIRD	Commonwealth Department of Infrastructure and Regional Development. The department responsible for planning the Western Sydney Airport.
Direct impact	A physical change occurring to an item or place which results in the diminution of the European and other heritage values of that item or place. Direct impacts may include minor and peripheral changes, or large scale removal and destruction.
EIS	Environmental impact statement.
NSW EP&A Act	The NSW *Environmental Planning and Assessment Act 1979*.
C'th EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Commonwealth legislation designed to balance the protection of the environment, especially those aspects of the environment that are matters of national environmental significance, with society's economic and social needs by creating a legal framework and decision-making process based on the guiding principles of ecologically sustainable development.
HHIMS	Historic Heritage Information Management System.
Impact	A change in the physical, natural or cultural environment brought about by an action. Impacts can be direct or indirect.
Indirect impact	As defined in the EPBC Act *Significant impact guidelines 1.2*, indirect impacts are downstream or downwind impacts, such as impacts on wetlands or ocean reef; upstream impacts, such as those associated with the extraction of raw materials; or facilitated impacts, such as urban or commercial development of an area made possible by a project.
Initial development	The initial stage in the development of the Western Sydney Airport, including a single runway and 10 million annual passenger movements, nominally occurring in 2030. Also referred to as the Stage 1 development.

Term	Definition
LEP	Local environmental plan. An environmental planning instrument prepared and administered by local governments.
LGA	Local government area.
Likely	As defined in the EPBC Act *Significant impact guidelines 1.2*, an impact is 'likely' if it is a real or not remote chance or possibility.
Longer term development	A longer term development at Western Sydney Airport could include dual runways and approximately 82 million annual passenger movements. The Western Sydney Airport EIS considers this patronage level could be reached around 2063.
Major development plan	A major development plan is required for each major development at an airport and is prepared by the airport lessee company taking into account public comments. Part 5, Division 4 of the *Airports Act 1996* provides a full definition.
Master plan	The principal planning document required under the *Airports Act 1996* setting out a 20-year plan for each leased federal airport.
MNES	Matters of national environmental significance.
NSW	New South Wales.
OEH	The NSW Office of Environment and Heritage of the Department of Planning and Environment.
SEPP	A state environmental planning policy made by the Governor on the recommendation of the NSW Minister for Planning. State environmental planning policies are numbered according to their order of development or year of development, for example: State Environmental Planning Policy No. 55 - Remediation of Land or State Environmental Planning Policy (State and Regional Development) 2011.
Significant impact	As defined in the EPBC Act *Significant impact guidelines 1.2*, a 'significant impact' is an impact which is important, notable, or of consequence, having regard to its context or intensity. Whether or not an action is likely to have a significant impact depends upon the sensitivity, value, and quality of the environment which is impacted, and upon the intensity, duration, magnitude and geographic extent of the impacts.
Study area	The area subject to investigation for the purposes of this assessment. This includes the airport site, and properties beyond the airport site where there is the potential for impact to European and other heritage resulting from the construction and/or operation of the airport, including the township of Luddenham.
the airport	Western Sydney Airport.
Western Sydney Airport	The proposed airport at Badgerys Creek and assessed in the Western Sydney Airport environmental impact statement.
Western Sydney Airport environmental impact statement	The document containing the assessment of the potential environmental impacts of the airport under the C'th EPBC Act 1999.

1 Introduction

1.2 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development (DIRD) is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.3 Previous studies

Previous European and other heritage assessments of the airport site

The two previous EISs for the airport identified a number of European and other heritage items in the study area. Particularly, Chapter 21 of the *1997 Draft EIS* (PPK Environment & Infrastructure Pty Ltd 1997) addressed the non-Aboriginal (European and other) cultural heritage impacts of the then proposed Second Sydney Airport. Discussion was based on a separate specialist investigation documented in *Technical Paper 12: Non-Aboriginal Cultural Heritage* (Godden Mackay 1997).

The *Auditor's Report on the 1997 Draft EIS* (SMEC 1998) concluded that the investigation achieved all the objectives identified in the EIS Guidelines for the Draft EIS studies, and that the *Technical Paper 12* followed a methodology that complied with (then) current best practice in the heritage field.

In 1999 the *Supplement to the Draft EIS* (PPK Environment & Infrastructure Pty Ltd 1999) was prepared, summarising the findings of the *1997 Draft EIS* and issues raised in public submissions to the Draft EIS. Further information was provided on the methodology and scope of the assessment for the non-Aboriginal heritage investigation including:

- justification for not undertaking a preliminary field survey; and
- justification for exclusion of historic heritage items not located within or immediately adjacent to the airport options (there were three options for the Badgerys Creek airport examined in this EIS).

Additional assessment considered the cumulative impacts of the airport development on European and other heritage in the Liverpool local government area. It was concluded that cumulative impacts would not be severe given the affected items were not of high heritage significance. It was also noted that there were comparable heritage items to those identified, in nearby areas and throughout the region.

The *Supplement to the Draft EIS* also discussed the potential listing of the Greater Blue Mountains Area as a World Heritage site. It acknowledged that the basis of the nomination for listing was not related to historic heritage values, rather, biodiversity, landscape and Aboriginal heritage values.

Additional information was also provided in relation to management measures for heritage items.

The *Auditor's Report on the 1999 Supplement to the Draft EIS* (SMEC 1999) noted that the *Supplement* had addressed the comments made in public submissions and re-evaluated 23 heritage items associated with all three airport options in terms of National Heritage values. It also noted that nine heritage items were re-assessed and found to have sufficient cultural significance to warrant entry on the Register of the National Estate. The *Auditor's Report* recommended that future comparison of options include consideration of how each item would be affected.

In 1999 Environment Australia prepared an *Environmental Assessment Report* summarising and analysing the findings of the *1997 Draft EIS*, the *Supplement to the Draft EIS*, and the two Auditor's Reports. It noted that an understanding of the collective value of the identified heritage items would have been beneficial, but conceded that the assessed significance of the items was unlikely to change as the result of such an assessment. The *Environmental Assessment Report* also noted that the cumulative impact assessment prepared for the *Supplement to the Draft EIS* did not consider the impact of airport operations on the setting of remaining heritage items. It observed that the *Supplement to the Draft EIS* also did not consider the impacts of consequential land uses or infrastructure on remaining heritage resources in the region.

Environment Australia concluded that the loss of heritage items within the site and consequential regional impacts of an airport and associated infrastructure would have a significant impact on the heritage resources of the region. This significance would be elevated due to the loss of sites at Badgerys Creek.

Environment Australia recommended that a survey of the airport site be carried out prior to construction to identify further heritage items and potential archaeological deposits. It further recommended a survey be conducted early in the planning period for an airport at Badgerys Creek to identify all non-Aboriginal regional heritage items which may be affected by the operation of an airport. It was recommended that the identified heritage items each have conservation management plans prepared including management measures to mitigate the impacts of airport operations.

In 2014, Australian Museum Consulting was commissioned by SMEC on behalf of the Western Sydney Unit of DIRD to prepare an environmental survey of Commonwealth-owned land at Badgerys Creek. The investigation was designed to build on the substantial body of existing information about the property to provide an updated baseline of the status and condition of non-Aboriginal heritage sites. The report was included as part of the EPBC Act referral which was submitted to the Commonwealth Department of the Environment in November 2014.

1.4 Scope and content of this report

RPS has undertaken this assessment of impacts on European and other heritage for the proposed Western Sydney Airport to support the EIS for the project.

This report draws on the results of all previous assessments undertaken and augments this information with further research, site investigations, test excavation and analysis. This report has been prepared in accordance with the EIS guidelines.

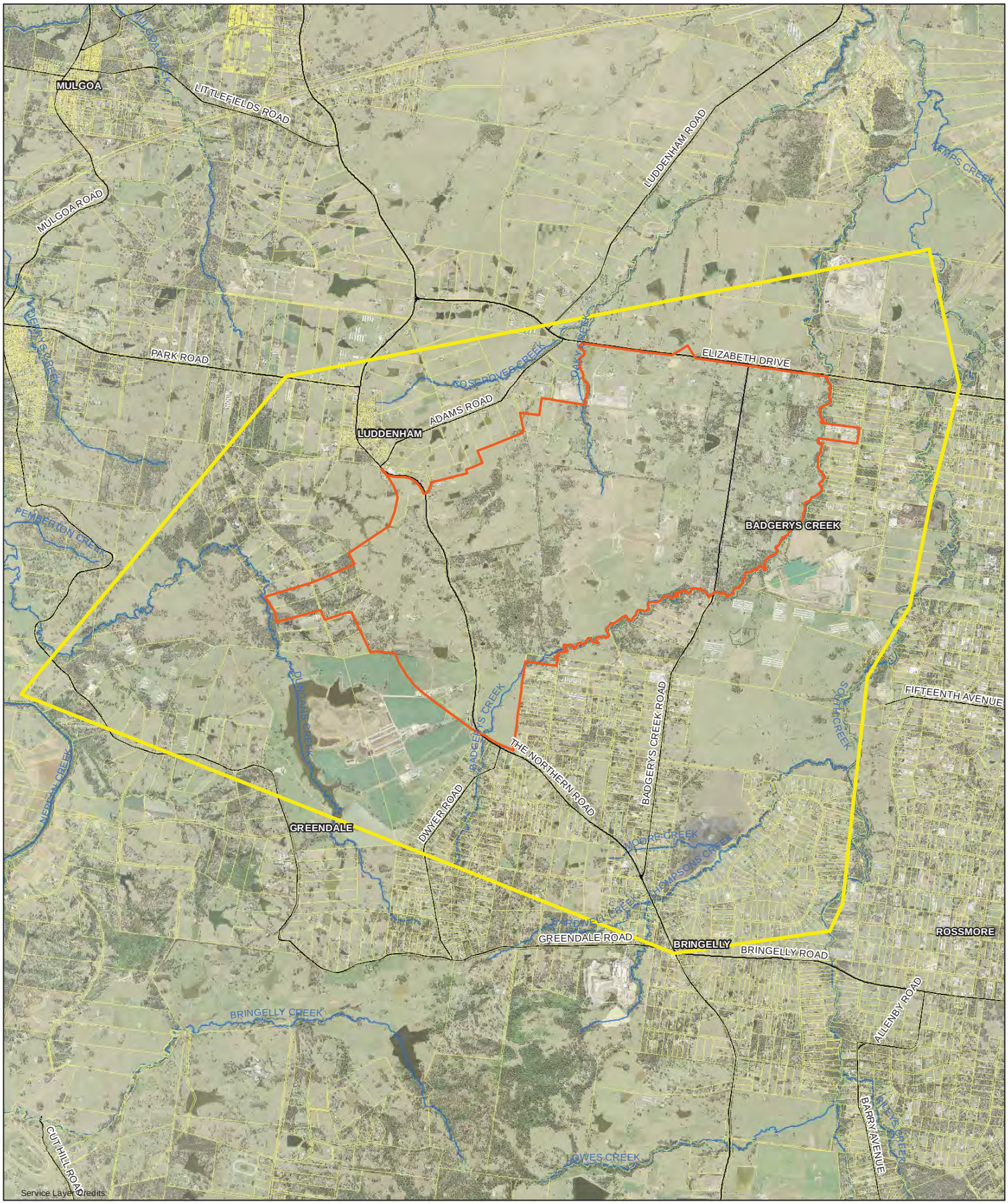
For the purposes of this report, the airport site and study area are defined as follows.

Airport site

The airport site is located 56 kilometres from Sydney's centre and is bounded by Elizabeth Drive to the north, Willowdene Avenue to the south, Adams Road to the west, and Badgerys Creek to the east (Figure 1). The Northern Road currently cuts across the south-western side of the site but will be acquired in the future to become part of the airport site. The Northern Road will be relocated to allow the development to proceed. The airport site is approximately 1,700 hectares.

Study area

The study area is the area subject to investigation for the purposes of this report. The study area includes the airport site, and properties beyond the airport site where there is potential for impact to European and other heritage resulting from the construction and/or operation of the airport. This includes the township of Luddenham, some parts of Bringelly, and some parts of Greendale (Figure 1).



LEGEND

- Study area
- Airport site
- Cadastre

Paper Size A3

0 375 750 1,500

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Job Number	21-24265
Revision	A
Date	29 Jul 2015

Airport Site and study area

Figure 1

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2 Methodology

This chapter details the methods used in completing the assessment of European and other heritage. An outline of the assessment approach is provided. Details of previous and current field surveys of the airport site are presented. The chapter also presents the approach taken in assessing the significance of heritage items, the approach taken to the project's European and other heritage environmental impact assessment, consultation undertaken and the relevant guidelines and legislation used in undertaking the assessment.

The overall approach to the assessment involves the identification of heritage items within the airport site and the study area through a review of previous heritage studies, searches of relevant heritage registers and schedules, and by undertaking field survey. The significance of each heritage item will be assessed consistent with the Commonwealth Heritage List criteria. The impact of the project on each heritage item will then be assessed, both for direct and indirect impacts including impacts from demolition, archaeological disturbance, altered historical arrangements and access, landscape views and vistas, and architectural noise treatment. Appropriate management measures will be identified to avoid, minimise and manage impacts to each heritage item.

For the purposes of this report we have defined the airport site and a study area.

Initial development – construction and initial operations (2016)

During this period, major site preparations including earthworks to prepare the airport site will take place. Site preparation activities could commence in 2016.

Airport operations are proposed to commence in the mid-2020s. The initial development of the airport would cater for up to 10 million passengers per annum, a level of demand anticipated to occur in about 2030.

The initial development will require the construction of one 3,700 metre runway in the north of the airport site on an approximate 50/230 degree orientation with a single full length parallel taxiway. The Stage 1 airside system is planned to be capable of handling both domestic and international regular public transport services.

Aviation infrastructure, aviation support precincts, network infrastructure including utilities and ground transport facilities will be developed in advance of operations commencing. Areas of land have also been reserved for commercial development. An indicative layout for the initial development is illustrated in the main volume of the EIS.

Long term development (c.2063)

As demand increases beyond forecast Stage 1 levels, additional aviation infrastructure and aviation support precincts will add capacity to meet growing aviation demand. Incremental development of the airport will continue as additional taxiways, aprons, terminals and support facilities are developed. The airport would also include some commercial development in designated areas which would grow over time with demand.

The first runway is expected to reach capacity at around 37 million passengers per annum. This equates to approximately 164,000 air traffic movements per year or 45 per hour.

To meet additional demand a second parallel runway, 3,700 metres in length is expected to be required. The second runway is expected to have a runway centre-line separation distance of 1,900 metres from the first runway. Current expectations suggest that the development of a second parallel runway could be required around 2050.

By around 2063 the total number of air traffic movements per year is forecast to be 370,000, serving approximately 82 million passengers annually. An indicative long term layout of the development is illustrated in the main volume of the EIS.

2.1 Assessment approach

Overall approach

A summary of the assessment approach is as follows:

- review relevant heritage legislation;
- review background information including previous thematic studies, field surveys and assessments undertaken during previous assessments of the airport site (refer Section 1.2);
- search all available historic heritage registers for the airport site and the study area, including the World Heritage List, National Heritage List, Commonwealth Heritage List, State Heritage Register, state agency s170 Heritage and Conservation registers, Local Environmental Plans, National Trust of Australia (NSW) list, Register of the National Estate, Historic Heritage Information Management System, Australian Institute of Architects Register of Significant Architecture in NSW;
- collate any known heritage curtilage (boundary) information as part of the heritage searches;
- undertake a literature review including previous archaeological reports, heritage studies, local heritage studies, conservation management plans, as well as regional and local history documents and maps where available;
- prepare thematic history;
- develop a predictive model for occurrence of historical site types in the landscape and apply this to the study area to inform further field survey requirements;
- undertake field survey of the airport site to identify known historic heritage items, unrecorded historic heritage items, and to assess the potential for any unrecorded historic heritage items;
- develop a database of historic heritage items and features located within the study area;
- undertake consultation with relevant councils and the Heritage Division of the NSW Office of Environment and Heritage (OEH), regarding heritage significance and curtilage of heritage listed items;
- undertake targeted survey to record identified historic heritage items and determine heritage curtilage;
- undertake assessment of cumulative impacts on historic heritage including cultural landscapes; and
- recommend management and mitigation measures.

2.2 Approach to heritage values of Badgerys Creek

The heritage values of the suburb of Badgerys Creek were examined as part of the assessment. The heritage assessment of Badgerys Creek as a heritage landscape has not been undertaken as part of any previous assessments of the airport site. Rather than using the site specific approach defined above, a broader landscape approach has been used. The assessment presents the historical background of Badgerys Creek, the known physical remains and former fabric of the settlement, a significance assessment of the settlement as a whole, and the impacts of the airport on the settlement overall.

2.3 Archival research

Numerous primary and secondary sources held by the State Library of New South Wales, State Records of New South Wales, Land and Property Information (NSW), and the Penrith City Council Library Special Collections were examined during research on the historical development of the airport site. Attempts were made to access information from Liverpool City Council's Library, however RPS was informed that much of the relevant information had been destroyed by a fire in the 1960s. Material examined at State Records included photographs, maps and land records associated with Badgerys Creek and individual properties and their owners. The maps and plans associated with the subdivision and use of the airport site, Trove, Land and Property Information's Six Viewer, parish maps, and local heritage studies were also consulted.

The aerial photograph series held by the Land and Property Information Division of the NSW Department of Finance and Services provided the main source of primary information regarding the development of the airport site after WWII. Aerial runs of the airport site from 1947, 1965, 1975, 1986 and 1991 were also collected for analysis.

2.4 Historic heritage register searches

This assessment of European and other heritage includes searches of all heritage registers to identify items located within the project area and within the study area. Heritage registers and schedules searched are as follows:

- UNESCO World Heritage List;
- Australian Heritage Database including the World Heritage List, Register of the National Estate, Commonwealth Heritage List, National Heritage List;
- NSW State Heritage Register;
- Historic Heritage Information Management System;
- s170 Heritage and Conservation Registers;
- heritage schedules in Liverpool Local Environmental Plan (2008) and Penrith Local Environmental Plan (2010);
- National Trust (NSW) list; and
- Australian Institute of Architects Register of Significant Architecture in NSW.

All registers and schedules were initially searched in January 2015 to inform the predictive model and early field survey. Registers were searched again in June 2015 to ensure any changes to items were captured.

Heritage studies and anecdotal information about registered sites have been sourced from:

- Liverpool City Council;
- Penrith City Council; and
- local historical societies including Campbelltown and Airds Historical Society, and the Nepean Family Historical Society.

2.5 Predictive model

A predictive model was developed to identify the most likely types of European or other heritage site types to be found at the airport site, and areas of greater or lesser potential for the presence of European or other heritage sites. The predictive model will also be used to inform further requirements for field survey.

The model was developed as follows:

- previous predictive models and statements made for the region in various heritage assessments and investigations were reviewed;
- known and recorded European and other heritage sites were identified from heritage registers and databases and previous heritage investigations;
- literature review including primary documents and local histories;
- identification of key historical themes for the area based on the historical activities undertaken;
- a review of information gathered during the research and register search phases formed the basis for the predictive modeling of the effect of various development episodes and changes in land boundaries that led to the current configuration and uses of the site. All maps and plans providing detailed information were compared against a current survey in order to test their veracity;
- a review of photographs, drawings and paintings collected during research was compared with the current landscape and a current survey plan in order to place features illustrated in them within a contemporary context. The technique has varying degrees of accuracy and in the case of non-photographic information, assumes that the original illustrator was creating an accurate record of the scene; and
- consideration of information about the current landscape and land use assisted in the identification of likely presence or survival of particular types of European and other heritage sites.

2.6 Field survey

Information from field surveys undertaken as part of the 1997 *Draft EIS* was used to inform the current field survey strategy.

Previous field surveys

Previous field surveys were undertaken in and adjacent to the current airport site as part of the 1997 *Draft EIS*.

Godden Mackay (1997) assessed a study area which was generally limited to the area within the boundary of the then proposed Second Sydney Airport master plan (refer 1997 *Draft EIS*), however, sites immediately adjacent to that boundary were also assessed. Godden Mackay identified heritage items and sites through a combination of primary and secondary research, scrutiny of existing heritage studies and reviews of existing heritage listings. Further primary research was undertaken to establish the history and archaeological potential of individual sites identified during the field surveys and from historical maps. Site inspections were undertaken in 1996 to record physical evidence and to verify historical research.

A full survey methodology was not included in Godden Mackay's *Non-Aboriginal Cultural Heritage Technical Paper* for the 1997 *Draft EIS*. It is unclear whether the investigations focused on known historic heritage items with a limited field program, or whether access to properties may have hindered the survey coverage. A review of the previous survey results informed the more recent field survey program as part of the current proposal. Overall the methodology and coverage of the previous field survey appears to have been sufficient.

In 2014, Australian Museum Consulting was commissioned by SMEC on behalf of the DIRD to update and build upon the previous work relating to the European and other heritage constraints and issues of the project area. A physical survey of the airport site and the local area in the vicinity was undertaken over two days by car with each street traversed and each identified item accessed, where possible. Where properties

could be accessed, the survey was undertaken on foot. The methodology allowed for opportunistic sightings of some new potential heritage items. The survey was subject to considerable time constraints, and acknowledged the potential for other items or places within the airport site to have been overlooked. Some problems were encountered gaining access to properties within the dedicated field survey days due to landholder notification requirements; and some objections to access. Archaeological sites could only be identified where there were physical remains associated with the original structure(s), as such, there was some uncertainty regarding the precise location of some sites. The investigation did not include a comprehensive survey of listed and potential heritage items in the study area.

Recent field programme

Preliminary field survey

The recent field survey programme focused on areas identified through primary and secondary research as having potential to contain European and other heritage sites. A preliminary field survey was undertaken over two days from 1-2 April 2015. The field team comprised two qualified archaeologists: Erin Williams and Deborah Farina.

Prior to undertaking the field survey, priority areas were identified by undertaking analysis of background information including topography, predictive model results, previous studies and field survey results, and heritage register listings. This provided a summary of target areas for the survey.

The survey sampled a range of different land use and landforms within the airport site. There was a focus on properties known to have been developed and thought to contain residual evidence or European and other heritage with the aim of maximising coverage in areas considered to be of higher sensitivity. Additionally, ground truthing was undertaken at known heritage sites which could be directly impacted by the project.

The field survey was undertaken as follows.

- Survey areas were defined on the basis of landholder information and property identification numbers held by DIRD. At the time of the survey the bulk of the airport site had been consolidated into one title, but each former title retained a unique identifier attributed by DIRD. The field survey was undertaken on foot and was opportunistic, with particular attention given to areas identified as having the potential to contain evidence of historic occupation, and areas of higher ground surface visibility or where the surface was exposed. Much of the airport site was very overgrown and numerous properties were vacant at the time of the survey.
- On sites where the location of a former structure or feature was known, the survey sought to identify surface evidence in order to establish the potential for subsurface evidence at that place.
- At properties where access was not possible a visual assessment was undertaken from the adjacent property. This method was useful where it was noted that ground surface visibility was extremely low due to thick vegetation and would render pedestrian survey ineffective. All properties within the airport site were subject to a “drive by” inspection.
- The locations of all European and other heritage sites (built heritage or archaeological sites) were recorded using a Garmin 60CSx handheld GPS.
- Field notes including commentary on ground surface visibility and exposures, vegetation, previous modifications and disturbance, landform, and land use were noted for each survey area.
- The survey did not include areas that had been subject to previous significant ground disturbance, except where specific items of interest had been noted in these properties which required a more detailed recording.

- The environmental and archaeological context of each item was recorded. This included general location, site components, landscape features and photographs. The curtilage of each item was determined and recorded in the field.

The main constraints to survey were property access and ground surface visibility as the airport site was generally very overgrown.

Secondary survey

Following the preliminary field survey, the completion of historical research and the receipt of historical aerial photographs, a further seven locations within the airport site were identified for field survey. The purpose of the survey was to determine whether any European or other heritage evidence remained at these locations, and whether test excavation was required. The same methodology as the preliminary field survey applied.

The secondary survey was undertaken from 1-2 June 2015. The field team comprised four qualified archaeologists: Deborah Farina, Joshua Madden, Jakob Ruhl and Georgia Wright.

Test excavation

As a result of the field surveys, one site was identified as requiring test excavation. The purpose of test excavation was to identify the presence of structural evidence associated with the place, the character of any remains to better understand the date(s) of occupation at the place, and the potential for lengthy or continued occupation of the site.

The methodology adopted for the test excavation program was framed by the following research questions.

- Is there any evidence indicating continued occupation of a site?
- If so, is there enough evidence to warrant an open area excavation?
- If not, is further archaeological investigation warranted?

Test excavation was undertaken from 3-5 June 2015 at the site of the former Orange Hill homestead. Orange Hill was identified by a local leaseholder as the site of the original Orange Hill homestead (Australian Museum Consulting 2014). Surface evidence at the site included a small stand of cape honeysuckle trees, two wells and several sandstock bricks. The test excavation was undertaken by a field team comprising four qualified archaeologists: Deborah Farina, Joshua Madden, Georgia Wright and Jakob Ruhl. Further details can be found below in Section 3.

2.7 Archaeological assessment

The evaluation of the historical archaeological potential associated with the history of the airport site is based on a consideration of historical information about the development and occupation of the airport site, physical evidence observed during field surveys, and identified areas of previous disturbance. A broad approach to the identification of potential archaeological evidence has been adopted and is based on the predictive model discussed above, which assumes that historical archaeological remains are generally located in close proximity to occupation and activity areas.

The assessment of archaeological impacts has been prepared based on historical research, a field survey, and the results of test excavation.

Historical background and significance assessment of identified archaeological sites has been primarily based on historical research. Field survey results were used to assess the anticipated condition of the historical archaeological sites.

2.8 Assessment of significance

Statements of significance for the assessed heritage items have been drawn from Federal and State statutory and non-statutory heritage registers where available, and supplemented with additional historical research as required.

The methodology for assessment of heritage significance is based on the Commonwealth heritage criteria (Department of the Environment and Water Resources n.d). These criteria are defined by the EPBC Act and relate to the place's natural and cultural environment having aesthetic, historic, scientific or social significance, or other significance. These criteria indicate that an item is of Commonwealth heritage significance if it meets one of nine criteria. The Commonwealth heritage criteria align closely with New South Wales state heritage criteria (NSW Heritage Office 2001) (refer Table 1 below).

Table 1 Commonwealth and New South Wales heritage criteria

	Commonwealth heritage criteria	New South Wales heritage criteria
Events and processes	**Criterion (a)** the place has significant heritage value because of the place's importance in the course, or pattern, of Australia's natural or cultural history.	**Criterion (a)** an item is important in the course, or pattern, of NSW's cultural or natural history (or the cultural or natural history of the local area)
Rarity	**Criterion (b)** the place has significant heritage value because of the place's possession of uncommon, rare or endangered aspects of Australia's cultural or natural history.	**Criterion (f)** an item possesses uncommon, rare or endangered aspects of NSW's cultural or natural history (or the cultural or natural history of the local area)
Research	**Criterion (c)** the place has significant heritage value because of the place's potential to yield information that will contribute to an understanding of Australia's natural or cultural history.	**Criterion (e)** an item has potential to yield information that will contribute to an understanding of NSW's cultural or natural history (or the cultural or natural history of the local area)
Principal characteristics of a class	**Criterion (d)** the place has significant heritage value because of the place's importance in demonstrating the principal characteristics of: (i) a class of Australia's natural or cultural places, or (ii) a class of Australia's natural or cultural environments.	**Criterion (g)** an item is important in demonstrating the principal characteristics of a class of NSW's: ▪ Cultural or natural places; or ▪ Cultural or natural environments. (or a class of the local area's ▪ Cultural or natural places; or ▪ Cultural or natural environments.)
Aesthetic	**Criterion (e)** the place has significant heritage value because of the place's importance in exhibiting particular aesthetic characteristics valued by a community or cultural group.	**Criterion (c)** an item is important in demonstrating aesthetic characteristics and/or a high degree of creative or technical achievement in NSW (or the local area)
Creative or technical achievement	**Criterion (f)** the place has significant heritage value because of the place's importance in demonstrating a high degree of creative or technical achievement at a particular period.	**Criterion (c)** an item is important in demonstrating aesthetic characteristics and/or a high degree of creative or technical achievement in NSW (or the local area)

	Commonwealth heritage criteria	New South Wales heritage criteria
Social	**Criterion (g)** the place has significant heritage value because of the place's strong of special association with a particular community or cultural group for social, cultural or spiritual reasons.	**Criterion (d)** An item has strong or special associations with a particular community or cultural group in NSW (or the local area) for social, cultural or spiritual reasons
Associative	**Criterion (h)** the place has significant heritage value because of the place's special association with the life or works of a person, or group of persons, of importance in Australia's natural or cultural history.	**Criterion (b)** an item has strong or special association with the life or works of a person, or group of persons, of importance in NSW's cultural or natural history (or the cultural or natural history of the local area)
Indigenous tradition	**Criterion (i)** the place has significant heritage value because of the place's importance as part of indigenous tradition.	NSW laws provide separately for indigenous heritage (see *National Parks and Wildlife Act 1974*). Indigenous heritage is addressed in a separate report for the EIS.

Each of the criteria above will be considered in regard to the history and physical evidence of the heritage items identified. It is noted that the criteria detailed in the Australia ICOMOS Burra Charter (2013) are very similar to the Commonwealth criteria, and as such they are not considered separately. Each identified heritage item within the airport site will also be considered with regard to the *Australian Historic Themes Framework* (Australian Heritage Commission 2000).

As well as assessing a place against criteria for its heritage value, the Australian Heritage Council applies a 'significant threshold' test. This test helps the Council to judge the level of significance of a place's heritage value by asking 'just how important are these values?'. To be entered on the CHL, a place must have 'significant' heritage value (Department of the Environment, Heritage website, accessed June 2015). In guidelines prepared by the Australian Heritage Council for Commonwealth agencies on the identification of Commonwealth heritage values, it is stated that "the threshold for inclusion on the Commonwealth Heritage List is local heritage significance" (Australian Heritage Council 2010:7).

2.9 Definition of impacts

The potential impacts of the project on the heritage significance of European and other heritage items is described using two categories of potential impact: direct and indirect.

Direct impact is defined as physical change occurring to an item or place which results in the diminution of the European and other heritage values of that item or place. For the purposes of this report, direct impact is considered to be a likely consequence of any site or place situated within the airport site. Direct impact may include minor and peripheral changes, or large scale removal and destruction.

Indirect impact is defined as an impact to an item or place (or to its surrounding where those surroundings contribute significantly to the European and other heritage values of that item or place), where this is likely to occur within the study area, and as a consequence of the construction and operation of the project. The potential for indirect impact varies according to the nature of the item or place, its proximity to activities associated with the development and operation of the airport. Indirect impact may include impacts to landscapes and vistas, changing use, change to access, or changed associations.

2.10 Consultation informing this assessment

Consultation was undertaken with a number of stakeholders to inform this assessment.

A meeting was held with the Heritage Division of the OEH on 29 May 2015 to discuss the approach to the European and other heritage technical report. OEH expressed general satisfaction with the approach, and made it clear that although New South Wales heritage legislation and requirements did not apply to the airport site, the general consistency of the approach with State requirements was suitable. OEH acknowledged that all heritage items within the airport site would be directly impacted by the project, and was interested in the proposed mitigation measures for the airport site, particularly interpretation of the site and the recording of oral history.

A meeting was held with heritage staff from Liverpool City Council on 28 May 2015. The approach to the European and other heritage technical report was discussed. At this meeting, RPS handed over information regarding the location of Lawson's Inn, the location of which is incorrectly recorded in the Liverpool Local Environmental Plan (2008). Council staff were particularly interested in the recording of cultural plantings within the airport site and the collection of samples of these if they were determined to be heirloom varieties.

2.11 Relevant legislation and guidelines

Commonwealth legislation

Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act provides a legal framework for the protection and management of matters of national environmental significance, including World Heritage properties, National Heritage places and Commonwealth Heritage places. The EPBC Act also provides for the protection of heritage as part of the environment generally, in the case of actions by the Commonwealth or actions on Commonwealth land. The heritage lists addressed by the EPBC Act include the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage List (WHL), National Heritage List (NHL) and the Commonwealth Heritage List (CHL).

All WHL properties in Australia are 'matters of national environmental significance,' protected and managed under the EPBC Act (UNESCO 2014). The NHL protects places that have outstanding heritage value to the nation. The CHL protects places of heritage significance which are owned or managed by Australian Government agencies. The Commonwealth Department of the Environment is responsible for implementing national policy, programs and legislation to protect and conserve Australia's environment, water and heritage and promote climate action. The Minister's approval is required before an action is taken that has, will have or is likely to have a significant impact on places included on the WHL, NHL or CHL. Approval is also required for an action by the Commonwealth or on Commonwealth land which is likely to have a significant impact on heritage values, even if those values are not included in one of these lists. A 'heritage value' of a place includes the place's natural and cultural environment having aesthetic, historic, scientific or social value, or other significance, for current and future generations of Australians (EPBC Act s528).

The EPBC Act also provides for the management of places on the WHL, the NHL or the CHL.

Environment Protection and Biodiversity Conservation Regulation 2000

Under s341Z of the EPBC Act, Commonwealth agencies must take "all reasonable steps to assist the Minister and the Australian Heritage Council in the identification, assessment and monitoring of the place's Commonwealth Heritage values". Identification of heritage values is the first step in the process of

developing management strategies to guide the management and conservation of heritage values of items and places for present and future generations. Assessment of heritage values is undertaken in accordance with the CHL criteria as set out in the EPBC Regulation 2000 (No. 1) r10.03A. The threshold for listing is that the place has **significant** heritage value against one or more of the criteria.

Section 341ZA of the EPBC Act requires preparation of a heritage strategy for places owned or controlled by a Commonwealth agency, which identifies the Commonwealth heritage values and appropriate measures for the management of the places to "protect and conserve their Commonwealth Heritage values". The Commonwealth Heritage management principles, as set out in Schedule 7B (r10.03D) of the EPBC Regulations 2000, provide the guidelines for the appropriate management of Commonwealth Heritage places. The following principle is relevant to the local heritage environment:

> *3. The management of Commonwealth Heritage places should respect all heritage values of the place and seek to integrate, where appropriate, any Commonwealth, State, Territory and local government responsibilities for those places.*

In 2005, the Commonwealth Department of Transport and Regional Services (DOTARS, now known as DIRD) prepared a Heritage Strategy that complied with the EPBC Regulations and sections 341Z and 341ZA of the EPBC Act. The DOTARS Heritage Strategy included the 1700 hectare Commonwealth owned land at Badgerys Creek, within which are listed and potential heritage items described in Technical Paper No. 12. This report formed the background to the Non-Aboriginal Cultural Heritage chapter of the 1997 EIS.

In 2011, the Commonwealth Department of Infrastructure and Transport (now known as DIRD) engaged Godden Mackay Logan to prepare an updated Heritage Strategy in compliance with the EPBC Act and Regulations. This included basic processes for the assessment of Commonwealth of National heritage values, and is based on the Australia ICOMOS Burra Charter.

Although there are no items within the study area listed on the CHL, heritage values should be assessed in accordance with s341ZB of the EPBC Act, to determine whether any of the items or places warrant listing on the CHL.

Matters of national environmental significance

The Greater Blue Mountains Area (GBMA) is listed on the WHL and NHL and consists of 1.03 million hectares of sandstone plateaux, escarpments and gorges dominated by temperate eucalypt forest. The site comprises eight protected areas including Wollemi National Park, Blue Mountains National Park, Yengo National Park, Nattai National Park, Kanangra-Boyd National Park, Gardens of Stone National Park, Jenolan Caves Karst Reserve and Thirlmere Lakes National Park. The closest part of the GBMA is located approximately six kilometres north west of the airport site.

The GBMA was inscribed on the WHL in 2000 because it satisfies two of the criteria for natural values of outstanding universal value. It contains outstanding examples of ongoing ecological and biological processes significant in the evolution of Australia's highly diverse ecosystems and communities of plants and animals, particularly eucalypt dominated ecosystems; and significant natural habitats for the in situ conservation of biological diversity, including the eucalypts and eucalypt dominated communities, taxa with Gondwanan affinities, and taxa of conservation significance.

Apart from those particular features which have been recognised as having world heritage value, the GBMA has numerous other important values which complement and interact with its world heritage values. The GBMA includes numerous places of historic significance, some dating back to the earliest years of European settlement and exploration in Australia. Recorded sites demonstrating post-1788 human use are associated with:

- rural settlement, pastoral use and timber getting, for example Euroka and Burralow Creek (Blue Mountains National Park), a number of small graziers' huts in Wollemi National Park and cedar logging

roads and stock routes in the Kanangra-Boyd National Park;

- mining, for example the ruins of oil shale mines at Newnes and Baerami (Wollemi national Park), lead/silver/gold mines at Yerranderie (Blue Mountains National Park) and coal/shale mines at Jamison and Grose Valleys (Blue Mountains National Park);
- road and rail transport routes, for example parts of the Old Great North Road and the Putty Road/Old Bulga Road (Yengo National Park) which linked Sydney with the earliest settlements in the Hunter Valley and remnants of a mid nineteenth century pumping station (Thirlmere Lakes National Park) which supplied water for steam engines on the main southern railway line; and
- tourism and recreation; for example Jenolan Caves was one of the first tourist attractions in Australia, with visitation dating back to the early 1800s, and the Reserve contains numerous historic relics related to tourism and the village's infrastructure; many lookouts and walking tracks on the central Blue Mountains ridgeline (including Blue Mountains National Park) have been in continuous use since the late nineteenth century.

The project will not impact, directly or indirectly, on the heritage significance of any European or other heritage items within the GBMA. A full consideration of the potential impacts of the project to the GBMA is detailed in the EIS.

There are no places on the CHL within the airport site.

NSW legislation

Environmental Planning and Assessment Act 1979

The NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) is the main Act regulating land use planning and development in NSW. The EP&A Act provides for the making of two types of environmental planning instrument: Local Environmental Plans (LEPs), which cover local government areas; and State Environmental Planning Policies (SEPPs), which address matters of state or regional environmental planning significance. LEPs commonly identify, and have provisions for, the protection of locally significant heritage items and heritage conservation areas. The airport site is located wholly within the boundaries of the Liverpool local government area, although the Penrith local government area is immediately adjacent and within the study area.

Liverpool Local Environmental Plan 2008

Clause 5.10 of the Liverpool Local Environmental Plan 2008 (Liverpool LEP 2008) provides for the protection of items, places and archaeological sites which have been identified as having local heritage significance.

Heritage Act 1977

The NSW *Heritage Act 1977* provides protection for heritage places, buildings, works, relics, moveable objects, precincts and archaeological sites that are important to the people of NSW. These include items of Aboriginal and non-Aboriginal (European and other) heritage significance. Where these items have particular importance to the people of NSW, they are listed on the State Heritage Register (SHR).

Part 8 s170 of the Heritage Act requires NSW Government departments and agencies to maintain a Heritage and Conservation Register, commonly known as a s170 Register. These registers include items of Aboriginal and non-Aboriginal heritage significance.

The Historic Heritage Information Management System (HHIMS) replaced the previous National Parks and Wildlife Service Historic Places Register in August 2002, and enables OEH to meet its obligations under s170 of the *Heritage Act 1977*. HHIMS aids in the protection and management of these sites by maintaining and proving information about the nature, current status and location of sites. HHIMS information facilitates

inquiries, supports site protection, enables better management and research and provides the secure protection of sensitive cultural and historical information.

Heritage Regulation 2012

The NSW *Heritage Regulation 2012* assists in the administration of the NSW *Heritage Act 1977*. It details information such as fees and forms required for permits (Part 2), the minimum standards of repair for heritage items (Part 3) and miscellaneous information (Part 4) such as the minimum allowable time between recommendation of a heritage listing and its registration by the Minister and the types of items to be included in Heritage and Conservation Registers required to be maintained by NSW Government bodies under s170 of the NSW *Heritage Act 1977*.

Other agencies

National Trust of Australia (NSW)

The National Trust of Australia (NSW) is the NSW division of the Australian Council of National Trusts (ACNT). The ACNT is the national peak body for community-based, non-government organisation committed to promoting and conserving Australia's indigenous, natural and historic heritage. The ACNT was incorporated in 1965 and federates autonomous National Trusts in every Australian state and internal self-governing territory. Collectively, the constituent National Trusts own or manage over 300 heritage places, the majority of which are held in perpetuity.

The National Trust of Australia (NSW) maintains a register of landscapes, townscapes, buildings, industrial sites, cemeteries and other items or places which the Trust determines to have cultural significance and are worthy of conservation. There are currently over 12,000 items listed on the Trust's register. They are said to be Classified. The register is maintained for its historical, research, conservation and educational value, but does not offer statutory protection to heritage places. There are no Classified properties within the airport site.

Australian Institute of Architects

The NSW Chapter of the Australian Institute of Architects has maintained a register of significant architecture in the state since October 1949. By the early 1970s an agreement was reached with the National Trust of Australia that the focus of listings undertaken by the NSW Chapter would be buildings post 1900. The list is maintained for historical, research, conservation and educational values, but does not offer statutory protection. There are no listed properties within the airport site.

Guidelines

This assessment has been undertaken according to the principles outlined in the following documents.

- Australia ICOMOS, 2013, The Burra Charter: the Australia ICOMOS Charter for Places of Cultural Significance.
- Department of the Environment, 2013, EPBC Act Policy Statement 1.1 – Significant Impact Guidelines – Matters of National Environmental Significance.
- Department of the Environment, 2013, EPBC Act Policy Statement 1.2 - Significant Impact Guidelines – Actions on, or impacting upon, Commonwealth land, and actions by Commonwealth agencies.
- DOTARS Heritage Strategy, 2005.
- New South Wales Heritage Office, 1996, New South Wales Heritage Manual.

- Heritage Council of NSW, 2002, Statements of Heritage Impact.
- Heritage Council of NSW, 2001, Assessing Heritage Significance.
- Heritage Council of NSW, 2009, Assessing Significance for Historical Archaeological Sites and 'Relics'.

3 Existing environment

3.1 Historical context

This chapter provides a historical framework to understand local site histories. It will be used to establish the importance and rarity of the heritage values associated with each European and other heritage site identified in the airport site and study area.

Early exploration

European exploration and subsequent settlement of the western reaches of the colony of NSW along the Hawkesbury-Nepean river system began as early as 1789, when Governor Phillip led an expedition in search of arable land (Paul Davies Pty Ltd 2007:17). Lured by the rich alluvial soils of the Hawkesbury-Nepean, settlers established farms at Castlereagh, Emu Plains and Agnes Banks, but the unpredictable cycles of flood and drought in the 1790s caused serious financial hardship and prompted the search for suitable land in neighbouring districts.

European settlement in the Badgerys Creek area occurred around the same time as the earliest agriculturally driven expansion beyond the Sydney Cove and Parramatta settlements. The airport site was probably first crossed by Europeans in 1802 when botanist George Caley led a party through the Mulgoa Valley (Godden Mackay 1997:5-1). It is likely that a number of private expeditions were also undertaken in these formative years with the view of securing arable land that could sustain farming (Paul Davies Pty Ltd 2007:17-18). The intensive farming that had taken place to support the colony around Sydney and Parramatta had exhausted the soil, and alternative farming land was required.

Access to Sydney and fresh water from a number of creeks added to the appeal of Badgerys Creek. This was based on the principle that those who had the money would be more likely to provide advantages to the colony through capital investment in their property which would, in time, ease food shortages (Neustein and Associates 1992). Formal surveys of the Castlereagh Road and surrounding farms were commissioned in 1803 and of the Mulgoa Valley in 1809.

Aboriginal contact with Europeans

The traditional way of life for Aboriginal people changed markedly after the arrival of Europeans in the area. It is unclear how many Aboriginal people lived in the area, but the population of the western Cumberland Plain (including the airport site) was considered by settlers to be less dense than the coast (Australian Museum Consulting 2014:16).

George Caley's 1802 expedition party had contact with the local Aboriginal people, probably of the Cabrogal clan of the Darug, and described their huts, walking tracks and the effects of burning of the local environment between Prospect, South Creek and Cowpastures (Caley 1801:47). The use of fire had left the area like an "English Park… with large trees separated by a grassy understorey" (Keating 1996).

The settlement in the early 1800s was on the fringe of European expansion. The influx of settlers and the establishment of farms inevitably pushed the traditional owners off their land. Clashes occurred as was becoming common elsewhere along the frontier in NSW. In 1816 an Aboriginal uprising was reported at Bringelly where 30 Aboriginal people attacked a settler's farm. The following day a party of seven men crossed the Nepean River to track the party. In the resulting clash four Europeans were killed, one was wounded and two escaped. Fighting continued in the district until a military detachment was established at nearby Airds (Royal Australian Historical Society 1920).

European settlement and land tenure

With the exception of fertile tracts of land around the surrounding creeks and streams, the vast majority of land in the south-western Cumberland Plain was densely forested and comprised highly clayey soil, which was better suited for stock grazing and wheat growing (Keating 1996:10,22).

Initial land grants were made shortly after the turmoil surrounding the arrest of Governor Bligh during the Rum Rebellion of January 1808. Bligh had been seen by some of the most influential landholders and by the military, as being both obstructive and in some cases damaging to their interests.

On 26 January 1808, the twentieth anniversary of the establishment of the colony, John Macarthur wrote a letter to the commanding officer of the NSW Corps, Major Johnson, asking for the immediate arrest of the Governor. The letter read:

> *Sir,*
>
> *The present alarming state of this colony, in which every man's property, liberty and life is endangered, induces us most earnestly to implore you instantly to place Governor Bligh under an arrest and to assume the command of the colony. We pledge ourselves, at a moment of less agitation to come forward to support the measures with our fortunes and our lives.* (Clark 1979)

The letter was signed by Macarthur and over 100 other residents, including James Badgery and the brothers John and Gregory Blaxland. Badgery and John Blaxland were to receive substantial land grants under the succeeding administrations.

The first land grants in the region were used as a testing ground for the emerging social policies of the fledgling colony. The land grants here were larger than parcels which had been previously offered to settlers. These large parcels of land, supplemented by ample convict labour, were granted to settlers with enough capital to establish and manage substantial rural estates (Proudfoot 1990). It was intended that these rural capitalists would contribute resources for the betterment of the colony, raising surplus crops and livestock to feed the growing population. Land was granted by Governor Paterson on a freehold basis, and was later reissued by Governor Macquarie.

Settlement in the area began in 1809 with a grant to James Badgery of 840 acres at South Creek. Robert Lowe's grant of 1,000 acres at Bringelly in 1812 was next and in 1813, John Blaxland received a grant of 6,710 acres which he named *Luddenham* (Keating 1996) (refer Plate 1). Smaller grants were made to Sarah Howe, Edward Powell, Ellis Bent, D'Arcy Wentworth and Thomas Laycock.

James Badgery

James Badgery arrived in the colony onboard the *Walker* in November 1799 as an emigrant in the employ of William Paterson of the NSW Corps (Donald and Gulson 1996:2; Paul Davies Pty Ltd 2007:13). He had few financial resources and was not eligible for a land grant, but leased 11 acres on the Hawkesbury for farming purposes. Badgery farmed his land intensively and with the proceeds established a mill in Sydney. The mill proved so successful that by 1801, his property comprised a bakery, mill-house, dwelling and pigsty. In recognition of his new found wealth and status, he was granted 100 acres at Agnes Banks near Yarramundi Lagoon in 1803 (Donald and Gulson 1996:3, Liverpool City Council 2012:1). By 1806, it was reported that Badgery owned 225 bushels of wheat, 300 bushels of corn and 50 pigs (Donald and Gulson 1996:3).

In 1809 Badgery, who along with other Hawkesbury farmers had supported the arrest of Governor Bligh the year prior, was granted 840 acres at South Creek near Bringelly under the new administration headed by Colonel William Paterson (*Sydney Gazette and New South Wales Advertiser* 1809:2). The grant encompassed land to the north of Orphan School Road (now Elizabeth Drive) between South Creek and its unnamed western arm (now Badgerys Creek). His estate was named Exeter Farm after his childhood home in Devon, England (Paul Davies Pty Ltd 2007:13, Liston 2009:46, Liverpool City Council 2012:1).

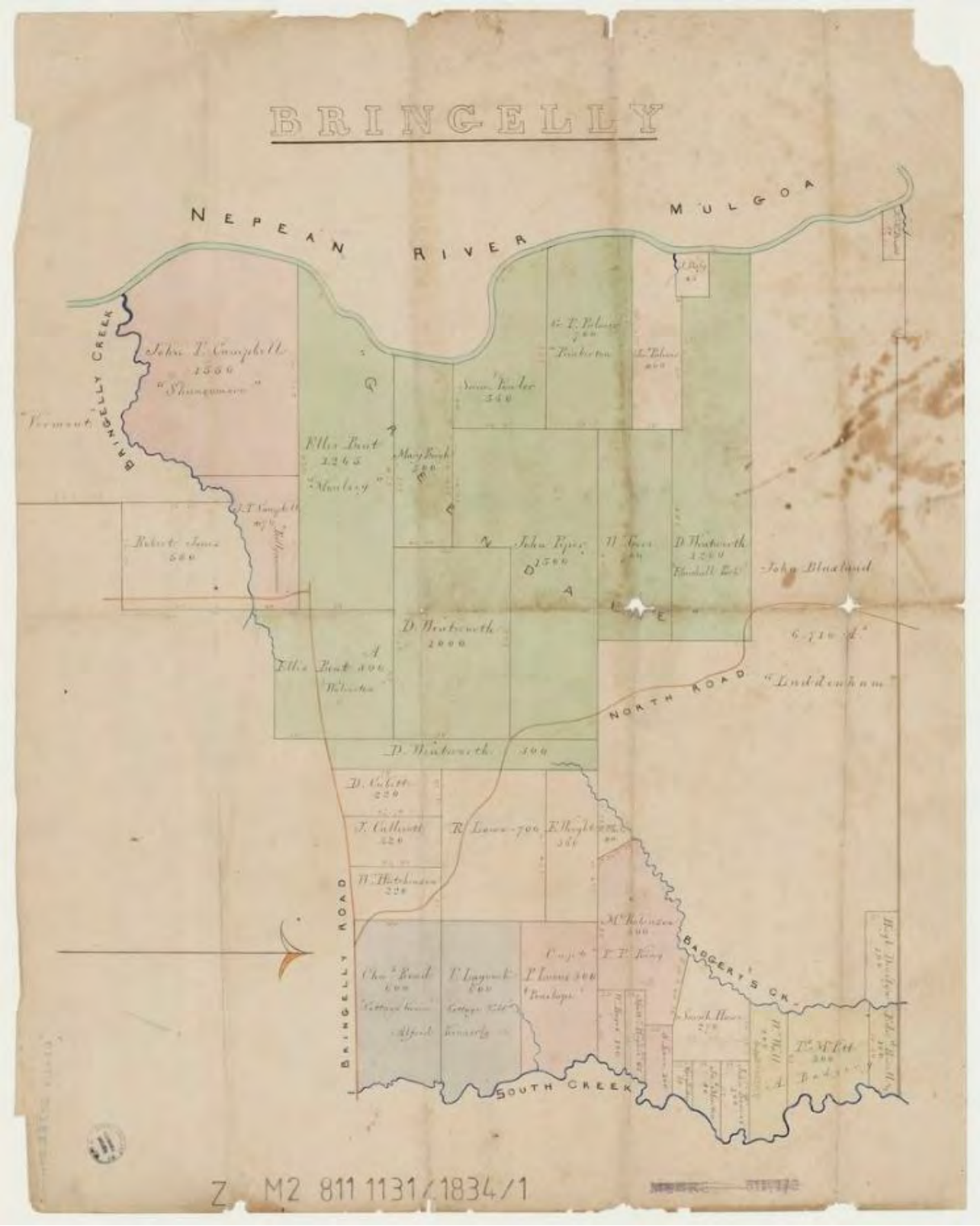


Plate 1 1835 map of Bringelly showing Blaxland's Luddenham property at the proposed airport site. (Source: National Library of Australia)

Many of the grants made under Paterson were recalled on the arrival of the replacement Governor, Lachlan Macquarie in 1810. James Badgery's was one of these and he had to re-apply for his land. Macquarie approved Badgery's application but reduced it to 640 acres which Badgery increased through purchase over

the following 10 years, to include an extra 1,300 acres (Donald and Gulson 1996:4, Keating 1996:22, Godden Mackay 1997:5-2, Paul Davies Pty Ltd 2007:12).

When it was first granted, Badgery's Exeter Farm estate was heavily wooded with ironbark and spotted gum. Badgery immediately set about constructing a wattle and daub hut on the property, which was rapidly replaced with a more substantial structure (Plate 2). During his tour of the interior of the colony between 1810 and 1811, Governor Macquarie inspected the farms of the Bringelly district, and made the following remarks on Badgerys' estate:

> *Called first at Badgerys Farm close on the left bank of the South Creek, where I was much pleased to find a good Farm House built, a good Garden, and a considerable quantity of ground cleared.* (Macquarie 1956 [1810-1811]:19)

Badgery used Exeter Farm to establish a vast farming enterprise where he produced grain and bred cattle, sheep and champion horses (*Sydney Gazette and New South Wales Advertised* 1823:2, Donald and Gulson 1996:4, Paul Davies Pty Ltd 2007:13). He frequently leased thoroughbred bulls to neighbouring landowners for breeding, and was a well known breeder of racehorses and workhorses (Liston 2009:46). In 1815, he constructed a road through Lord Folly's property from his Exeter Farm to another farm he owned in the Nepean, to save himself the trouble of using the main road. This road became known as Badgerys Creek Road and saved a total distance of 15 miles (*Sydney Gazette and New South Wales Advertiser* 1822:2).

Throughout the 1810s and 1820s, the Badgery family continued to expand their holdings, purchasing properties on the southern side of Orphan School Road and in neighbouring districts (Australian Museum Consulting 2014:20). In 1818, James Badgery offered farming land for lease at Richmond, where 100 acres were cleared and the greater part of that was already in cultivation (*Sydney Gazette and New South Wales Advertiser* 1818:2). By 1820, he purchased a further 1,300 acres and owned 450 head of cattle, 16 horses and over 650 sheep (Donald and Gulson 1996:5).



Plate 2 Photo of the substantial brick Exeter Farm house, originally constructed by James Badgery. Photography was taken in 1995 before the house was demolished. (Source: Liverpool City Library, Heritage Library Collection, 1776-12).

James Badgery died at Exeter Farm in 1827, "a very old and highly respectable emigrant, leaving a wife and large family" (*The Monitor* 1827:6). He was described as industrious, frugal and a most hospitable traditional

English farmer, and left his family a vast estate of over 1,900 acres (*The Monitor* 1827:3, Paul Davies Pty Ltd 2007:13).

Robert Lowe

Robert Lowe (1783-1832) arrived in NSW from London with his wife and two children in the *Mary* in May 1812. He brought an official letter testifying to his respectable connections, and recommending him for a liberal land grant since he possessed property worth £1,000. As a result he was granted 1,000 acres at Bringelly in August 1812, and a further 500 acres in September 1818. He named the property *Birling* for the town on the Sussex coast near his wife's former home, and extended the property until in 1828 it amounted to 5,600 acres (Godden Mackay 1997:5-3, Liston 2009:41, Parsons 1967). Lowe also held 1,280 acres at Liverpool, and was later granted a ticket of occupation in the Mudgee and Bathurst districts to graze sheep and cattle (Parsons 1967).

At Bringelly, Lowe immediately constructed a homestead called Birling Gap, though it was destroyed by fire shortly thereafter (Austral Archaeology Pty Ltd 2011:112). A second homestead was constructed in close proximity to the first and featured a substantial wrap-around veranda under a broken-back shingled roof (Plate 3) (Apperley 1994:26).

Lowe was appointed by Macquarie to be magistrate for the Badgerys Creek, Bringelly area from 1815 and for the County of Cumberland from 1820. He held the Bringelly Court at Birling, which was strategically located near the junction of The Northern Road and Bringelly Road. In Court, the local convict workforce was assigned to settlers, punished for misdeeds and had their tickets of leave issued (Liston 2009:4).

In July 1820, Lowe wrote to Commissioner John Thomas Bigge who was in the colony to inquire into conditions under Governor Macquarie. Lowe expressed the view that convicts could be better rehabilitated if employed in agricultural pursuits on the estates surrounding the settled townships. He believed that convicts left in the town of Sydney congregating with other convicts would remain set in their ways and were more likely to re-offend. Under the direction of sober and industrious masters, the convicts, according to Lowe, would have time to think of their deeds (Lowe 1820, Godden Mackay 1997:5-3, Parsons 1967). Lowe was vocal in his distaste for the allocation of convicts:

> *I must observe that the convicts are not fairly distributed. They are mustered at Sydney upon their arrival and after the mechanics all the better farmers men are separated for the use of Government, the wants of the people of Sydney are next consulted… I can confidently assert that amongst the last three allotments of convicts to the district of Bringelly or Cook not one useful farming man could be found amongst them.* (Lowe 1820)

Lowe also complained about the lack of mechanical skills amongst the convicts, and the distance of 40 miles return to Parramatta that had to be covered in order to gain repairs on carts or ploughs. Sarah Matthews, wife of Government Surveyor Felton Matthews, who accompanied her husband on his trips, described The Northern Road in 1833 as having been laid down without any regard to the nature of the land with some areas being close to impassable due to the clayey soil, especially after rain (Godden Mackay 1997:5-3). Other sections traversed the steepest part of hills or the deepest hollows. With poor maintenance, including on bridges, the trip was arduous and slow, and made more perilous with bushranging gangs operating in the area, including those of Jack Donohue (Proudfoot 1990).

Following the death of his first wide Barbara in 1818, Lowe married 21 year old widow Sarah Hazard in 1821, who bore him a further three sons and three daughters. Following Robert's death in 1832, Sarah and her children abandoned their Birling Estate for their Goree property in the Mudgee district, where she died in 1878 (Parsons 1967).

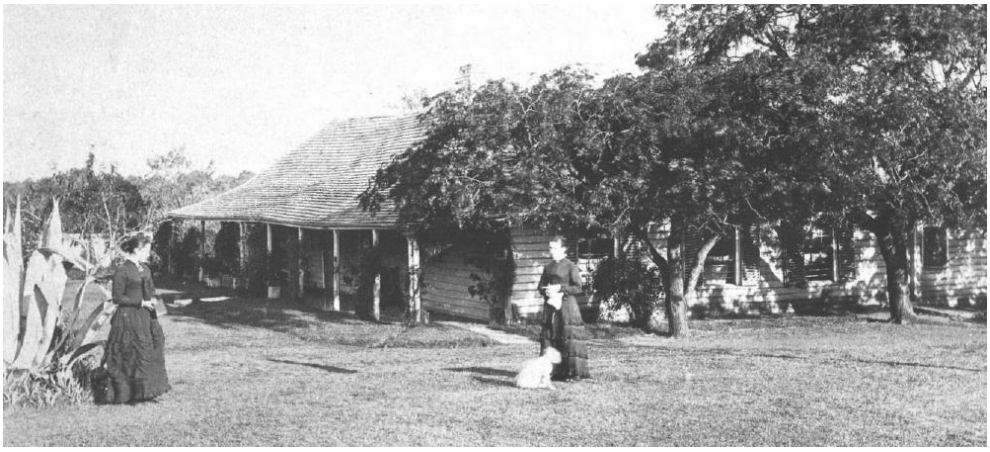


Plate 3 Members of the Lowe family outside the second Birling Gap, photograph taken in the 1880s. (Source: Liston 2009:41)

John Blaxland

At the time of the first Crown grants made by Governor Macquarie the Badgerys Creek area represented the new frontier of settlement and was characterized by moderately fertile soils and open forest. The largest landholder in the region, whose land covered much of the airport site, was John Blaxland.

John and Gregory Blaxland arrived in NSW in 1806 as wealthy free settlers in the convict colony. John had managed his family farms in Kent and was convinced by Sir Joseph Banks that NSW offered greater opportunities for financial advancement (Liston 2009:38). The brothers were enticed by the promise of 5,000 acres of land, the use of 18 convicts for 18 months and free passage for their family and goods (Godden Mackay 1997:5-4, Paul Davies Pty Ltd 2007:34).

Despite poor relations with Governor Blight and subsequently with Governor Macquarie, John Blaxland, as one of the first wealthy capitalist farmers to arrive in the colony, was granted 6,710 acres in 1813, stretching from Badgerys Creek to the Nepean River, which he named *Luddenham* (Donald and Gulson 1996:12, Keating 1996:24).

While John Blaxland based himself at Newington on the Parramatta River where he fattened, slaughtered and sold cattle, Luddenham Estate was used exclusively as grazing property. It appears the Blaxland brothers were utilizing the land at Luddenham as early as 1810. When Governor Macquarie inspected their Luddenham Estate during a tour of the Bringelly district, he remarked:

> *Thence we proceeded to Mr. Blaxland's own farms, about 5 or six miles distant from the South Creek in a westerly direction. This is entirely as yet a grazing farm, with only a miserable hut for the stock keepers, and stock-yards for the cattle. The land in some parts is tolerably good, and is pretty well watered, but is better adapted to grazing than tillage.* (Macquarie 1956 [1810-1811]:19)

From 1813 until his death in 1845, Blaxland ran sheep and cattle on the property, gradually clearing it to develop pasture. Although he was running 462 cattle and over 2,600 sheep by 1821, this was not a significant number considering that he was in the richest area for agriculture in the colony (Keating 1996:29). In fact, Blaxland as an absentee landlord, had been criticized for neglecting his property and concentrating on cattle instead of growing grain when the colony was short of food. Blaxland's absenteeism could explain why no substantial dwelling was ever erected on the property (Godden Mackay 1997:5-4).

Blaxland did develop the western portion of Luddenham Estate, principally along the Nepean River. In 1834, he constructed a dam across the Nepean River, and a water-powered timber and stone wheat mill. He also erected simple housing for the overseers and convict workers, as well as massive storehouses for grain

(Donald and Gulson 1996:14, Keating 1996:45, Paul Davies Pty Ltd 2007:29-30). These were located on high ground above the mill, and were described by Sarah Matthews in 1833 as:

> *…nothing, a mere settler's habitation, of wood principally and set up with all other neglect of comfort, convenience and appearance, which is so strikingly displayed in all the earlier buildings of the colony, but it is most beautifully situated, on the summit of a gentle slope which rises from the river's banks.* (Harvard 1943 [Matthews 1833]:100, Royal Australian Historical Society 1920)

It was from Blaxland's property that the successful crossing of the Blue Mountains started in May 1813. The expedition, which included John's brother Gregory, established a viable crossing over the mountains, and returned to John's property 26 days later.

By 1839, Blaxland had developed the western portion of his Luddenham Estate further, installing rabbit warrens and constructing a brewery with a malt house complete with brewing coppers, vats, steam engine, coolers, malt mill, cask and brewing utensils valued at £7,000. The brewery reportedly used hops grown on Blaxland's Newington Estate, had a workforce of 300 men and was in operation until the late 1850s when it was destroyed by flooding of the Nepean River (Keating 1996:45, 50, Paul Davies Pty Ltd 2007:29-30, Liston 2009:38). By the end of the 1830s, Blaxland's land and associated properties, totaling 29,000 acres, was valued at £30,000.

The depression of the 1840s severely affected the Blaxland family and in 1841, they were forced to mortgage the estate. Following Blaxland's death in 1845 the family struggled to make mortgage repayments. In default of payment, the family was forced to sell the Luddenham Estate, which was purchased by Sir Charles Nicholson (Keating 1996:69, Godden Mackay 1997:5-6).

Other grantees and estates

Sarah Howe

Other grantees of note in the area included Sarah Howe. Independently wealthy after being widowed by her first husband in 1811, Howe was granted 270 acres along the eastern bank of Badgerys Creek. Her land was one of the grants that had been created on what was to have been common grazing land. The common had been proposed by Governor Macquarie in 1811 after his visit to the region the year before, but was incorporated into the local grants after it was discovered that the land would not be good enough to support small landholders (Keating 1996:22). Sarah went on to marry George Howe, printer of the *Sydney Gazette and New South Wales Advertiser.* Howe's estate was eventually purchased by the grandson of Governor Gidley Philip King (Liverpool City Council 2012:1).

Ellis Bent

Living nearby at Bringelly was Ellis Bent, who having come to Australia with Governor Macquarie, was appointed Deputy Chief Judge Advocate. While he is attributed with naming the area Bringelly after an estate he owned in Wales, other reports suggest it comes from the Aboriginal word Bringelli, meaning unobtainable.

D'Arcy Wentworth

Another prominent landholder in the area was D'Arcy Wentworth. Wentworth arrived in NSW in June 1790 having agreed to emigrate after being acquitted on three counts of highway robbery. After being transferred to Norfolk Island as assistant in the hospital, he returned to Sydney in February 1809 as assistant surgeon to the colony. In 1816, Wentworth was granted 1,200 acres between The Northern Road and the Nepean River, which he called *Greendale*. By this time, The Northern Road was an important public road connecting the town settlement at Richmond with the rural estates at Cowpastures (now Camden area), and was maintained by both the local populace and the Government (Paul Davies Pty Ltd 2007:41). By 1818 Wentworth held a considerable amount of land in various grants, including one adjoining Blaxland's

Luddenham Estate (Godden Mackay 1997). At the time of his death in 1827, Wentworth was one of the wealthiest people in the colony and left 22,000 acres of land in his will to numerous heirs (Keating 1996).

Thomas Laycock

Of the remaining grants, that of Thomas Laycock is significant in that his house, Kelvin Park (SA2), remains as a near-complete example of a rural homestead plus associated buildings dating from the 1820s to 1850s. Laycock arrived in NSW as a child and was commissioned as an ensign with the New South Wales Corps in 1795 when he was nine years old (Australian Museum Consulting 2014:22). He left for England in 1810 with his wife but returned to Sydney seven years later, and after the death of his first wife, remarried and established himself in Sydney. In late 1817, he received a grant of 600 acres in the District of Bringelly along the western side of South Creek, which he called *Cottage Vale* (Australian Museum Consulting 2014:22). He purchased the adjoining farm, *Cottage Grove*, which had been owned by Charles Reid and had a frontage to Bringelly Road. In the 1820s, Laycock constructed an elegant brick home of eight rooms surrounded by a veranda on three sides, as well as a dairy, a cellar, a coach house and other outbuildings. Laycock had little time to appreciate his surroundings, and died unexpectedly at his Bringelly estate in 1823 (Keating 1996:25, Liston 2009:40). Laycock's holdings were immediately purchased by neighbor John Thomas Campbell, who renamed it *The Retreat* and immediately advertised the 1,200 acre estate for rent:

> *Retreat contains 1200 acres, is all enclosed, has 200 acres and upwards (constituting a beautiful lawn) cleared and fenced in; the remainder of the estate is also divided into several paddocks. On this estate there is a handsome and roomy residence, fit for the immediate reception of a gentleman's family.* (*The Australian* 1824:2)

From 1825 to 1833, The Retreat served as the first Australian headquarters of the Australian Agricultural Company. Formed in 1824 with the aim of breeding fine-wooled sheep in NSW, the Australian Agricultural Company used the site as its initial base. In December 1825, the appointed manager Robert Dawson and his employees, being 15 men, 14 women and 40 children, arrived in Sydney aboard the ships *York* and *Brothers*. These people, along with 600 sheep, 12 cattle and seven horses were accommodated at The Retreat. Most stayed only a short while before relocating to a one million acre grant at Port Stephens in 1826 (Godden Mackay 1997:5-5, Liston 2009:40). Dawson's reason for relocating his workers was that at The Retreat, he felt that they were surrounded by small settlers of bad character. Dawson was concerned that the inevitable contact that would occur between the locals and his own people "would produce bad consequences" (Australian Council of National Trusts 1982).

On the death of John Thomas Campbell in 1830, The Retreat was purchase by Alfred Kennerley who renamed the property Kelvin. Kelvin had several occupants after Kennerley moved to Tasmania in 1857 and eventually came into the ownership of the Macdonald family (Australian Museum Consulting 2014:23).

Lawson's Thistle Inn

Subdivision plans of the western and central portions of the Luddenham Estate show an inn, known as John Lawson's Thistle Inn (SA8), on the eastern side of The Northern Road immediately adjacent to D'Arcy Wentworth's Greendale estate (Plate 1). The exact date of construction is unclear but it is likely to have been built shortly after the establishment of The Northern Road in the 1820s to service travelers between Cowpastures and Richmond (Keating 1996:103). The Inn also functioned as a general store, and was used as a public meeting place for local residents throughout the 1860s. Following the death of John Lawson in 1885, it was maintained by members of the Lawson family, though it is unclear what fate befell the Inn thereafter (Australian Museum Consulting 2014:23). It was certainly abandoned, and may also have been demolished, by the 1930s (*Nepean Times* 1932:6).

The first phase of settlement and development in the Badgerys Creek area was characterized by the land grants and use of the land for grazing and wheat crops. In the broader area, smaller early land grants of 100 to 600 acres typically had river frontages, and were made to a number of settlers including Sarah Howe,

Thomas Laycock, D'Arcy Wentworth, William Hutchinson, Edward Powell, Thomas M. Pitt, William Wall and Gustavus A. Low (Australian Museum Consulting 2014:23). With the exception of those grants made to Laycock and Wentworth, it appears that these smaller grants remained largely undeveloped and were eventually purchased and incorporated into both Charles Nicholson's (formerly Blaxland's) and James Badgery's vast estates.

In the 1825 census, the Bringelly area had 717 free settlers and another 120 male convicts living there. The end of transportation and the consequent withdrawal of convict labour signaled the start of a decline in the fortune for the Bringelly and Badgerys Creek area. A severe drought from 1838 to 1840 resulted in wheat crop failure for two consecutive years. This was followed in 1841 by an economic depression due in part to a crash in wool prices and a reduction in British investment capital (Keating 1996). The increasing demand for land close to the growing population centres, the collapse of viable wheat farms after an outbreak of rust, and the de-population of the area as small tenant farmers moved in search of better land, culminated in the subdivision of many large estates into smaller allotments.

Rural subdivision

The most obvious effect of the downturn in the area was the sale and subsequent subdivision of Luddenham Estate. The breakup and sale of Luddenham Estate between 1859 and 1864 has been identified as the beginning of the next phase in the area, which saw the subvidision of the original grants.

Subdivisions of the mid-nineteenth century changed the pattern of land settlement in the region, by breaking up the larger estates into much smaller farming lots, and laying out streets and allotments in a regular grid and to a uniform street width. In many instances, this supplanted an existing irregular alignment of informal roads and paddock fence lines. The subdivisions were set out by private surveyors often working on different estates. Surveyor Samuel Jackson laid out the initial Luddenham and Regentville subdivisions representing an area of well over 10,000 acres (Paul Davies Pty Ltd 2007:49). The boundaries of earlier farms and their associated buildings, which included huts, barns, sheds, dams and a saw pit (AS6), were clearly marked on early survey plans (refer Plate 4). It is likely that these small properties were leased by tenant farmers prior to subdivision.

As a result of subdivision, small farmers were attracted to the area. Improvements were made, orchards and vineyards planted, and sometimes cottages built (Paul Davies 2007:13).

For instance, Franz Anschau and his family established a 200 acre vineyard south of Luddenham village in the late 1850s, complete with wine cellars, a substantial home and a working farm with sheep (AS14) (*Camden News* 1954:1). The Anschaus were German vineyard workers who were originally brought to Australia as wine dressers for the Macarthur and Cox families in Camden (Paul Davies Pty Ltd 2007:11). Vignerons brought out in this way were generally contracted for three years, though Germans were contracted for five, after which they often established vineyards of their own.

Land advertised as 'Luddenham Village' was offered for sale in 1859. Luddenham Village was located along the eastern boundary of The Northern Road and featured one acre and half acre blocks. In 1859, the central and western portions of Luddenham Estate had been surveyed (3,515 acres) and the survey of the eastern district (within the airport site, refer Plate 4) representing the balance of the estate at 4,158 acres, followed in 1862 on Nicolson's return to London. At the time of the 1859 survey, 2000 acres of the Estate was under cultivation, which over the following decades appears to have been managed by tenant farmers (*Sydney Morning* Herald 25 May 1859, Davies 2007:153).



Plate 4 Plan of the Eastern Division of the Luddenham Estate, by Samuel Jackson, 1859, showing various sized allotments for sale and details of existing structures and property boundaries. (Source: State Library of NSW)

Resident population figures at Luddenham are difficult to determine but by 1860, the local community warranted the establishment of a local school, and a post office followed in 1872 (*Sydney Morning Herald* 2 October 1860). The village was in close proximity to Lawson's Thistle Inn and made provisions for a church and a public reserve (Neustein and Associates 1992). Immediately surrounding the village, allotments of no more than 75 acres were offered, while lots of 100 to 300 acres were offered further east to the boundary of Badgerys Creek (Australian Museum Consulting 2014:24). When Nicholson returned to England in 1862, the remainder of the western and central divisions around Lawson's Thistle Inn was also auctioned (Kinhill Stearns 1985:215, Keating 1996:103).

Greville's Directory of 1872 noted 29 residents, and the village offered a range of services including two blacksmiths, a bootmaker, a butcher and an inn (Lawson's). Rural life revolved around farming, but Anschau had established his winery at his property Steinberg, and five local people were employed in the timber trade as sawyers and wood splitters (Paul Davies Pty Ltd 2007:153).

In 1885, Luddenham Estate was purchased by a syndicate of Sydney land developers and re-subdivided to form a patchwork of semi-rural allotments in freehold title. From this time, the village of Luddenham developed as a centre for civic services.

The small rural Luddenham village provided the surrounding estates with a focal point and Luddenham soon established itself as a viable settlement. A small weatherboard Methodist school was established in 1857 and was replaced with a more substantial brick school in 1862 (SA7) (Keating 1996:103, Godden Mackay 1997:5-6). On 1 March 1872, Luddenham Post Office was opened with local resident CH Beardow as the Post Master. The post office played an important role in the village, serving as a money order office from January 1885, acquiring a telephone and telegraph service from August 1905, and a Commonwealth

Savings Bank Office in April 1914 (Hopson and Tobin 1995). Both the Luddenham Uniting Church (SA15) and Progress Hall (SA14) were established in the 1880s (Australian Museum Consulting 2014:25).

In comparison to Luddenham, neither Bringelly nor Badgerys Creek developed into the same well defined village centres, despite being offered for sale on similar terms (Plate 5).

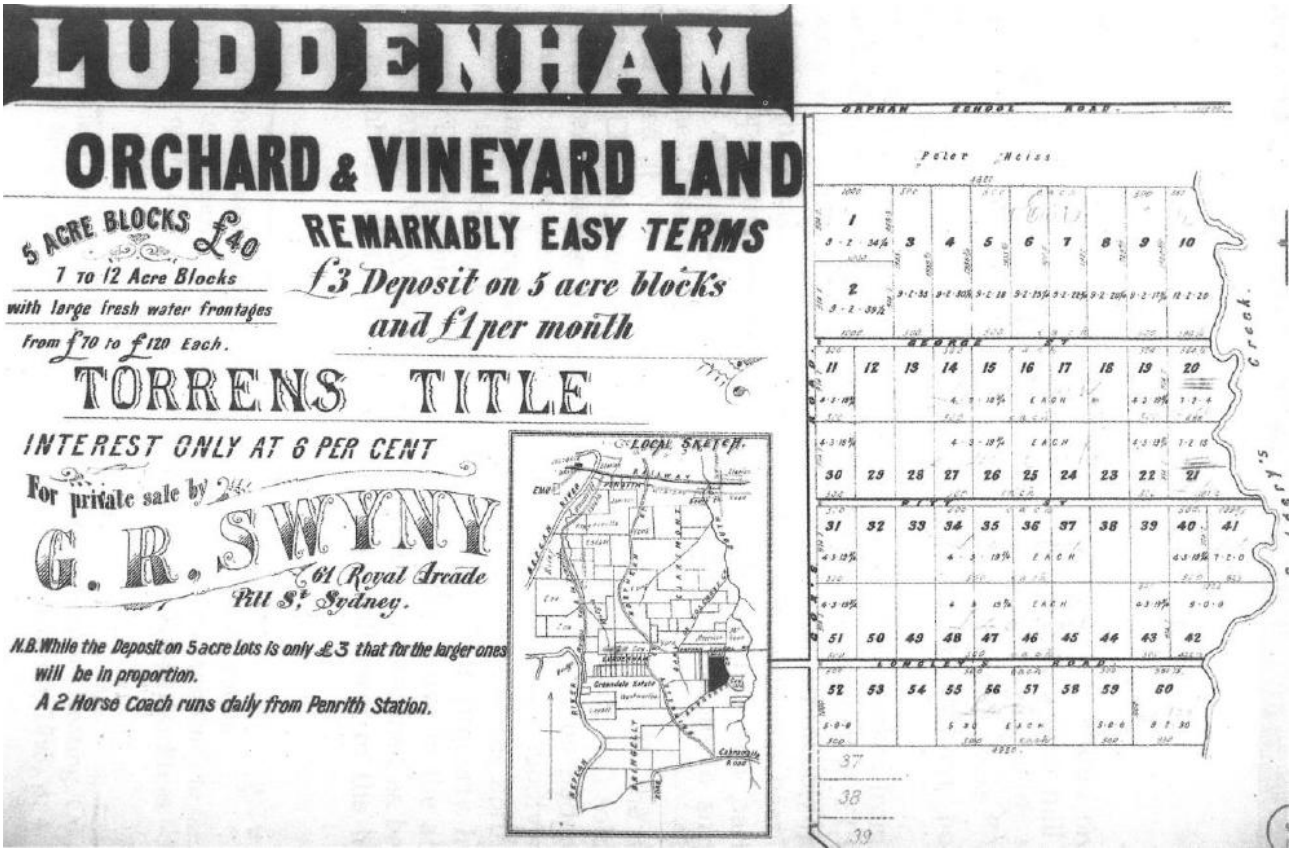


Plate 5 Undated advertisement for the sale of orchard and vineyard land on Nicholson's Luddenham Estate, between Cox's Road (now Badgerys Creek Road) and Badgerys Creek. (Source: Donald and Gulson 1996:15)

Around the turn of the century, the main alternative land use to grazing and cropping in the area was orchards. City families, displaced by the depression of the 1890s, were attracted by the subdivision of the large estates into smaller manageable land parcels. The subdivisions, many of lots between three and 10 acres, were designed to encourage settlement in the area. Reasonable deposits and easy repayments belied the trouble that many of these new farmers were to face. Inexperience, seasonal changes and small lots combined to make life difficult on the land.

Roads to Sydney such as Mulgoa Road (now Elizabeth Drive) and Bringelly Road were in poor condition, while the closest railway station was located 12 miles away at St Marys (Donald and Gulson 1996:9, Godden Mackay 1997:5-7). There was no easy access to waterways for taking perishable goods to market, so the area tended to be used for fruit growing, grazing, and for the production of milk for the local Liverpool area. Small orchards dominated land use on the smaller properties, while dairy farms and some vine growing occupied other farms (Godden Mackay 1997:5-7, Neustein and Associates 1992, Stearns 1985:216).

William Longley was one such farmer in the Badgerys Creek district who established an extensive, well-known fruit orchard, after purchasing land during the first Luddenham subdivision of 1859 (AS9, AS10). The Longley family grew fruit in the district for over 50 years before their estate was sold, together with their home and household furniture, in 1912 (*Camden News* 1912:8). Other orchards of the period, including

those belonging to the Anschaus, Booths, Outridges, Leggos and Smiths, “appeared to be well attended to… being trenches, ploughed, nicely pruned and free from weeds” (*Nepean Times* 1901:2).

Often, farmers in the area supplemented their farm income with a trade such as carting, shoemaking, coach building or stints at the local brick pits (Keating 1996:82). To service the small Badgerys Creek community, a butcher’s shop (AS4) was in operation from 1886, a public school (AS3) was opened on Badgerys Creek Road in 1895 (the school was closed by the Department of Education in 2014), and a Post Office (AS5) was established in 1896 (Paul Davies Pty Ltd 2007:38, Liverpool City Council 2012:2). St John’s Anglican Church (AS8) and Badgerys Creek Uniting (Methodist) Church (AS7) serviced local residents and were constructed in the early 1900s (Australian Museum Consulting 2014:26). Despite the modest development in the area, Badgerys Creek remained essentially rural and sparsely populated throughout the nineteenth century.

By 1904, the areas of Badgerys Creek, Luddenham and Bringelly were at least moderately settled when a Parliamentary Standing Committee was established for the purpose of determining the viability of a railway between Mulgoa and Liverpool (Australian Museum Consulting 2014:27). To the committee, William Leggo of Wallacia stated:

> *There has been considerable settlement at a place called Badgery’s Creek, about 6 miles from me, along the line of the railway. The settlers are mostly little men – men who go in for 10, 20, and 40 ac for poultry farming, bee farming and a little cultivation.* (New South Wales Parliamentary Standing Committee on Public Works 1904:26)

William Longley described how isolation limited what and how much farmers could grow:

> *We all grow a little of other things just for our own use, as well as fruit… the area could not be beaten for fruit growing in any part of NSW… But if we had a railway we should grow more. Even in the fruit-growing line, I could put in a lot more if I were near a railway; but at present, I am 12 miles from the railway station* [St Marys] *and my fruit is spoiled before it gets there, unless it is picked half-ripe* (New South Wales Parliamentary Standing Committee on Public Works 1904:30-31).

The proposed railway never eventuated and the districts of Badgerys Creek and Bringelly remained sparsely populated, retaining their rural character. It was noted that in the 1900s, there were still large areas available for purchase around Badgerys Creek and Nicholson Park Estate in Luddenham (Donald and Gulson 1996:11).

Local government representation was forced on Badgerys Creek by the government in 1906 through the establishment of Nepean Shire.

In 1916, Cecil Vicary purchased a portion of D’Arcy Wentworth’s Greendale estate for the purpose of establishing a dairy, grazing land and a vineyard (AS11). The property on the south western side of The Northern Road, opposite Anschau’s vineyard, had served as a working farm from the 1880s and featured a slab homestead, a woolshed and shearers quarters. Originally a sideline to running the sheep and dairy farm, the first grapes were planted in 1917 and commercial production began in 1923, though dairy cows were reared until the early 1940s (Australian Museum Consulting 2014:27). In the 1930s at the height of production, 65 hectares of land were in cultivation, though production began declining from the late 1930s (Australian Museum Consulting 2014:27; Lester Firth Associates 1991).

From the 1920s, further settlement occurred in Badgerys Creek, when portions of James Badgery’s early grant were subdivided under the provisions of the *Soldier Settlement Act 1919*. Exeter House was at that time in the ownership of the Stivens family, who later sold a portion of the Exeter estate to Ern Kent (Australian Museum Consulting 2014:27). In the 1930s, Kent sold his property to Peter Nobbs, who moved into the homestead with his family to pursue dairying (Donald and Gulson 1996:8-9, refer also Plate 6). In 1936, a large area with frontage to South Creek was acquired by the Commonwealth of Australia for a CSIRO research station for animal health – McMaster’s Field Station – and also for a short time was a field station for research into radio astronomy. The site was sold by CSIRO in 1996 (Paul Davies Pty Ltd

2007:14). Also in 1936 the Veterinary Department of the University of Sydney, in association with the McGarvie Smith Institute, purchased and developed a 160 hectare property at Badgerys Creek for the training of veterinary students in animal husbandry (SA20) (Paul Davies Pty Ltd 2007:14).



Plate 6 Ploughing on Nobbs' farm at Badgerys Creek in the 1940s. Note the hipped roof, bullnose veranda homestead, Exeter House, in the background. (Source: Liston 2009:46).

Rural intensification and land acquisition

The sparsely populated and rural nature of Badgerys Creek and its surrounding districts saw the establishment of a number of Government-funded research stations in the area from the 1950s. These facilities were located on former large land grants that had not been subdivided, particularly Thomas Laycock's Cottage Vale estate.

Cottage Vale was chosen as the site for the Overseas Telecommunications Commission (OTC) station (SA1) because of its isolation from intensive settlement, having only 200 residents living nearby at the time (Godden Mackay 1997:5-8). The OTC station was built from 1952-1955, as part of a final upgrade of the OTC facilities. The station provided radio telephone and telegraph services between Australia and a number of countries in Asia, America, South Africa and the United Kingdom, as well as ships at sea. Architectural firm Hennessey, Hennessey and Co. was commissioned to design the station and its associated staff quarters. Originally the station required staff to operate the equipment but by 1970 its operations were automated. With rapid changes in communications technology in the 1980s the station became obsolete (Liston 2009:44).

In 1955, the Royal Australian Air Force Radio Receiving Station was constructed immediately adjacent to the OTC station on a 550 acre property. The radio receiving station was designed to receive radio telegrams and telephone calls from 18 countries and from ships at sea. The station was installed to replace an earlier station at La Perouse and featured 32 rhombic-shaped aerials on masts ranging in height from 70 to 120 feet (Naval Intelligence Division 1955:17). Changes in technology rendered the radio receiving station obsolete and it was also dismantled in the late 1980s. Two water towers (SA3) are the key remaining structures associated with this site.

Land development changed little from the 1960s, with the establishment of intensive dairy and poultry farming, bee keeping, timber getting, horse and dog training and market gardening (Kinhill Stearns 1985:216, Paul Davies Pty Ltd 2007:14, Liverpool City Council 2012:1).

The districts of Badgerys Creek, Luddenham and Bringelly retain a great deal of their former rural character. Though subdivision and development of large estates has occurred, early slab cottages and substantial

homesteads, cisterns and sheds, vineyards and small rural allotments survive as tangible reminders of the district's humble beginnings. Market gardens, working farms, vineyards and close knit village communities pay homage to the district's rural development.

Proposal for a second airport

In the 1970s, Badgerys Creek became the focus for the proposed development of a second Sydney airport. The *Major Airport Needs of Sydney Study* (Major Airport Needs of Sydney Study Committee 1979) identified the Badgerys Creek area as its preferred site. The findings of the study were never seriously refuted and in response, the Commonwealth Government began buying property that might be affected by the construction of an airport in this location (Godden Mackay 1997).

Propositions for a second airport for Sydney were re-initiated in November 1985, when then Aviation Minister, the Hon Peter Morris OAM, lodged a submission noting that the airport at Mascot would be at capacity by about 2010. The Department of Aviation commissioned a report – *Second Sydney Airport Site Selection Programme: Draft Environmental Impact Statement* – prepared by Kinhill Stearns in April 1985, which included a preliminary assessment of sites at Badgerys Creek, Bringelly, Darkes Forest, Goulburn, Holsworthy, Londonderry, Scheyville, Somersby, Warnervale and Wilton. The Badgerys Creek and Wilton sites were determined to be the most promising and were assessed in more detail, with Badgerys Creek the recommended preferred option. With the construction of the third runway at Sydney (Kingsford Smith) Airport in the early 1990s, the proposal was deferred.

In 1996, the Howard Government came into power and the proposition of a second Sydney airport was again raised. The European and other heritage investigation into the Badgerys Creek site, prepared by Godden Mackay for inclusion in the *Draft Environmental Impact Statement: Second Sydney Airport Proposal* (PPK Environment & Infrastructure 1997) considered three options. Option A proposed at that time most closely aligns to the current project area, and was located on 1,700 hectares of land already owned by the Commonwealth. Following acquisition, properties were leased back to residents, commonly those who were the previous owners (Liverpool City Council 2012:2).

3.2 Physical context

Historic heritage register search

Historic heritage items or places identified on the relevant heritage registers and schedules within the study area are presented below. In all tables, shaded items are located within the airport site.

World Heritage List (WHL)

There are no World Heritage properties within the study area.

National Heritage List (NHL)

There are no currently listed National Heritage places in the study area.

The McGarvie Smith University Farm, located at 124 Elizabeth Drive, Badgerys Creek was nominated for the NHL, but the nomination is now ineligible (Table 2). Under the EPBC Act, the Australian Heritage Council can only assess places for the NHL if the places are on the Council's assessment work plan (known as the "priority assessment list"). The Minister sets this work plan each financial year. A nomination becomes ineligible if it has been considered for two consecutive work plans but not included. However a nominated place ruled ineligible in this way can be re-nominated, thereupon becoming eligible again for consideration. No detail is provided in the NHL as to why this item was not included in the priority assessment list.

The farm was the first veterinary farm established by Sydney University. Its benefactor, the McGarvie Smith Institute, utilised funding provided by Sir John McGarvie, the developer of the first 'long' living anthrax vaccine. The first vets trained at Sydney University utilised this facility for their hands-on training. The original laboratory and outbuilding still existed on the property at the time of nomination. The property has links with Sir Frederick Tout who commenced and helped to run the McGarvie Smith Animal Husbandry Farm. It was seen as the first step in the establishment of training and research farms which were later acknowledged as an integral part of the teaching programmes for veterinary science and agriculture.

Commonwealth Heritage List (CHL)

There are no currently listed Commonwealth Heritage places in the study area.

Register of the National Estate

There are two heritage items in the study area currently listed on the Register of the National Estate (Table 2).

Table 2 Heritage items or places within the study area on the Register of the National Estate

Place ID	Name	Property description	Significance	Distance from airport site
100263	Bringelly Radio Receiving Station Complex (Overseas Telecommunications Commission Site Group)	About 317 ha, Badgerys Creek Road, Bringelly	Not specified	1.6 kilometres south of Badgerys Creek boundary of the airport site
3298	Kelvin, Outbuildings and Curtilage	The Retreat, 3 km north east of Bringelly village	Not specified	2.3 kilometres south of Badgerys Creek boundary of the airport site

At the time of listing, Bringelly Radio Receiving Station Complex consisted of a total of 317.58 hectares, occupied by the main radio receiving station building, which was surrounded by a number of masts and a small 1950s staff housing development which consisted of fifteen domestic dwellings. The station is now decommissioned.

Kelvin is a stuccoed single storey Georgian farmhouse with sandstock brick kitchen, dairy, offices and a small carriage house at the rear.

State Heritage Register (SHR)

There is one item listed on the State Heritage Register within the study area (Table 3).

Table 3 Heritage items or places within the study area on the State Heritage Register

Item No.	Name	Property description	Significance	Distance from airport site
00046	Kelvin (also known as Kelvin Park Group, The Retreat, Thomas Laycock's Cottage Vale, Cottage-ville)	30 The Retreat, Bringelly Lot 2711, DP 1128906; Lot 2712, DP 1128906; Lot 2713, DP 1128906; Lot 271, DP 803167	State	2.3 kilometres south of Badgerys Creek boundary of the airport site

Historic Heritage Information Management System

There are no items listed on the Historic Heritage Information Management System in the study area.

S170 Heritage and Conservation Registers

There are no items listed on s170 Heritage and Conservation Registers in the study area.

Liverpool Local Environmental Plan 2008

There are 14 heritage items in the study area which are listed in the Liverpool LEP 2008. Three of these are within the airport site (Table 4).

- St John's Anglican Church group is located opposite Badgerys Creek Public School on Pitt Street.
- Badgerys Creek Public School is located at the north east corner of the intersection of Pitt Street with Badgerys Creek Road.
- Vicary's Winery Group is located on The Northern Road, south of Luddenham.

Table 4 Heritage items or places within the study area on Schedule 5 of the Liverpool LEP 2008.

Item No.	Name	Address	Property description	Significance as identified in Liverpool LEP 2008	Distance from airport site
2	St John's Anglican Church Group, including church and cemetery (former Badgerys Creek Anglican Church Group)	30 Pitt Street, Badgerys Creek	Part Lot 1, DP 838361 (formerly Lot 1, DP 795707)	Local	Within
3	Badgerys Creek Public School	Corner of Pitt Street and Badgerys Creek Road, Badgerys Creek	Part Lot 1, DP 838361 (formerly Lot 30, Sec D, DP1841)	Local	Within

Item No.	Name	Address	Property description	Significance as identified in Liverpool LEP 2008	Distance from airport site
4	Two water tanks (RAAF receiving station site and former water supply to OTC staff)	Badgerys Creek Road, Bringelly	Lot 1, DP 90328; Lot 1, DP 109666	Local	1.9 kilometres south of Badgerys Creek boundary of the airport site
5	Former OTC Site Group, including radio receiving station and site of former staff housing	Badgerys Creek Road, Bringelly	Lot 1, DP 109666	Local	1.6 kilometres south of Badgerys Creek boundary of the airport site
6	Dwelling and rural lot ("Mount Pleasant")	3 Shannon Road, Bringelly	Lot 44, DP 581187	Local	1 kilometre south of Badgerys Creek boundary of the airport site
7	Bringelly Public School Group, including schoolhouse and former headmaster's residence	1205 The Northern Road, Bringelly	Lot 50, DP 764911	Local	3.9 kilometres south of Badgerys Creek boundary of the airport site
8	Kelvin Park Group, including site landscaping, homestead, kitchen wing, servant's quarters, coach house, 2 slab barns and other works and relics (former "The Retreat", cottage vale, stables and lock-up)	30 The Retreat, Bringelly	Lots 2711-2714, DP 1128906	State	2.3 kilometres south of Badgerys Creek boundary of the airport site
24	Shadforth Monument (former pioneer's monument)	Greendale Road	Western side of Greendale Road, adjacent to the common boundary of Lot 1, DP520904 and Part Lot 1, DP 236562	Local	3.6 kilometres west of western boundary of the airport site
25	Private dwelling (former St Mark's Anglican Church Group, including church cemetery)	Greendale Road	Lot 1, DP 742417	Local	3.6 kilometres west of western boundary of the airport site

Item No.	Name	Address	Property description	Significance as identified in Liverpool LEP 2008	Distance from airport site
26	Greendale Roman Catholic Cemetery	Greendale Road	Lot 1, DP 195955	Local	3.6 kilometres west of western boundary of the airport site
50	Willmington Reserve	17 Jamison Street, Luddenham	Lot 7004, DP 93052	Local	300 metres north of the north western boundary of the airport site
51	Vicary's Winery Group, including woolshed, slab horse shed, land area and main house and garden	1935 The Northern Road, Luddenham	Lot 1, DP 838361	Local	Within
52	Luddenham Public School	The Northern Road, Luddenham	Lot 1, DP 194409	Local	300 metres north of the north western boundary of the airport site
53	Lawson's Inn site (former "The Thistle" site)	2155 The Northern Road, Luddenham	Lots 1 and 2, DP 851626 (formerly Lot 1, DP 793566)	Local	50 metres east of the airport site near Luddenham

It should be noted that Lawson's Inn site is incorrectly identified in Liverpool LEP 2008 as being located within the airport site. Based on the findings of the earlier SMEC site survey (2014), it has been assumed for the purposes of this study that the former Lawson's Inn site is not located within the airport site. The correct location is Lot 2 DP 623457, on the eastern side of the current alignment of The Northern Road, outside of the airport site.

Penrith Local Environmental Plan 2010

There are nine heritage items in the study area which are listed in the Penrith LEP 2010. None of these are within the airport site (Table 5).

Table 5 Heritage items or places within the study area on Schedule 5 of the Penrith LEP 2010.

Item No.	Name	Address	Property description	Significance as identified in Penrith LEP 2010	Distance from airport site
117	Brick cottage	21-55 Campbell Street, Luddenham	Lot 1, DP 972057	Local	780 metres north west of northern boundary of the airport site

Item No.	Name	Address	Property description	Significance as identified in Penrith LEP 2010	Distance from airport site
843	Luddenham Road Alignment	Luddenham Road, Luddenham		Local	475 metres west of the Elizabeth Drive boundary of the airport site
678	Weatherboard cottage	3065-3067 The Northern Road, Luddenham	Lot 1, DP 930372	Local	700 metres north west of the northern boundary of the airport site
118	Weatherboard cottage	3075 The Northern Road, Luddenham	Lot 1, DP 304800	Local	650 metres north west of the northern boundary of the airport site
119	Luddenham Progress Hall	3091-3095 The Northern Road, Luddenham	Lot 7, DP 1655	Local	450 metres north west of the northern boundary of the airport site
120	Luddenham Uniting Church and Cemetery	3097-3099 The Northern Road, Luddenham	Lot 8, DP 1655	Local	390 metres north of the northern boundary of the airport site
122	St. James Anglican Church and Cemetery	3101-3125 The Northern Road, Luddenham	Lot 2, DP 529143	Local	150 metres north of the northern boundary of the airport site
830	Brick cottage	406 Park Road, Luddenham	Part Lot 2, Sec A, DP 1452	Local	Demolished
679	Showground	428-452 Park Road, Luddenham	Lot 1, DP 931631; Lot 2, DP 972057	Local	1.1 kilometres north west of the northern boundary of the airport site

Previous historical and archaeological assessments in the study area

Council heritage studies

In 2004, Penrith City Council commissioned the Penrith Heritage Study (Paul Davies Pty Ltd 2007). An earlier comprehensive heritage study of Penrith was completed in 1987 by Fox and Associates Pty Ltd. At that stage, the local government area of Penrith encompassed Badgerys Creek including part of the airport site. Following gazettal of Penrith Local Environmental Plan 1994, some 200 individual items and three heritage conservation areas identified in the 1987 heritage study were listed. None of these were within the airport site. As a result of the 2007 Penrith Heritage Study, no additional heritage items were identified within the airport site (Paul Davies Pty Ltd 2007, Penrith LEP 2010).

In 2004, FORM Architects Aust Pty Ltd prepared the *Liverpool Heritage Study Review* to inform the updated heritage schedule of the Liverpool LEP.

Previous historical and archaeological assessments of the airport site

The European and other heritage issues of the airport site have been subject to a number of past investigations. The first of these, *Second Sydney Airport Site Selection Programme: Draft Environmental Impact Statement* (Kinhill Stearns 1985) was commissioned by the Department of Aviation and considered the Badgerys Creek and Wilton areas as potential airport sites. Further assessment was undertaken about a decade later for inclusion in the *Second Sydney Airport Draft Environmental Impact Statement* and a *Supplement to the Draft EIS* (PPK Environment & Infrastructure Pty Ltd 1997 and 1999 respectively).

Godden Mackay, 1997, Technical Paper 12: Non-Aboriginal Cultural Heritage

Chapter 21 of the 1997 *Draft EIS* addressed non-Aboriginal (European and other) cultural heritage impacts of the then proposed Second Sydney Airport at Badgerys Creek. The chapter was based on the results of Godden Mackay's *Technical Paper 12: Non-Aboriginal Cultural Heritage*.

A total of 24 European and other heritage items were identified within and adjacent to the boundaries of the proposed Badgerys Creek airport site options through a combination of primary and secondary research including revision of existing heritage studies, review of heritage registers and site inspections (Table 8). Fourteen of these are located within the current airport site. Each identified heritage item was assessed using the criteria provided in the *NSW Heritage Manual* (Heritage Office, Department of Urban Affairs and Planning 1996). The report also detailed management measures to mitigate impacts to European and other heritage as a result of the proposed airport.

Australian Museum Consulting, 2014, Badgerys Creek Initial Environmental Survey: Historic Heritage

In 2014, Australian Museum Consulting was commissioned to prepare an historic heritage assessment of the airport site to inform the referral of the project to the Commonwealth Department of the Environment. The assessment built upon Godden Mackay's 1997 Non-Aboriginal Cultural Heritage study. Australian Museum Consulting identified eight European and other heritage items within the airport site and 19 European and other heritage items within the study area, reflecting the results of heritage register searches and the 1997 *Technical Paper 12* (Table 6).

Table 6 Heritage items or places identified in Godden Mackay 1997 *Technical Paper* and Australian Museum Consulting 2014 *Initial Environmental Survey*

Name	Address	Significance as identified in Godden Mackay 1997 and/or Australian Museum Consulting 2014	Identified in Godden Mackay 1997	Identified in Australian Museum Consulting 2014
Luddenham Public School	The Northern Road, Luddenham	Local	✓	✓
Vertical slab dairy c.1930	Lot 10, Adams Road, Badgerys Creek	Local	✓	✓

Name	Address	Significance as identified in Godden Mackay 1997 and/or Australian Museum Consulting 2014	Identified in Godden Mackay 1997	Identified in Australian Museum Consulting 2014
Luddenham Uniting Church, Cemetery and Progress Hall	The Northern Road, Luddenham	Regional[1]	✓	✓
Lawson's Inn site – demolished 1930s	The Northern Road, Luddenham	Regional[1]	✓	✓
Luddenham Anglican Church and Cemetery	The Northern Road, Luddenham	Regional[1]	✓	✓
Anchau [sic] vineyard site – vineyard operated up until c.1910	The Northern Road, Luddenham	Local	✓	✓
Vicary's Winery – c.1880s original house	The Northern Road, Luddenham	Regional[1]	✓	✓
Vicary's Winery – c.1910 Winery Building	The Northern Road, Luddenham	Regional[1]	✓	
Vicary's Winery – c.1880s woolshed	The Northern Road, Luddenham	Local	✓	
Vicary's Winery – c.1880s Shearers Quarters	The Northern Road, Luddenham	Regional[1]	✓	
'Evergreen' homestead – c.1900 small farm house	Off Derwent Road, Bringelly	Local	✓	✓
'Mount Pleasant' homestead – c.1900 small farm house	Shannon Road, Bringelly	Local	✓	✓
RAAF Water Tanks – two c.1950 steel elevated water tanks	Badgerys Creek Road, Bringelly	Local	✓	✓
Overseas Telecommunications Commission Bringelly Remote Receiving Station – c.1955 overseas radio receiving station	Badgerys Creek Road, Bringelly	Regional[1]	✓	✓
Kelvin Park – c.1820 Estate homestead and associated buildings	Off Kelvin Park Drive, Bringelly	State	✓	✓

Name	Address	Significance as identified in Godden Mackay 1997 and/or Australian Museum Consulting 2014	Identified in Godden Mackay 1997	Identified in Australian Museum Consulting 2014
Braeburn Homestead – turn of the century homestead	Private road off Longleys Road, Badgerys Creek	Local	✓	✓
Former Badgerys Creek butchery – c.1880s building	Badgerys Creek Road, Badgerys Creek	Local	✓	✓
St John's (Badgerys Creek) Anglican Church Cemetery – approximately 30 graves	Pitt Street, Badgerys Creek	Local	✓	✓
Badgerys Creek Methodist Church Cemetery – two graves	Pitt Street, Badgerys Creek	Local	✓	✓
Gardiner Road Farm Cottage – c.1900 weatherboard cottage	Gardiner Road, Badgerys Creek	Local	✓	✓
Gardiner Road Farm Outbuildings – c.1930s timber slab buildings	Gardiner Road, Badgerys Creek	Local	✓	✓
Pitt Street Bridge – steel truss bridge[2]	Pitt Street, Badgerys Creek	Local	✓	✓
Badgerys Creek Public School – c.1895 Public School building	Badgerys Creek Road, Badgerys Creek	Regional[1]	✓	✓
The Northern Road	The Northern Road, Badgerys Creek	Regional[1]	✓	✓
Greater Blue Mountains Area	Blue Mountains, Kanangra-Boyd, Gardens of Stone, Wollemi, Nattai, Yengo and Thirlmere Lakes National parks and Jenolan Karst Conservation Reserve	World	×	✓
Bringelly Public School Group, including schoolhouse and former headmaster's residence	1205 The Northern Road, Bringelly	Local	×	✓

Name	Address	Significance as identified in Godden Mackay 1997 and/or Australian Museum Consulting 2014	Identified in Godden Mackay 1997	Identified in Australian Museum Consulting 2014
Willmington Reserve	17 Jamison Street, Luddenham	Local	×	✓
Brick cottage	21-55 Campbell Street, Luddenham	Local	×	✓
Brick cottage	406 Park Street, Luddenham	Local	×	✓
Showground	428-452 Park Street, Luddenham	Local	×	✓
Cottage	3065-3067 The Northern Road, Luddenham	Local	×	✓
Cottage	3075 The Northern Road, Luddenham	Local	×	✓

[1] The category of regional heritage significance is no longer used.

[2] Pitt Street Bridge has since been relocated to Cabramatta Street, Miller.

Summary of previously identified European and other heritage places in the study area

Thirty three previously identified European and other heritage items are located within the study area. Of these, 24 are listed in formal heritage registers. Ten are located within the airport site. The key historical themes associated with the heritage items at the airport site are as follows:

Table 7 Australian historical themes of the European and other heritage items at the airport site

Theme	Heritage item
Peopling Australia	Anschau Vineyard
Developing local economies	Anschau Vineyard, Braeburn, Vicary's Winery, The Northern Road alignment, Badgerys Creek butchery site, Gardiner Road farm complex
Building settlements, towns and cities	Badgerys Creek Public School
Working	Anschau Vineyard, Braeburn, Vicary's Winery, Gardiner Road farm complex
Educating	Badgerys Creek Public School
Developing Australia's cultural life	St John's Anglican Church and cemetery, Badgerys Creek Uniting Church and cemetery
Marking the phases of life	St John's Anglican Church and cemetery, Badgerys Creek Uniting Church and cemetery

3.3 Predictive model for European and other heritage sites

A predictive model has been developed to identify the most likely types of European and other heritage sites to occur within the airport site, and areas with greater or lesser potential for the presence of European and other heritage sites.

The types and distribution of European and other heritage sites within the airport sites may consist of sites associated with:

- peopling Australia, particularly changing the face of rural Australia through migration;
- developing local economies, particularly the development of primary production, establishing communications, moving goods and people, farming for commercial profit, and feeding people;
- building settlements, towns and cities, particularly planning urban settlements;
- working on the land;
- educating, particularly establishing schools;
- developing Australia's cultural life, particularly worshipping, living in the country and rural settlements; and
- marking the phases of life, particularly dying.

A discussion of the predictive model as it applies to areas of the airport site is presented below.

Badgerys Creek

For the purposes of this report, the Badgerys Creek area is considered to be bounded to the east by Badgerys Creek and to the west by Oaky Creek. Badgerys Creek Road and Longleys Road are the major roads in the area.

Badgerys Creek was part of the Eastern Division of Luddenham Estate, which was originally subdivided as land suitable for orchards and vineyards. Recent land use within the Badgerys Creek area includes small rural allotments set about a central hub of village amenities, including two churches, a school, a former butcher, and post office and general store. There are a number of chicken farms present within the Badgerys Creek area.

European and other heritage sites within Badgerys Creek are likely to include sites associated with early land grants; the subdivision of Luddenham Estate; the development of orcharding and viticulture; farming and pastoral activities such as homesteads, sheds and other ancillary farming structures, farm machinery, stockyards, fence lines or other land subdivision markers; early roads including Badgerys Creek Road alignment; and places associated with the development of Badgerys Creek as a village hub, including civic amenities, religious sites, shops and communal places. Evidence of contact and convict periods may be encountered, although this is unlikely as very early homesteads were not present within the Badgerys Creek area.

Areas with greater potential for European and other heritage sites include those areas associated with known homesteads, elevated areas in close proximity to fresh water, and areas along historic roads.

Areas with lesser potential for European and other heritage sites include those areas which have been subject to substantial ground disturbance (notably the quarry site near Oaky Creek, south of Elizabeth Drive), and low-lying areas prone to flooding.

Luddenham

For the purposes of this report the Luddenham area is considered to be the remaining portion of the airport site, west of Oaky Creek.

The Luddenham area includes early land grants to Blaxland and Wentworth, and was later subdivided into smaller farms. Recent land use within the Luddenham area includes horse training facilities, vineyards, rural and semi-rural properties.

European and other heritage sites within the Luddenham area are likely to include sites associated with early land grants; the subdivision of those grants into smaller semi-rural parcels, the development of orcharding and viticulture including evidence of wineries, farming and pastoral activities including homesteads, dairies and other farming structures, farm machinery, stock yards, subdivision markers; and early roads including current and former alignments of The Northern Road. Other potential sites include early burials in association with the homesteads, particularly on older, larger family holdings inhabited prior to the construction of nearby churches.

Evidence of contact and convict periods may be encountered, although this is unlikely as very early homesteads were not present within the Luddenham area of the airport site.

Areas with greater potential for European and other heritage sites include those associated with known homesteads, elevated land in close proximity to fresh water, west facing slopes, and areas along historic roads.

Areas with lesser potential for European and other heritage sites include those which have been subject to substantial ground disturbance, and low-lying areas prone to flooding.

3.4 Field survey

Field survey was undertaken over four days from 1-2 April 2015 and 1-2 June 2015.

During the April 2015 field survey, eight additional European and other heritage sites were identified.

- Well at 1972 The Northern Road.
- Cottage at Lot 2 Jackson Road.
- Steinberg ruin.
- St Francis Xavier Church and cemetery.
- Orange Hill.
- Badgerys Creek post office site.
- Saw pit.
- Badgerys Creek Road alignment.

During the June 2015 field survey, two additional European and other heritage sites were identified.

- Spredenberg.
- Howe residence.

These sites are summarised in Table 8. Detailed descriptions, photographs, curtilage and significance assessments of these sites are presented in Appendix A.

3.5 Test excavation

Test excavation was undertaken over three days from 3-5 June 2015.

Following the field survey and research stages of this project, it was determined that the Orange Hill homestead site would require archaeological testing.

Orange Hill homestead is located approximately 450 metres south east of Braeburn and was identified by Australian Museum Consulting (2014) as the site of the original Orange Hill homestead (DIRD ID 404610) (Australian Museum Consulting 2014:44). This view was formed through consultation with a local landowner, who was aware of the existence of that home at that location. Surface evidence in 2015 included a small stand of cape honeysuckle trees, two wells and several sandstock bricks. It was noted by Australian Museum Consulting that no mortar was adhered to the bricks, leading them to conclude that the bricks may have predated the introduction of Portland cement in the 1870s (Australian Museum Consulting 2014:44). This timeframe is consistent with the known occupation by the Longley family on the property from around the 1860s. A line of trees on the adjacent property 404600 may have marked access to the site.

The purpose of test excavation was to identify the location of structural evidence associated with Orange Hill, identify the character of any remains to better understand the probable dates of the structure(s), and identify the potential for lengthy or continued occupation of the site.

A 2 x 1 metre trench was hand excavated over a feature comprising partially overgrown bricks embedded into the ground surface. The trench initially revealed a scatter of bricks, some whole, mostly broken. Following the removal of the bricks, an arranged course of sandstone blocks was uncovered, thought to be flagging or foundations of a building. Other evidence of occupation, including ceramics, glass, metal, a bead and a brass button with a military-style insignia were also recovered during the test excavation at Orange Hill.

Table 8 Results of field survey and test excavation, 2015

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
Corner of Pitt Street and Badgerys Creek Road, Badgerys Creek 404685	4 March 2015	Badgerys Creek Public School	Commonwealth	Inspection of site confirmed and updated the layout and description of the site as presented in Australian Museum Consulting 2014. School buildings had been subject to vandalism including arson and removal of copper wire. Monument to James Badgery had been removed by the NSW Department of Education to Luddenham Public School. The school orchard and garden area had been pulled out. The school principal's residence, a c.1960s brick building, was located immediately adjacent to the school at property 404686.

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
5 Gardiner Road, Badgerys Creek 404680, 404681	4 March 2015	Gardiner Road farm complex	Commonwealth	Inspection of the site confirmed and updated the layout and description of the site as presented in Australian Museum Consulting 2014. The farm complex had been abandoned and vandalised, and was boarded up and overgrown at the time of inspection. The alignment of the eastern part of Gardiner Road (then George Street) which was never constructed was marked by a row of mature trees.
Gardiner Road, Badgerys Creek	1 April 2015	None	None	No further heritage items were identified on Gardiner Road.
15 Pitt Street, Badgerys Creek 404773	1 April 2015	Badgerys Creek Uniting Church	Commonwealth	Inspection of site confirmed and updated general layout and description as presented in Australian Museum Consulting 2014. Possible presence of unmarked graves at this site noted. Evidence of church including building rubble, glass, ceramics etc. noted centrally on the site. Cultural plantings noted at the rear of the property.
30 Pitt Street, Badgerys Creek 404689	1 April 2015	St John's Anglican Church and cemetery	Commonwealth	Inspection of the site confirmed the general layout and description as presented in Australian Museum Consulting 2014. Numerous marked graves including one war grave, and a plinth. Likely to be unmarked graves at this site. Note the neighbour informed RPS that bones had been found during civil (drainage?) works behind the cemetery site.
Bridge over Badgerys Creek, Pitt Street	1 April 2015	Former location of heritage listed bridge, since relocated to Miller	None	Inspection of bridge confirmed that the heritage listed bridge had been relocated. The current bridge is of recent construction.
Pitt Street, Badgerys Creek	1 April 2015	None	None	No further heritage items were identified on Pitt Street.
Lot 51A Badgerys Creek Road, Badgerys Creek 404659	1 April 2015	Badgerys Creek butchery	Commonwealth	The site was inspected from the road as it was fenced off and locked. Inspection of the site confirmed the description as presented in Australian Museum Consulting 2014.

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
50 Longleys Road, Badgerys Creek 404637	1 April 2015	None	None	This site was inspected from the road as the site was fenced off and locked. A brick pile was noted at the north east of the property, further research was undertaken into previous structures on the site. The site was concluded to have no archaeological potential.
55 Longleys Road, Badgerys Creek 404600	2 April 2015	Braeburn homestead	Commonwealth	Inspection of the site confirmed the general layout and description as presented in Australian Museum Consulting 2014. The immediate vicinity of the homestead site had been subject to extensive recent ploughing, and the homestead site was under long grass. The concrete remains of the garage were visible. Extensive construction rubble was noted about the site, including broken bricks.
55 Longleys Road, Badgerys Creek 404600	1 June 2015	None	None	This site was identified by aerial photographs alone. An aerial photograph from 1947 indicated a small dwelling near the Longleys Road frontage of the property. Although some surface material was noted, it was of relatively modern (c. 1930-1940) manufacture and therefore not of any archaeological interest. The current leaseholder advised that it was the remains of a small red brick dwelling of relatively recent construction.
55 Longleys Road, Badgerys Creek 404600	1 June 2015	None	None	This site was identified by aerial photographs alone. It is currently used as a corral for cattle and has been repurposed from a relatively modern concrete slab. The purpose of the former structure is uncertain but is likely to have been a structure associated with the dwelling identified above.

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
55 Longleys Road, Badgerys Creek 404600	1 June 2015	Spredenburg	Unknown	This site was the area marked "Spredenburg" on the Eastern Division of the Luddenham Estate. A house was also noted in the general area of Spredenburg on the 1947 aerial. On inspection, the site was completely overgrown with blackberries, however a number of modern bricks and other builders' refuse were observed on the surface within and atop the blackberry bushes. No heritage building material was observed. The heritage significance of this site cannot be assessed until vegetation has been cleared from the site.
55 Longleys Road, Badgerys Creek 404600	1 June 2015	None	None	This site was marked as "Fencer's Hut" on the Eastern Division of the Luddenham Estate. A large area in the vicinity of the presumed location of the fencer's hut was surveyed however no surface evidence of the hut was identified. The ground surface was heavily vegetated with few exposures. Whilst there are few remaining examples of these huts, it is likely to have been a lightweight structure, and is unlikely to have left any evidence in the archaeological record which would have survived recent farming practices on the site.
Longleys Road, Badgerys Creek	1 April 2015	None	None	No further heritage items were identified on Longleys Road.
Lot 52, Badgerys Creek Road 404660	1 April 2015	Badgerys Creek post office	Commonwealth	This is the site of the former Badgerys Creek post office which was opened in1894. No surface evidence remains of the post office, however, it is likely that subsurface evidence is in situ on the site. The site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
61 Badgerys Creek Road, Badgerys Creek 404656	1 April 2015	Saw pit	Commonwealth	This property was inspected from the road as it was fenced and very overgrown at the time of inspection. The dam on this property is thought to be a former saw pit marked on an 1859 map of Luddenham Estate (refer Plate 4). The site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.
Corner Badgerys Creek Road and Longleys Road, Badgerys Creek 404363	5 June 2015	Howe Residence	Commonwealth	Analysis of the 1947 aerial photograph shows a residence at this site. A number of features consistent with the remains of a homestead were identified during the survey, including a square-rectangular area lined with exotic trees marking the residential area, a number of wooden posts, bricks and corrugated iron. A brick-lined circular depression was noted at the west of the residential area, most likely being the remains of a well. Some fence posts, both metal and timber, were still in place. It was concluded that an open area excavation would be appropriate to uncover the remains of the homestead and associated buildings. The site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.
Leggo Street, Badgerys Creek	1 April 2015	None	None	No heritage items were identified on Leggo Street.
Fuller Street, Badgerys Creek	1 April 2015	None	None	No heritage items were identified on Fuller Street.
Badgerys Creek Road, Badgerys Creek	1 April 2015	Badgerys Creek Road alignment	Commonwealth	Badgerys Creek Road is an early road alignment along a route originally chosen by James Badgery. Badgerys Creek road alignment within the airport site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
Badgerys Creek Road, Badgerys Creek	1 April 2015	None	None	No further heritage items were identified on Badgerys Creek Road.
5 Jagelman Street, Badgerys Creek 404610	2 April 2015, 2-4 June 2015	Orange Hill homestead	Commonwealth	This property is the location of a former homestead site, thought to be Orange Hill, which was owned by the Longley family. The site is marked by cape honeysuckle and two wells are present on the site. Building rubble including broken bricks was noted on the site. A line of trees on the adjacent property 404600 may have marked access to the site. A 2 x 1 metre trench was excavated over a feature comprising bricks embedded into the ground surface and partially overgrown with grass. This trench initially revealed a scatter of bricks, some whole, but most broken. Following removal of the bricks, an arranged course of shaped sandstone blocks were uncovered. Artefacts uncovered include an iron hinge, an iron door key, ceramic pieces, glass shards and nails. The site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.
Jagelman Road, Badgerys Creek	1 April 2015	None	None	No further heritage items were identified on Jagelman Road.

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
Lot 6 Taylors Road, Badgerys Creek	5 June 2015	None	None	This was the site of the cottage of former Badgerys Creek resident Thomas Shadlow. The descendants of the Shadlow family stayed in th Badgerys Creek area until the purchase of land by the Commonwealth Government in 1991. A modern construction consisting of a concrete slab and modern, machine made bricks was noted near the site of Shadlow's cottage. Substantial cut and fill had been undertaken at the site as part of that residence's construction. Adjacent to the concrete slab was a fenced area. This was surveyed as a potential site for Shadlow's cottage owing to a number of mature exotic plants having been identified within this fenced area. The area had recently been used for dumping of building material, forming mounds across the site. The current leaseholder of the property advised that this fenced area was the former works site for the construction of the nearby reservoir on Taylors Road and that it had been substantially modified. The leaseholder also advised that most of the land had been owned by David Howe, a descendant of Sarah Howe, one of the early settlers in the area, and that a well was located to the south of the property. This well was also inspected and found to be inconsistent with a well used for residential purposes. Given the extensive disturbance to the site, test excavations were considered unnecessary, particularly given the low potential for remains to be identified, and the low scientific value of any such remains. From all accounts, the cottage was unremarkable and not likely to contribute further to the knowledge of Badgerys Creek's cultural history.

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
Taylors Road, Badgerys Creek	1 April 2015	None	None	No further heritage items were identified on Taylors Road.
Winston Close	1 April 2015	None	None	No heritage items were identified on Winston Close.
1935 The Northern Road, Luddenham 404757	1 April 2015	Vicary's Winery	Commonwealth	Inspection of the site confirmed the general layout and description as presented in Australian Museum Consulting 2014. The slab horse shed recorded in 1992 no longer remains on site. A description of the structure in 1997 indicated its condition was very poor and collapse was imminent. Early farming and winemaking machinery was also noted on the site. The site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.
Lot 2 Jackson Road, Luddenham 404804	2 April 2015	Jackson Road cottage	Commonwealth	This property is the location of a c.1890 cottage with ancillary farming structures. The site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.
Jackson Road, Luddenham	2 April 2015	None	None	No further heritage items were identified on Jackson Road.
Lot 2 Anton Road, Luddenham 404604	2 April 2015	None	None	This property was viewed from the road. Two post and rail corral areas were visible on the property. These were later found to have no heritage significance
Anton Road, Luddenham	2 April 2015	None	None	No further heritage items were identified on Anton Road.
1 Ferndale Road, Badgerys Creek 404585	2 April 2015	None	None	Two substantial gate posts were identified on this property. Subsequent research into the property found no evidence to suggest this place has heritage significance.

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
1972 The Northern Road, Luddenham 404774	2 April 2015	Well	Commonwealth	At the time of the site inspection, the field team was informed that the house on this property had been constructed about a sandstone well. The well is likely to have been constructed by the Earlam family as part of their development of the property as an orchard and vineyard. The site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.
1966 The Northern Road, Luddenham 404607	2 April 2015	St Francis Xavier Church and cemetery	Commonwealth	Historic research and aerial photographs indicated that this property was the site of St Francis Xavier Church and cemetery. The Church was removed from the site and burials exhumed and reinterred at the Greendale Roman Catholic Church. The property was largely overgrown at the time of inspection, with large open areas of grass central to the property. The ruins of a structure including timber and a concrete slab were identified east of the former church site. The provenance of this structure is currently unknown. It is unknown whether all human remains were removed from this site, and it is likely that subsurface evidence of the church remains on the site. The site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
1845-1875 The Northern Road, Luddenham 404800	2 April 2015	Anschau Vineyard, Steinberg and grave(s)	Commonwealth	Inspection of the site identified the overgrown ruins of a homestead (Steinberg) and blacksmith tools located approximately 100 metres behind the current house complex. Several sandstock bricks, iron and other building materials were noted and mapped, however the extensive vegetation covering did not allow for a comprehensive assessment of the site. Four large timber posts formed a square around the site, possibly demarcating a residential precinct for the homestead. In June 2015, around the time the property was due to be vacated, the occupant reported a suspected grave on the site. At the time of reporting, the grave had not been subject to inspection, however this is likely to be the grave of an Anschau family member. The site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.
The Northern Road, Luddenham	2 April 2015	The Northern Road alignment	Commonwealth	Within the airport site The Northern Road alignment has been modified a number of times, including opposite St Francis Xavier Church, and near the site of Lawson's Inn. The Northern Road within the airport site is considered to have commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.
The Northern Road, Luddenham	2 April 2015	None	None	No further heritage items were identified within the airport site on The Northern Road.

Location, DIRD ID	Fieldwork date	European and other heritage items	Heritage significance	Results of survey
2170 Elizabeth Drive, Badgerys Creek 404573	2 April 2015	Pennell's property	Commonwealth	This property was viewed from the road as access was not permitted at the time of inspection. The property is marked on an 1859 map of the area as buildings on "Pennell's" property. It is likely that this site has subsurface evidence of Pennell's. The current building on this property is the Luddenham Scout Hall. In the event that evidence of Pennell's is identified on this site it is likely to be of commonwealth heritage significance and would be of local heritage significance if assessed under NSW legislation.
Elizabeth Drive, Badgerys Creek	2 April 2015	None	None	No further heritage items were identified within the airport site on Elizabeth Drive.
Martin Road, Badgerys Creek	2 April 2015	None	None	No heritage items were identified within the airport site on Martin Road.
Lawson Road, Badgerys Creek	2 April 2015	None	None	No heritage items were identified within the airport site on Lawson Road.
400 Willowdene Avenue, Luddenham 404802	2 April 2015	None	None	This property was viewed from the road as it was unavailable to access at the time of the inspection. The house was not visible from the street but was reported by the property manager as appearing to be a Federation cottage. A subsequent review of historical aerial photographs of the site indicates that there was no house on the site until at least the late 1970s. This property is not considered to have heritage significance.
Willowdene Avenue, Luddenham	2 April 2015	None	None	No heritage items were identified within the airport site on Willowdene Avenue.
Greendale Road, Greendale	2 April 2015	None	None	No heritage items were identified within the airport site on Greendale Road.

3.6 Effectiveness of the predictive model

The predictive model for European and other heritage at the airport site has been effective in comparison to the results of the survey. The types and distribution of heritage places identified during the assessment were generally consistent with those predicted. The survey generally confirmed the predictions for European and other heritage items made in the model particularly in relation to the level of disturbance and the corresponding absence of European and other heritage sites in those areas.

A number of place types were predicted but not identified at the airport site. These include sites with evidence of Aboriginal and European contact, including Aboriginal sites in close proximity to homesteads, and convict sites. This reflects the lack of established occupation in the form of homesteads associated with early land grants at the airport site.

The effectiveness of the predictive model within each part of the airport site is detailed below.

Badgerys Creek

Within the Badgerys Creek area, the predicted evidence of early land grants and the subdivision of Luddenham Estate (saw pit, Gardiner Road farm complex), the development of orcharding and viticulture, farming and pastoral activities (Orange Hill, Braeburn), early roads (Badgerys Creek Road alignment), and the development of Badgerys Creek as a village hub (Badgerys Creek Public School, St John's Anglican Church and cemetery, Badgerys Creek Uniting Church and cemetery, Badgerys Creek butchery site, Badgerys Creek post office) were identified.

The predicted site types of contact and convict sites were not identified within the Badgerys Creek area.

Luddenham

Within the Luddenham area, the predicted evidence of early land grants and the subdivision of those estates (Pennell's), the development of orcharding and viticulture including evidence of wineries (Anschau Vineyard, Vicary's Winery, well at 1972 The Northern Road), farming and pastoral activities including homesteads, dairies, other farming structures and farm machinery (Vicary's Winery, Jackson Road cottage, Steinberg), and early roads (The Northern Road alignment) were identified. A burial site in association with a homestead was identified on the site (Anschau grave at Steinberg).

The predicted site types of contact and convict sites were not identified within The Northern Road area.

3.7 Summary of historical and physical contexts

Table 9 provides a summary of all 41 heritage items identified during previous surveys and studies, recent heritage register searches, and the 2015 field work.

Table 9 Summary of all European and other heritage sites identified within the airport site and the study area

Item no.	Name	Location	Reference
European and other heritage items within the airport site			
AS1	Pennell's property	2170 Elizabeth Drive, Badgerys Creek	1859 Map of the Eastern Division of Luddenham Estate
AS2	Gardiner Road farm complex	5 Gardiner Road, Badgerys Creek	Godden Mackay 1997

Item no.	Name	Location	Reference
AS3	Badgerys Creek Public School	Corner of Pitt Street and Badgerys Creek Road, Badgerys Creek	Liverpool LEP 2008
AS4	Badgerys Creek butchery	Lot 51A Badgerys Creek Road, Badgerys Creek	Godden Mackay 1997
AS5	Badgerys Creek post office	Lot 52 Badgerys Creek Road, Badgerys Creek	Historic research
AS6	Saw pit	61 Badgerys Creek Road, Badgerys Creek	1859 Map of the Eastern Division of Luddenham Estate
AS7	Badgerys Creek Uniting Church and cemetery	15 Pitt Street, Badgerys Creek	Godden Mackay 1997
AS8	St John's Anglican Church and cemetery	30 Pitt Street, Badgerys Creek	Liverpool LEP 2008
AS9	Braeburn homestead	55 Longleys Road, Badgerys Creek	Godden Mackay 1997
AS10	Orange Hill homestead	5 Jagelman Street, Badgerys Creek	Australian Museum Consulting 2014, test excavation
AS11	Vicary's Winery	1935 The Northern Road, Luddenham	Liverpool LEP 2008
AS12	Well	1972 The Northern Road, Luddenham	Personal communication
AS13	The Northern Road alignment within the airport site	The Northern Road, Luddenham	Historic research
AS14	Anschau Vineyard, Steinberg and grave(s)	1845-1875 The Northern Road, Luddenham	Godden Mackay 1997
AS15	St Francis Xavier Church and cemetery	1966 The Northern Road, Luddenham	Historic research
AS16	Jackson Road cottage	Lot 2 Jackson Road, Luddenham	Field survey
AS17	Badgerys Creek Road alignment within the airport site	Badgerys Creek Road, Badgerys Creek	Historic research
AS18	Spredenberg	55 Longleys Road, Badgerys Creek	Field survey, 1859 Map of the Eastern Division of Luddenham Estate
AS19	Howe residence	Corner Badgerys Creek Road and Longleys Road, Badgerys Creek	Field survey, pers comm.
European and other heritage items within the study area			
SA1	Former Overseas Telecommunications Commission site group	Badgerys Creek Road, Bringelly	Liverpool LEP 2008
SA2	Kelvin	30 The Retreat, Bringelly	State heritage register, Liverpool LEP 2008

Item no.	Name	Location	Reference
SA3	Two RAAF water tanks	Badgerys Creek Road, Bringelly	Liverpool LEP 2008
SA4	Mount Pleasant homestead	3 Shannon Road, Bringelly	Liverpool LEP 2008
SA5	Bringelly Public School group	1205 The Northern Road, Bringelly	Liverpool LEP 2008
SA6	Willmington Reserve	17 Jamison Street, Luddenham	Liverpool LEP 2008
SA7	Luddenham Public School	The Northern Road, Luddenham	Liverpool LEP 2008
SA8	Lawson's Inn	Lot 2 DP 623457	Liverpool LEP 2008
SA9	McGarvie Smith University Farm	124 Elizabeth Drive, Badgerys Creek	National Heritage List
SA10	Brick cottage	21-55 Campbell Street, Luddenham	Penrith LEP 2010
SA11	Luddenham Road alignment	Luddenham Road, Luddenham	Penrith LEP 2010
SA12	Weatherboard cottage	3065-3067 The Northern Road, Luddenham	Penrith LEP 2010
SA13	Weatherboard cottage	3075 The Northern Road, Luddenham	Penrith LEP 2010
SA14	Luddenham Progress Hall	3091-3095 The Northern Road, Luddenham	Penrith LEP 2010
SA15	Luddenham Uniting Church and cemetery	3097-3099 The Northern Road, Luddenham	Penrith LEP 2010
SA16	St James Anglican Church and cemetery	3101-3125 The Northern Road, Luddenham	Penrith LEP 2010
SA17	Showground	428-452 Park Road, Luddenham	Penrith LEP 2010
SA18	Shadforth Monument	Greendale Road, Greendale	Liverpool LEP 2008
SA19	Private dwelling (former St Mark's Anglican Church Group, including church cemetery)	Greendale Road, Greendale	Liverpool LEP 2008
SA20	Greendale Roman Catholic Cemetery	Greendale Road, Greendale	Liverpool LEP 2008
SA21	Vertical slab dairy	Lot 10, Adams Road, Badgerys Creek	Godden Mackay 1997
SA22	Evergreen homestead	Off Derwent Road, Bringelly	Godden Mackay 1997

4 Significance assessment

4.1 Specific heritage items

A statement of heritage significance has been prepared for each of the 19 European and other heritage items identified within the airport site. These are summarised in Table 10, expanded upon in Appendix A, and mapped in Figure 2. Consistent with industry practice the significance assessments were based on a review of all available information including previous assessments, historic research, field investigations and stakeholder consultation.

Of all 19 European and other heritage items in the airport site, 18 items were considered to meet the criteria for Commonwealth significance. One item was unable to be assessed due to vegetation coverage and as such is considered to have unknown significance.

The potential impacts of the project on the heritage significance of the 19 European and other heritage items within the airport site are considered in Section 5.

Table 10 Summary of heritage significance of European and other heritage items within the airport site

Item no.	Name	Summary statement of significance	Australian themes	Level of significance
AS1	Pennell's property	Pennell's property is likely to contain subsurface archaeological evidence of an early homestead on the site. Pennell was a former convict come farmer's man, and evidence of his dwelling may reveal evidence of a mid nineteenth century farming property.	Working – working on the land Developing Australia's cultural life – living in and around Australian homes Developing Australia's cultural life – living in the country and rural settlements	Commonwealth
AS2	Gardiner Road farm complex	The Gardiner Road farm complex is a typical turn-of-the-century modest farm cottage which retains its (overgrown) gardens and semi-rural context. Although once common, cottages such as this have become rare in Western Sydney in the past three decades. The group of farm outbuildings were once typical of the area but are now rare in the vicinity. They demonstrate building techniques and designs for agricultural activities. They illustrate the nature of settlement in the Badgerys Creek area in the early twentieth century.	Developing local economies – developing primary production – breeding animals, developing agricultural industries Working – working on the land Developing Australia's cultural life – living in and around Australian homes Developing Australia's cultural life – living in the country and rural settlements	Commonwealth

Item no.	Name	Summary statement of significance	Australian themes	Level of significance
AS3	Badgerys Creek Public School	Badgerys Creek Public School was a fine and representative example of a small rural school which contained original elements that dateed to the turn of the century. The school has historic significance as an element in the development of the area, and aesthetic qualities in its historic buildings and setting. It has social significance for the local community and for past students and residents of the area. The integrity and intactness of the school has been compromised by vandalism and arson which has occurred since the school's closure in 2014. Badgerys Creek Public School site demonstrates the history of education and settlement in the area. It is located in the vicinity of two early churches and a community hall and serves as an epicentre for a widely dispersed community.	Building settlements, towns and cities – developing institutions Educating – establishing schools	Commonwealth
AS4	Badgerys Creek butchery	The Badgerys Creek butchery site is considered to be significant for its associations with the Shadlow family, and for its social significance as one of two retail outlets in Badgerys Creek.	Developing local, regional and national economies – feeding people – retailing foods and beverages	Commonwealth
AS5	Badgerys Creek post office	Badgerys Creek post office site is considered to be significant for its historic and social values. The establishment of a post office at Badgerys Creek signified its independence as a village, rather than as an outpost of Luddenham, St Mary's or Bringelly. The post office provided an important connection and central hub for the local community. It was an important centre of personal and official communication.	Developing local, regional and national economies – establishing communications – establishing postal services Building settlements, towns and cities – developing institutions, making settlements to serve rural Australia Governing – Administering Australia – providing services and welfare Governing – Establishing regional and local identity	Commonwealth

Item no.	Name	Summary statement of significance	Australian themes	Level of significance
AS6	Saw pit	The saw pit is considered have heritage significance for its historic values. There is very little surviving information relating to the site excepting an early map of the Badgerys Creek area. The site is currently full of water and as such, the research values of the site are unable to be determined.	Developing local, regional and national economies – utilising natural resources – making forests into a saleable resource	Commonwealth
AS7	Badgerys Creek Uniting Church and cemetery	Badgerys Creek Uniting Church and cemetery is considered have significance primarily for its historic, research, and social values. The Church was the first formal place of worship in Badgerys Creek, and despite being used by both Methodists and Anglicans, local worshippers attended every week regardless of personal affiliations. The cemetery has two marked graves, and is likely to have unmarked graves which may reveal evidence about early burial practices in the Badgerys Creek area.	Developing Australia's cultural life – worshipping – worshipping together, making places for worship Marking the phases of life – dying – dealing with human remains, mourning the dead, remembering the dead	Commonwealth
AS8	St John's Anglican Church and cemetery	St John's Anglican Church Group demonstrates the foundation and development of the Anglican Church in a small settlement, Badgerys Creek, in the environs of Liverpool. Many early families of the area are buried in the cemetery. The site also provides evidence of early native vegetation species of the area and introduced exotic plantings. The plantings are representative of late nineteenth and early twentieth century trends in cemetery landscaping. There is the potential to gain more information on the site from further architectural, archaeological and documentary research.	Developing Australia's cultural life – worshipping – worshipping together, making places for worship Marking the phases of life – dying – dealing with human remains, mourning the dead, remembering the dead	Commonwealth
AS9	Braeburn homestead site	Braeburn had a long time association with the Longley family of Badgerys Creek. The property is assessed as having heritage significance on the basis of its aesthetic, research and social values and association with the Longley family.	Developing Australia's cultural life – living in and around Australian homes Developing Australia's cultural life – living in the country and rural settlements	Commonwealth

Item no.	Name	Summary statement of significance	Australian themes	Level of significance
AS10	Orange Hill homestead site	Orange Hill was the original home in the area of the Longley family, who were well known and influential in the Badgerys Creek area. Orange Hill is considered to be significant for its historic and research values, and associations with significant people.	Developing Australia's cultural life – living in and around Australian homes Developing Australia's cultural life – living in the country and rural settlements	Commonwealth
AS11	Vicary's Winery	Vicary's Winery group is an intact set of structures which document the agricultural change in the Luddenham area since the original granting of land to Blaxland in the early nineteenth century. The group includes structures such as a slab house, slab hut and former dairy (woolshed) which relate to the small scale agricultural industry of the late nineteenth century. Since the twentieth century the group has been predominantly in use as a winery and its surviving vineyard and complex demonstrate the history of a once thriving, but now diminished, wine industry in the Luddenham, Badgerys Mulgoa area. It is Sydney's oldest continually operating winery.	Developing local, regional and national economies – developing primary production – grazing stock/developing agricultural industries Developing local, regional and national economies - feeding people – preserving food and beverages Developing Australia's cultural life- living in the country and rural settlements Developing Australia's cultural life – living in and around Australian homes	Commonwealth

Item no.	Name	Summary statement of significance	Australian themes	Level of significance
AS12	Well at 1972 The Northern Road	The well at 1972 The Northern Road appears to have been associated with the Earlam family's use of the site from the late nineteenth century. The site is considered to be significant for its historical and rarity values, as well as its associations with the Earlams.	Developing local, regional and national economies – developing primary production – developing agricultural industries Developing Australia's cultural life- living in the country and rural settlements Developing Australia's cultural life – living in and around Australian homes	Commonwealth
AS13	The Northern Road alignment within the airport site	The Northern Road alignment is considered to be historically significant as one of the earliest roads in the area, predating the subdivision of early land grants in the area.	Developing local, regional and national economies – moving goods and people – moving goods and people on land Building settlements, towns and cities – supplying urban services	Commonwealth

Item no.	Name	Summary statement of significance	Australian themes	Level of significance
AS14	Anschau Vineyard, Steinberg and grave(s)	Anschau Vineyard and Steinberg is assessed as being significant for its historic associations with the prominent Anschau family, who had close connections with the development of a Catholic presence in Luddenham.	Peopling Australia – migrating – changing the face of rural and urban Australia through migration Developing local, regional and national economies – developing primary production – developing agricultural industries Developing local, regional and national economies - feeding people – preserving food and beverages Marking the phases of life – dying – dealing with human remains Developing Australia's cultural life- living in the country and rural settlements Developing Australia's cultural life – living in and around Australian homes	Commonwealth
AS15	St Francis Xavier Church and cemetery	St Francis Xavier Church and cemetery is considered to be significant for its historic and social values, and for its associations with the Anschau family. The site is also considered to be significant for its research values, as it is the site of one of the earliest churches in the Luddenham area, and may be the site of much earlier burials.	Developing Australia's cultural life – worshipping – worshipping together, making places for worship Marking the phases of life – dying – dealing with human remains, mourning the dead, remembering the dead	Commonwealth

Item no.	Name	Summary statement of significance	Australian themes	Level of significance
AS16	Jackson Road cottage	The Jackson Road cottage is considered to be a representative example of a late nineteenth century farming cottage. The site is considered to be significant for its rarity, research potential, principal characteristics and aesthetic values.	Working – working on the land Developing Australia's cultural life- living in the country and rural settlements Developing Australia's cultural life – living in and around Australian homes	Commonwealth
AS17	Badgerys Creek Road alignment within the airport site	The Badgerys Creek Road alignment is considered to be historically significant as one of the earliest roads in the area, predating the subdivision of early land grants in the area. This item is strongly associated with James Badgery, who allegedly selected the route as a short cut to his property.	Developing local, regional and national economies – moving goods and people – moving goods and people on land Building settlements, towns and cities – supplying urban services	Commonwealth
AS18	Spredenberg	The significance of the site of Spredenberg is currently unknown. The site is very overgrown and it is not known whether evidence of the (presumed) homestead remains on the site.	Unknown	Unknown
AS19	Howe residence	The site of the Howe residence is considered to have heritage significance for its historical and associative values. The Howes were a prominent family who lived in the Badgerys Creek area from the early nineteenth century.	Developing Australia's cultural life- living in the country and rural settlements Developing Australia's cultural life – living in and around Australian homes	Commonwealth

4.2 Significance assessment of the airport site

The cultural significance of the airport site is derived from the following factors:

- The region developed as a centre of agricultural production in the nineteenth century. The airport site was associated with the production of wheat and later orcharding.
- The airport site includes Blaxland's early land grant, Luddenham Estate. This land grant and subsequent subdivision represent some of the early attempts to develop an agricultural and pastoral economy in Australia. These farmlands have continued in rural use and due to the integrity of subdivision pattern provide insight into early agricultural production.

- The airport site is crossed by The Northern Road and Badgerys Creek Road, which have historic associations with development in Badgerys Creek and more generally in the region.
- The airport site retains longstanding historic associations with the nineteenth and early twentieth century market for the supply of meat and livestock for metropolitan Sydney. Remnant tracts of cleared grazing land at Badgerys Creek continue to provide insight into this economic activity.
- The airport site includes a public school which demonstrates the development of public education from the late 1800s. The scale, material and design of the school buildings reflects the evolving fortunes of Badgerys Creek, education reform, community and architectural styles.
- The emergence of a settled village and farm community at Badgerys Creek in the last half of the nineteenth century is historically associated with the breakup of the large estates for closer settlement. This is demonstrated in street alignments, subdivision patterns, dwellings, churches and cemeteries, community gathering places, recreation grounds, park reserves, and places for education.

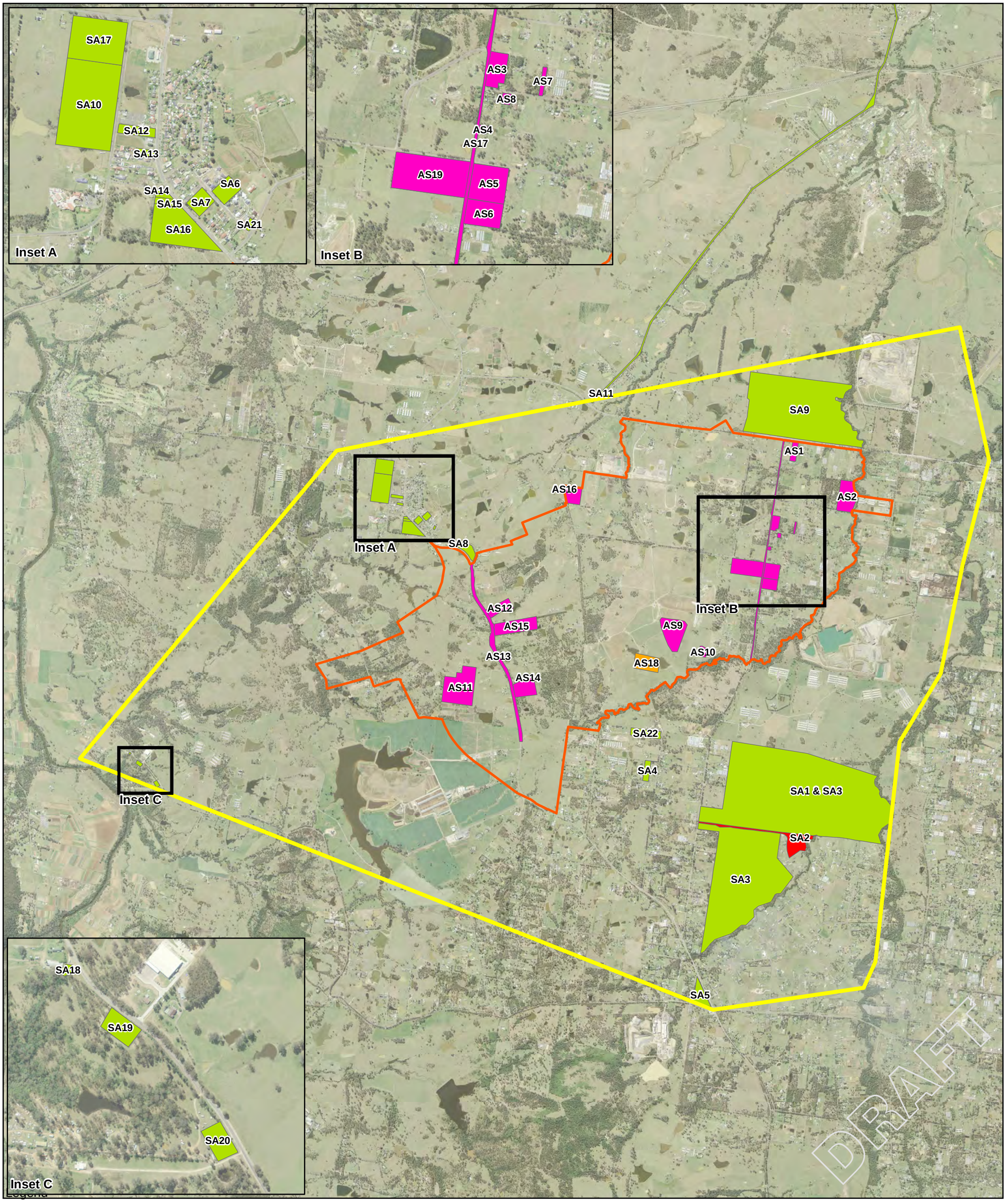
4.3 Potential for nomination of places to the Commonwealth Heritage List

This assessment has identified places within the airport site with heritage values that are significant as measured against the CHL significance criteria. These findings provide a basis for the consideration of nominating one or more places for listing on the CHL. Consideration should also be given to any consequential obligations defined by the EPBC Act for Australian Government agencies.

The Commonwealth would need to consider the Commonwealth heritage provisions of the EPBC Act in developing its strategy for managing heritage as part of the development of the proposed airport.

In the event that consideration is given to nominating places for listing on the CHL, the following issues should be addressed:

- the long term role of the Australian Government in the tenure and control of the subject place;
- the potential impact of the airport development and the potential for long term conservation of the place; and
- the need to prepare management plans for all listed places which are consistent with Commonwealth heritage management principles.



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Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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European and other heritage items within the study area

Figure 4

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5 Impact assessment

5.1 Initial airport development

Construction

Site preparation and bulk earthworks for Stage 1 will be undertaken including demolition and removal of some existing dwelling structures and other infrastructure on the airport site.

The area disturbed by earthworks (approximately 1,000 hectares) would be largely located in the northernmost part of the site. Some development activities may occur in the remaining area, subject to the requirements of the Airports Act.

Eighteen identified European and other heritage items within the airport site will be directly impacted by the initial construction works and it is unlikely that any known archaeological deposits within the initial airport development area could be preserved in situ. The southern alignment of Luddenham Road, outside of the airport site, will be subject to direct impact following Elizabeth Drive realignment.

Operation

The initial development at the site will cater for up to 10 million annual passenger movements.

Eighteen identified European and other heritage items within the study area are likely to be indirectly impacted by the operation of the initial stage of the airport development. Impacts are likely to include changes to landscape, vistas and ambience.

5.2 Longer term development

Construction

To meet expected future demand for air travel, a second parallel runway, is expected to be required, separated by approximately 1,900 metres from the first runway. Current forecasts suggest that the development of the second runway could be required around 2050.

One additional heritage item will be directly impacted as a result of the longer term development of the airport. It is unlikely that any known archaeological deposits within the airport site could be preserved in situ.

Operation

By around 2063 the total number of passenger movements per year is forecast to be approximately 82 million. An indicative long term layout of the development is illustrated the main volume of the EIS.

No additional heritage items will be indirectly impacted by the longer term operation of the airport.

Table 11 summarises the impacts to each identified European and other heritage item as well as the stage of development (i.e. initial airport development or longer term development) which results in the predicted impact.

Likely impacts to European and other heritage sites

Table 11 European and other heritage items impacted by the project

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
	Airport site	Commonwealth	Direct, initial airport development	Oral history, interpretation, archive and keeping place
AS1	Pennell's property 2170 Elizabeth Drive, Badgerys Creek	Commonwealth	Direct, initial airport development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations
AS2	Gardiner Road farm complex 5 Gardiner Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Removal of all structures and destruction of any archaeological evidence associated with this site as a result of earthworks.	Archival recording, inventory of moveable heritage items, staged demolition, archaeological investigations, cultural plantings, relocation of structures
AS3	Badgerys Creek Public School Corner of Pitt Street and Badgerys Creek Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Removal of all structures associated with this site as a result of earthworks.	Archival recording, inventory of moveable heritage items, staged demolition, relocation of structures
AS4	Badgerys Creek butchery Lot 51A Badgerys Creek Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations
AS5	Badgerys Creek post office Lot 52 Badgerys Creek Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations
AS6	Saw pit 61 Badgerys Creek Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
AS7	Badgerys Creek Uniting Church and cemetery 15 Pitt Street, Badgerys Creek	Commonwealth	Direct, initial airport development: Removal of all graves and destruction of any archaeological evidence associated with this site as a result of earthworks.	Archival recording, relocation of remains interred at cemetery site
AS8	St John's Anglican Church and cemetery 30 Pitt Street, Badgerys Creek	Commonwealth	Direct, initial airport development: Removal of all graves and destruction of any archaeological evidence associated with this site as a result of earthworks.	Archival recording, relocation of remains interred at cemetery site
AS9	Braeburn homestead 55 Longleys Road, Badgerys Creek	Commonwealth	Direct, longer term development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations, cultural plantings
AS10	Orange Hill homestead 5 Jagelman Street, Badgerys Creek	Commonwealth	Direct, initial airport development: Destruction of any archaeological evidence associated with this site as a result of earthworks.	Archaeological investigations, cultural plantings
AS11	Vicary's Winery 1935 The Northern Road, Luddenham	Commonwealth	Direct, initial airport development: Removal of all structures and destruction of any archaeological evidence associated with this site as a result of earthworks.	Archival recording, inventory of moveable heritage items, staged demolition, archaeological investigations, cultural plantings, relocation of structures
AS12	Well 1972 The Northern Road, Luddenham	Commonwealth	Direct, initial airport development: Removal of well and destruction of any archaeological evidence associated with this site as a result of earthworks.	Archival recording, staged demolition, archaeological investigations

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
AS13	The Northern Road alignment within the airport site	Commonwealth	Direct, initial airport development t: Removal of all evidence of The Northern Road alignment through the airport site as a result of earthworks.	Archaeological investigations
AS14	Anschau Vineyard, Steinberg and grave(s) 1845-1875 The Northern Road, Luddenham	Commonwealth	Direct, initial airport development: Removal of all graves and destruction of any archaeological evidence associated with this site as a result of earthworks.	Relocation of remains interred at cemetery site, archaeological investigations, cultural plantings
AS15	St Francis Xavier Church and cemetery 1966 The Northern Road, Luddenham	Commonwealth	Direct, initial airport development: Removal of all graves and destruction of any archaeological evidence associated with this site as a result of earthworks.	Relocation of remains interred at cemetery site, archaeological investigations, cultural plantings
AS16	Jackson Road cottage Lot 2 Jackson Road, Luddenham	Commonwealth	Direct, initial airport development: Removal of all structures associated with this site as a result of earthworks.	Archival recording, staged demolition, archaeological investigations
AS17	Badgerys Creek Road alignment within the airport site	Commonwealth	Direct, initial airport development: Removal of all evidence of the Badgerys Creek Road alignment through the airport site. The southern section of Badgerys Creek Road is proposed to be retained but is expected to be removed to enable construction of the second runway when required.	Archaeological investigations
AS18	Spredenberg 55 Longleys Road, Badgerys	Unknown	Direct, initial airport development: Removal of any archaeological evidence associated with the site.	Archaeological investigations

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
AS19	Howe residence Corner of Badgerys Creek Road and Longleys Road, Badgerys Creek	Commonwealth	Direct, initial airport development: Removal of all archaeological evidence associated with the site.	Archaeological investigations
SA1	Former Overseas Telecommunications Commission site group Badgerys Creek Road, Bringelly	Local	Indirect, initial airport development: Visual impact.	None required
SA2	Kelvin 30 The Retreat, Bringelly	State	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA3	Two RAAF water tanks Badgerys Creek Road, Bringelly	Local	Indirect, initial airport development: Visual impact.	None required
SA4	Mount Pleasant homestead 3 Shannon Road, Bringelly	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA5	Bringelly Public School group 1205 The Northern Road, Bringelly	Local	None	None required
SA6	Willmington Reserve 17 Jamison Street, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site	None required
SA7	Luddenham Public School The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA8	Lawson's Inn Lot 2 DP 623457, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA9	McGarvie Smith University Farm 124 Elizabeth Drive, Badgerys Creek	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA10	Brick cottage 21-55 Campbell Street, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
SA11	Luddenham Road alignment	Local	Indirect, direct, initial airport development: Visual impact, impact to southern alignment of Luddenham Road following Elizabeth Drive realignment	None required
SA12	Weatherboard cottage 3065-3067 The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA13	Weatherboard cottage 3075 The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA14	Luddenham Progress Hall 3091-3095 The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA15	Luddenham Uniting Church and cemetery 3097-3099 The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA16	St James Anglican Church and cemetery 3101-3125 The Northern Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA17	Showground 428-452 Park Road, Luddenham	Local	Indirect, initial airport development: Visual impact, impact to ambience of site	None required
SA18	Shadforth Monument Greendale Road, Greendale	Local	None	None required
SA19	Private dwelling (former St Marks) Greendale Road, Greendale	Local	None	None required
SA20	Greendale Roman Catholic Cemetery Greendale Road, Greendale	Local	None	None required

Item no.	Item name and location	Heritage significance	Impact and stage	Recommended mitigation
SA21	Vertical slab dairy Lot 10, Adams Road, Badgerys Creek	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required
SA22	Evergreen homestead Off Derwent Road, Bringelly	Local	Indirect, initial airport development: Visual impact, impact to ambience of site.	None required

6 Mitigation and management

A number of mitigation and management measures are proposed prior to the commencement of construction, including further archival and archaeological investigations. Additional specific measures may also be implemented having regard to the heritage significance or potential of various sites identified and the practicability of taking particular approaches to heritage management. Although it will not be directly impacted by the initial airport development, in the interests of interpretation within a broader context of results it is recommended that mitigation and management measures in relation to Braeburn homestead site are undertaken concurrently with other European heritage mitigation and management for the airport site.

6.1 Specific measures

Archival recording

It is recommended that archival recording is undertaken for the following items.

- Badgerys Creek Public school.
- Vicary's Winery.
- Gardiner Road farm complex.
- Well at 1972 The Northern Road.
- Jackson Road cottage.
- St John's Anglican Church and cemetery.
- Badgerys Creek Uniting Church and cemetery.

The archival recording should have regard to the NSW OEH guidelines *How to Prepare Archival Records of Heritage Items* (1998) and *Guidelines for Photographic Recording of Heritage Items Using Film or Digital Capture* (2006) and should include the preparation of a photographic record and measured drawings of existing features which contribute to the heritage significance of each item. The archival recording should be prepared for the original buildings within the context of their landscape setting, local environment and associations with other buildings and features. The recording will ensure that the history and environment of each structure can be retained for future reference and research.

At the completion of the archival record, copies should be lodged at the on-site archive, Liverpool City Council archive, the library of the Heritage Division of the OEH and the State Library of NSW.

Inventory of moveable heritage items

It is recommended that an inventory of moveable heritage items is prepared for the following items.

- Gardiner Road farm complex.
- Badgerys Creek Public school.
- Vicary's Winery.

Individual items which are part of a heritage item may make an important contribution to the heritage significance of the item, or may have heritage significance in their own right. These may include tools of the trade and machinery. The inventory should be undertaken prior to the demolition or relocation of structures.

A catalogue of these items should be compiled by a heritage consultant. The catalogue should include information on the history, location, designer, creator, and previous owners or users of the item. At the completion of the inventory copies should be lodged at the on-site archive, Liverpool City Council archive, the library of the Heritage Division of the OEH and the State Library of NSW.

Staged demolition

It is recommended that staged demolition is undertaken for the following items.

- Gardiner Road farm complex.
- Badgerys Creek Public School.
- Vicary's Winery.
- Well at 1972 The Northern Road.
- Jackson Road cottage.

The staged demolition should seek to gain additional information about each item, including original finishes, earlier configurations, profiles of earlier structures, positions of earlier openings, and construction technologies used. It may be appropriate to catalogue a series of surface finishes and detailing from some items. At the completion of the staged demolition, copies of the records should be lodged at the on-site archive, Liverpool City Council archive, the library of the Heritage Division of the OEH and the State Library of NSW.

Cemetery sites

It is recommended that the relocation of remains interred in graves be undertaken for the following sites.

- St John's Anglican Church and cemetery.
- Badgerys Creek Uniting Church and cemetery.
- St Francis Xavier Church and cemetery.
- Grave(s) at Anschau Vineyard.

Prior to exhumation and reburial, the following should be undertaken:

- identification of the number of grave cuts at each site (including consideration of a buffer of at least 10 metres beyond the consecrated ground);
- production of a funeral register. This should provide any relevant details of the deceased and their executors or living relatives, and identify any reserved plots and the appropriate contact for the plot;
- determination of the number of burials recorded at each cemetery, and the number of burials exhumed from each cemetery;
- review of church, Government and other records to estimate the number of bodies likely to remain in situ, relative to the number of grave cuts identified;
- consideration of the heritage impact of relocation of burials; and
- consultation with the NSW Department of Health and other relevant agencies.

Determination of the preferred site(s) for the relocation of remains and the process of exhumation should be undertaken in consultation with all relevant stakeholder groups, including family members of the deceased, church groups and religious bodies. All relocation works must have regard to public health and heritage requirements.

Archaeological investigations

It is recommended that targeted archaeological investigations are undertaken at the following sites.

- Pennell's.
  - Archaeological test excavation should be undertaken at Pennell's to determine whether evidence of Pennell's use of the property remains on the site.
- Gardiner Road farm complex.
  - Archaeological test excavation should be undertaken at Gardiner Road farm complex, particularly under the cottage and slab huts and in their immediate vicinity to understand the age, layout and use of the site.
- Badgerys Creek butchery site.
  - Archaeological investigations should be undertaken at Badgerys Creek butchery site to understand the development of the site.
- Badgerys Creek post office site.
  - Archaeological test excavations should be undertaken at Badgerys Creek post office site to determine whether evidence of the post office remains on the site.
- Saw pit.
  - The saw pit should be drained and the site recorded prior to destruction. In the event that evidence of the use of the saw pit, including structural remains and/or machinery is present on the site, it should be recorded prior to removal.
- Braeburn homestead site.
  - Archaeological investigations should be undertaken at Braeburn homestead site to further understand the age, size and likely occupants of the place. Consideration should also be given to excavation of the dump site associated with the homestead.
- Orange Hill homestead site.
  - Archaeological investigations should be undertaken at the Orange Hill homestead site to further understand the age, size and likely occupants of the place. The wells should be excavated and, if relevant, their contents recorded.
- Vicary's Winery.
  - Archaeological investigations should be undertaken at Vicary's Winery, particularly in the immediate vicinity of the c.1860s dwelling.
- Well at 1972 The Northern Road.
  - Archaeological investigations should be undertaken in the immediate vicinity of the well at 1972 The Northern Road in order to understand whether previous structures were present on the site.
- The Northern Road alignment.
  - Archaeological investigations of former parts of The Northern Road alignment, particularly in the vicinity of St Francis Xavier Church should be undertaken to identify whether early road construction technologies such as corduroy were used in the alignment.
- Anschau Vineyard and Steinberg.
  - Archaeological investigations of Anschau Vineyard, and particularly in the immediate vicinity of Steinberg, should be undertaken to understand the layout and use of the site.

- St Francis Xavier Church.
  - Archaeological investigations of St Francis Xavier Church site should be undertaken to determine the layout of structures on the site.
- Jackson Road cottage.
  - Archaeological investigations in the immediate vicinity of Jackson Road cottage should be undertaken to understand the layout of the site, likely age, and likely occupants.
- Spredenberg.
  - Following vegetation clearance this site should be surveyed, and, if warranted, archaeological investigations undertaken to understand the layout of the site, likely age, and likely occupants.
- Howe residence.
  - Archaeological investigations should be undertaken at the Howe residence to understand the layout of the site, activities undertaken, and likely age.

Archaeological works should be undertaken in a manner generally consistent with the requirements of the NSW *Heritage Act 1977* and associated guidelines and best practice.

Cultural plantings

It is recommended that a botanist or garden historian is commissioned to investigate cultural plantings at the following sites.

- Gardiner Road farm complex.
- Braeburn homestead site.
- Orange Hill homestead site.
- Vicary's Winery.
- Anschau Vineyard.
- St Francis Xavier Church site.

Cultural plantings should be investigated to identify whether heirloom varieties are present at these sites. In the event that heirloom varieties are identified, consideration should be given to collecting samples for propagation. Opportunities for planting of heirloom varieties at the Western Sydney Airport should be explored.

Relocation of structures

It is recommended that options for the potential relocation of original buildings be explored at the following sites.

- Vicary's Winery.
- Badgerys Creek Public School.
- Gardiner Road farm complex.

Oral history

Consideration should be given to preparing an oral history of the airport site. Descriptions and reminiscences by people who have close association with the Badgerys Creek area may reveal additional information about the history and significance of the place.

This should be undertaken by an historian or anthropologist with experience in oral history. The oral history should be recorded professionally, and transcribed for archival purposes.

Interpretation

It is recommended that heritage information be placed on site during the construction phases to interpret the historic development and use of the airport site. Information could be in the form of heritage images and text on construction hoarding, or laminated posters adjacent to general project information boards.

Prior to the commencement of construction, a heritage interpretation strategy should be prepared for the airport site.

Consideration should be given to the creation of a heritage precinct within the airport site. This could include relocated buildings and artefacts recovered from archaeological investigations, and interpretation of the airport site.

Consideration should be given to the development of a small museum space or display within the airport terminal. This could be beyond the security screening, and in a public space for travelers to peruse while waiting for flights. The museum should be used to interpret the heritage of the airport site.

On-site archive

Consideration should be given to the development of an archive within the airport development. This should house records relating to the history of the airport site, should be secure, and should be accessible to the public on request.

Retrofitting of architectural noise treatments

In the event that identified European and other heritage items are required to be retrofitted with architectural noise treatments, a heritage impact assessment should be prepared for these items prior to the installation of works. Relevant permits and/or approvals may be required from the relevant council and/or from the Heritage Division of the OEH.

6.2 General measures

Commonwealth heritage values

This assessment has identified a range of Commonwealth heritage values within the airport site. It is recommended that the Department of Infrastructure and Regional Development consider the Commonwealth heritage provisions of the EPBC Act and the commitments established in the Department of Infrastructure and Transport Heritage Strategy (2011) when developing its strategy for managing these heritage values as part of the development of the proposed airport.

European heritage management sub plan

A European and other heritage management sub plan should be developed and implemented as part of the construction environmental management plan for the development of the airport site. This management plan should include the mitigation and management measures detailed in this technical report.

Heritage induction

European and other heritage awareness training should be provided for contractors involved in demolition and/or earthworks on the airport site. This training should be provided prior to the commencement of works to ensure an understanding of potential heritage items that may be impacted by the project, details of commitments in the European and other heritage management sub plan, and procedures to be undertaken in the event of unexpected finds.

Discovery of unexpected archaeological deposits, features or materials protocol

If at any time during the construction of the project unexpected European and other heritage archaeological deposits, features or materials are encountered an unexpected finds procedure should be followed. Specifically, the following actions should be undertaken:

- All construction that has the potential to harm the archaeological deposit, feature or material should cease, including stopping all construction within at least 25 metres. Only construction that is required to comply with occupational and environmental health and safety standards and/or to protect the deposit, feature or material should occur. Construction that does not have the potential to harm the deposit, feature or material should only continue if it is outside the minimum 25 metre buffer.
- The site supervisor should inform the developer's staff of the discovery.
- A suitably qualified and experienced archaeologist should be contacted as soon as practicable in relation to the unexpected discovery of any European and other heritage. The archaeologist should be responsible for recording the location and context of any unexpected find. Any materials, features and/or deposits should be analysed and/or catalogued and any official site records should be created or updated as appropriate. The archaeologist should also make recommendations for the management of the unexpected find in relation to the project.
- It is preferable to avoid impacts to European and other heritage where possible. If avoidance is not possible, the deposit, feature or material should be salvaged if this is recommended by the archaeologist. The aims of the salvage excavation should be to obtain as much information as possible from the deposit, feature or material.
- The archaeologist should prepare a report detailing the investigation, salvage and analysis results at the completion of the works. Copies of this report should be lodged with the developer and the Heritage Division of the OEH library.
- The developer should be responsible for the costs associated with the assessment, cataloguing, labelling, packaging etc. of any European and other heritage materials, features and/or deposits.
- Work should recommence within the area of exclusion when:
    - Appropriate protective measures have been implemented.
    - Relevant records have been updated and/or completed.
    - All parties agree there is no other prudent or feasible course of action.

Discovery of human remains protocol

In the event that construction of the project reveals possible human skeletal material the following procedure should apply:

- As soon as remains are exposed all construction shall immediately stop in that location and the area clearly demarcated using a method that does not result in additional ground disturbance. The site supervisor should be notified immediately to allow assessment and management.
- The site supervisor should notify the Environmental Representative of the client.
- The site supervisor should notify Police.
- A physical or forensic anthropologist should inspect the remains in situ. This should be organised by Police unless otherwise directed by Police. A determination should be made of ancestry (Aboriginal or not) and antiquity (prehistoric, historic or forensic).
- If the remains are identified as forensic, the area will be deemed a crime scene.
- If the remains are identified as Aboriginal, the procedure for identification of Aboriginal human remains should be followed (refer Appendix 7 of the Western Sydney Airport Aboriginal cultural heritage assessment (Navin Officer 2015)).
- If the remains are identified as European or other (non-Aboriginal), the site should be secured and the archaeologist contacted. Management of the remains would be determined through liaison with the client, the Coroner's Office, relevant government agencies and the archaeologist.
- If the remains are identified as not being human, work could recommence once the appropriate clearances have been given.

7 Conclusion

7.1 Key findings of the assessment

This report has assessed the potential impact on the European and other heritage values of the Western Sydney Airport site and study area. Through heritage register searches, review of previous heritage studies, historic research, field survey and test excavation, a total of 41 European and other heritage items were identified. Assessment of the heritage significance of those items identified 18 items of Commonwealth heritage significance and one item of undetermined heritage significance within the airport site; and one state significant heritage item, and 21 locally significant heritage items outside of the airport site but within the study area.

This assessment has identified a range of Commonwealth heritage values that variously fulfil seven of the nine CHL significance criteria. Values include those associated with the historic, aesthetic, social and associative significance, as well as values relating to rarity, principal characteristics of a place, and the potential to yield information. It should be noted that Commonwealth heritage values relate to the significant values of places on land owned or controlled by the Australian Government.

Of those identified European and other heritage items, 18 within the airport site would be directly impacted by the initial site development, and one would be directly impacted by the longer term development. One item beyond the airport site but within the study area would be subject to direct impact, and a range of indirect impacts would result at these places as a result of the initial development and the longer term airport development.

Mitigation and management measures for those items within the airport site involve the realisation of the information and research potential associated with each site, and with the airport site as a whole, through a range of methods.

General management measures have also been recommended, including the development and implementation of a European and other heritage management sub plan, a procedure for unexpected finds, a procedure for the identification of human remains, and the provision of heritage induction training for contractors working on demolition or earthworks on the site.

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Appendix A

Significance assessments

AS 1 Pennell's

List	-
Type of item	Archaeological
Primary address	2170 Elizabeth Drive, Badgerys Creek
DIRD ID	404573

Site description

Noted on the map of the Eastern Division of Luddenham Estate 1859 (Plate A1) is "Pennells". The property is believed to be the home of Samuel Pennell (also transcribed in various sources as "Pinnell"), a convict sent to Australia in 1820 for stealing.

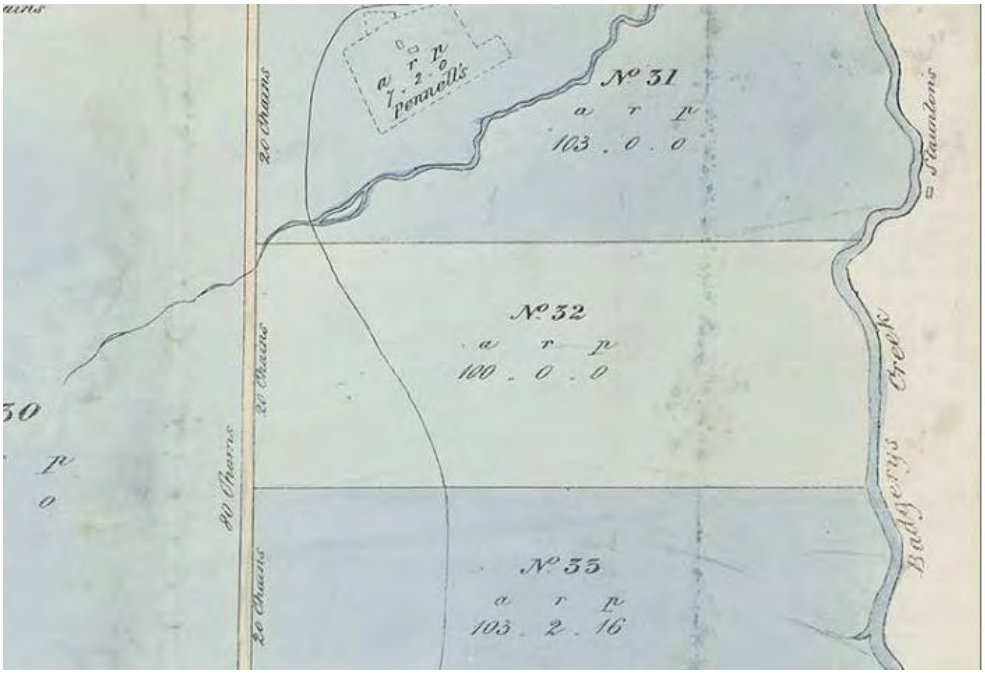

Plate A1 Plan of the Eastern Division of the Luddenham Estate, 1859. (Source: State Library of NSW)

On his arrival in Sydney, Pennell was placed into the service of Sir Nicholas Bayley, who had numerous land holdings across Sydney, including a holding called "Bayley Park" to the east of James Badgery's holding. Nicholas Bayley wrote the following character reference for him as part of his ticket of leave in 1825:

> *I hereby certify that Samuel Pinnell who came by the ship Asia which arrived in the year 1820 has not been convicted of any crime or misdemeanour in this Colony but is to our certain belief an honest, sober and industrious character having served faithfully the late Nicholas Bayley Esq. and family in the District of Cabramatta from his arrival in the Colony to the present time.* (NSW State Records 1825)

In the General Muster for 1825, Pennell is listed as being employed by Mr Norton of Bringelly (NSW State Records 1825). He was granted his Certificate of Freedom in 1832 and listed his occupation as a "farmer's man" (NSW State Records 1832). In 1851, he married Mary Ann Johnson (nee Pendergast) at Sydney and they thereafter settled at Badgerys Creek. Samuel and Mary had five sons and Mary had two daughters from a previous marriage. All children were born before Samuel and Mary's marriage. Pennell died near Penrith in 1874 and Mary died the following year. Both were buried in Luddenham's Anglican cemetery.

This property was viewed from the road as access was not permitted at the time of inspection. It is likely that this site has subsurface evidence of Pennell's. The current building on this property is the Luddenham Scout Hall. In the event that evidence of Pennell's is identified on this site, it is likely to be of Commonwealth significance.

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	The property was a locally known property warranting inclusion on the Eastern Division of Luddenham Estate map. The property was known as "Exeter Farms" after Badgerys Estate.	Commonwealth
Rarity	Little information exists regarding Pennell or his property. It therefore does not meet this criterion.	None
Research	In the event that subsurface evidence of Pennell's property is present on the site this may provide information about early farming and homesteading practices in the area.	Commonwealth
Principal characteristics of a class of place	Pennell's is not considered to meet this criterion.	None
Aesthetics	Pennell's is not considered to meet this criterion.	None
Creative or technical achievement	Pennell's is not considered to meet this criterion.	None
Social value	It is unknown whether Pennell's farm has any social value, however given the paucity of information and evidence relating to the farm, it is considered unlikely.	None
Significant people	There is little information regarding Pennell or his farm. The site is not considered to meet this criterion.	None
Indigenous values	Pennell's is not considered to meet this criterion.	None
Australian historic themes		
Working – working on the land Developing Australia's cultural life – living in and around Australian homes Developing Australia's cultural life – living in the country and rural settlements		
Statement of significance		
Pennell's property is likely to contain subsurface archaeological evidence of an early homestead on the site. Pennell was a former convict come farmer's man, and evidence of his dwelling may reveal a mid nineteenth century farming property. It is considered to be of Commonwealth heritage significance.		

AS2 Gardiner Road farm complex

List	-
Type of item	Farmstead and outbuildings
Primary address	5 Gardiner Road, Badgerys Creek
DIRD ID	404680, 404681

Site description

The farm complex on Gardiner Road is located at the easternmost area of John Blaxland's former estate, Luddenham (Godden Mackay 1997). Favourable environmental conditions and notably the failure of agricultural soils around Sydney and Parramatta necessitated the early settlement of the area to augment the colony's food supply. These were critical factors in the initial settlement of Badgerys Creek.

Blaxland mortgaged Luddenham estate to the Australian Trust Company in 1842. Following his death in 1845 his two sons, Edward James Blaxland and Arthur Blaxland, inherited all of his real estate. His sons defaulted under the mortgage and the estate was sold to Sir Charles Nicholson in 1851 (Thorp n.d). The property formed part of the 100 acre Lot 32 of the Eastern Division of Luddenham Estate (Plate A2). In 1859, Lot 32 the property was described as "open forest land, no improvements" (*Sydney Morning Herald*, 29 October 1859).

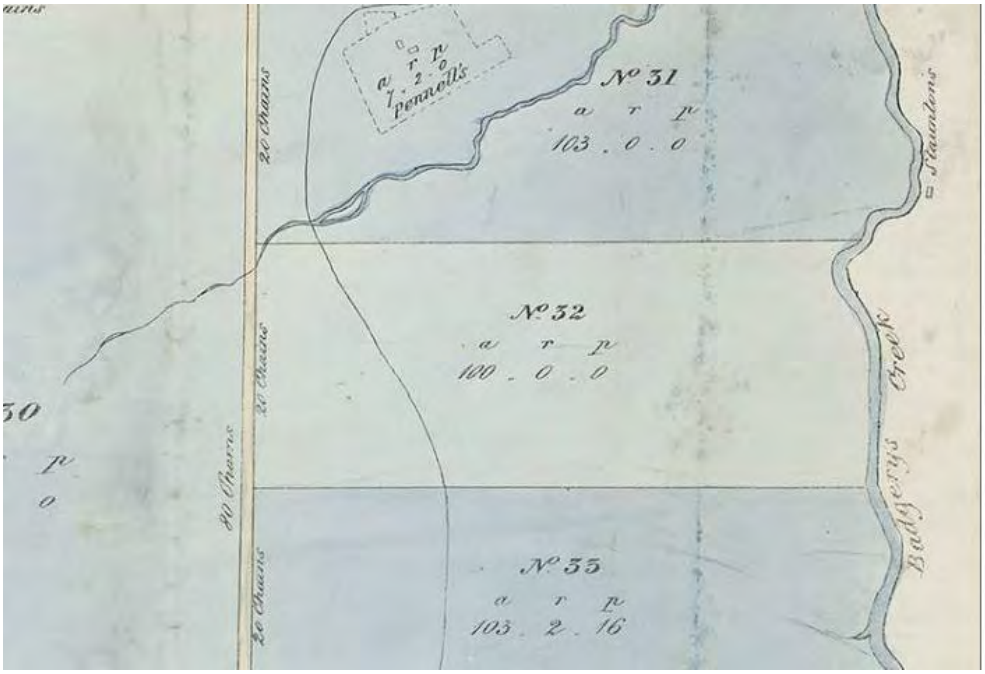

Plate A2 Part of the Plan of the Eastern Division of Luddenham Estate. Lot 32 is located centrally, bounded to the east by Badgerys Creek. (Source: National Library of Australia)

Between 1860 and 1882, the estate was subdivided and gradually sold by Nicholson. The lots along the eastern boundary of the airport site, including the current farm complex on Gardiner Road, were acquired by James Green of Sydney, painter; Ebenezer Vickery of Sydney, merchant; and Richard Watkins of Waverley, contractor. Property speculation was common at the time, and the land was re-subdivided into small farms of between four and nine acres. Sales of these lots began in 1887, with the whole of the land in Lots 32, 33, 34 and 36 being sold by the turn of the century.

During the further subdivision of the Eastern Division, Lot 32 was divided into Lots 30 and 31, as shown on Deposited Plan 1451 (Plate A3), before being further subdivided (Plate A4). Gardiner Road farm complex comprises the former Lot 10 of DP 1841.

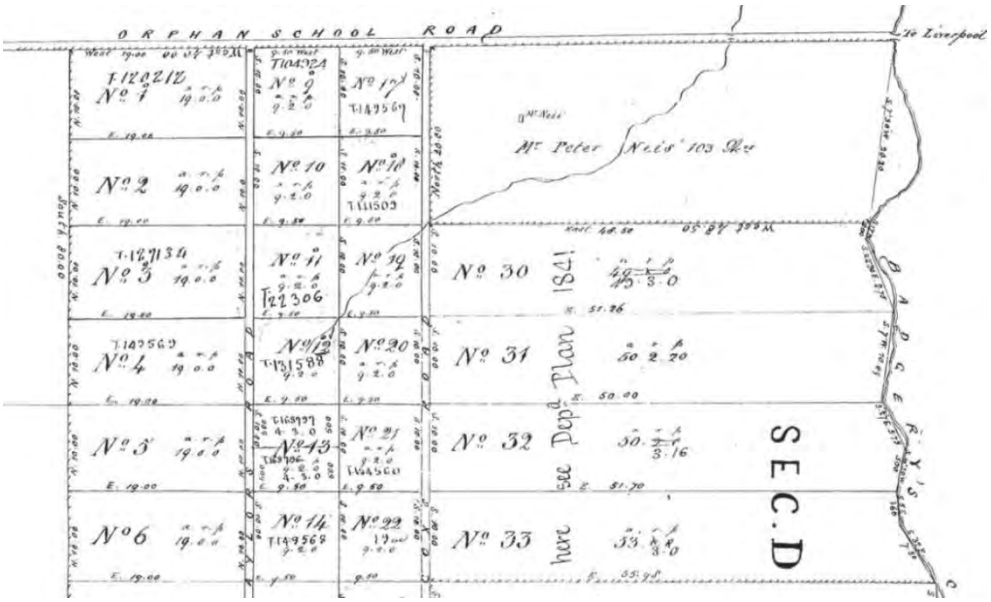

Plate A3 Deposited Plan 1451 showing Lots 30 and 31. (Source: NSW Land and Property Information)

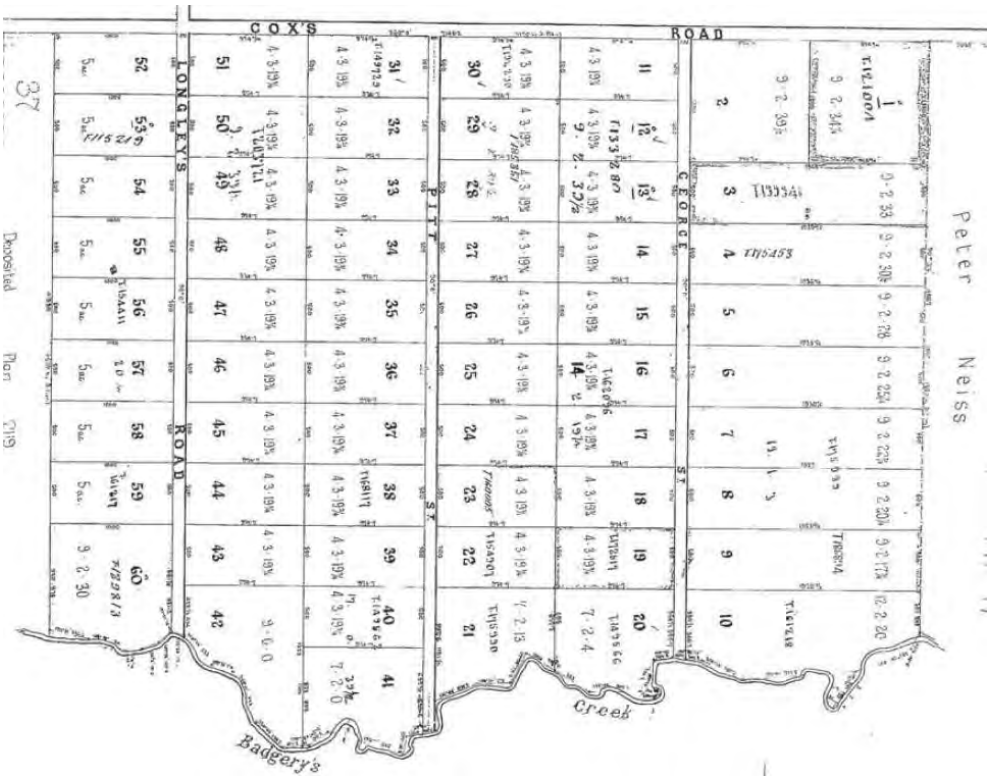

Plate A4 Deposited Plan 1841 following the subdivision of Lots 30 and 31, showing Lot 10 extended through to Peter Neiss' property. (Source: NSW Land and Property Information)

Peter Neiss purchased the property which fronted Elizabeth Drive. In the 1920s, Lesley Dorahy purchased Lot 10, which extended from George Street to Elizabeth Drive and operated a poultry farm there (Plate A5). Dick Watkin also owned a portion of the property (Donald and Gulson1996:27).



Plate A5 Lesley Dorahy on the poultry farm in the 1940s. (Source: Donald and Gulson 1996:27)

In July 1953, Ralph (Rudolf) Wiener purchased the poultry farm. Wiener was born in Vienna at the turn of the century and moved to Yugoslavia after World War I, where he worked before moving to Australia. Wiener engaged Roger Woods to assist on the farm and two years later entered a partnership with Woods which lasted 20 years. Together, they built up the farm from around 1200 to between 14,000 and 20,000 birds (Donald and Gulson 1996:31).

Wiener occupied the cottage on the property (Plate A6). In 1963, Woods married and built a second residence on the property.



Plate A6 Ralph Wiener's residence. (Source: Donald and Gulson 1996:31)

In the 1960s, the poultry industry experienced significant changes, with the introduction of the California style laying cage. Wiener and Woods had one of the first of these cages in the district, built in 1960. The new practice resulted in increased production and over-supply in the market. In the late 1960s, due to significant losses in overseas sales, the New South Wales government introduced regulation of the industry, limiting farmers to a specific number of fowls producing enough eggs for local consumption only. As a result of regulation, Wiener and Woods' production was cut by 17 per cent (Donald and Gulson 1996:106-107). Woods continued to operate the farm until recently.

The farm complex includes a single storey Georgian-style cottage with corrugated iron gable roof, and skillion verandah carried on timber posts. The cottage is small in scale and was described as well finished and well preserved at the time of the 1997 *Draft EIS* (Godden Mackay 1997), but was falling into a state of disrepair at the time of the inspection (see also Australian Museum Consulting 2014).

To the rear (north) of the cottage is a group of farm buildings which appear to date from the early to mid twentieth century. These buildings have low pitched corrugated iron skillion and hipped roofs, bush pole framing and are clad with slab timber. All are painted white and some have later wing additions. They are typical small farm outbuildings and appear to have had a range of uses, including as stables, barns, garages, byres and possibly a former dairy.

The cottage is of simple weatherboard construction with corrugated iron gable roof and two external brick chimneys at the east wall (Plate A7). The weatherboard appears to enclose an original slab cottage that is likely to pre-date the ascribed 1890s date. The cottage has been modified with the addition of newer windows and doors which date to its most recent period of use. The cottage has a rear fibro skillion addition, which appears to house the kitchen as it has a brick chimney.

Immediately east of the cottage and connected by a skillion addition, are two small timber slab huts. One of these has been lined with fibro and appeared to have been used as a bedroom. Remnant lath and plaster is visible through gaps in the timber cladding of the hut. A brick lined cistern is located north east of the cottage (Plate A8). Incorporated around the cottage are a number of cultural plantings of varying ages. Withered remains of wisteria were noted on the roof of the slab hut portion of the homestead, with the stumps of wisteria noted along the northern elevation of the slab hut. Other cultural plantings noted included orange trees, cypress pine, boronia and a number of palms (foxtail, kentia, fan). These plantings were chiefly in the vicinity of the cottage. A row of mature trees on the southern boundary of the property marked the alignment of the eastern end of Gardiner Road (formerly George Street), which was never constructed.



Plate A7 View north toward the cottage. (Source: RPS 2015)



Plate A8 Cistern behind Gardiner Road cottage. (Source: RPS 2015)

A sleep-out and garage is located north west of the cottage. The sleep-out is of fibro construction with corrugated roofing (Plate A9).

A shed is located immediately north of the sleep-out and garage (Plate A10). The shed is constructed of pole timber with corrugated iron cladding. There is a red painted grain hopper located immediately north of the shed, which feeds internal troughs.



Plate A9 View west toward sleep-out and garage. (Source: RPS 2015)



Plate A10 View west towards shed and hopper. (Source: RPS 2015)

Immediately north of the shed and hopper is a Lysaght silo, presumably used to store grain for the poultry operation (Plate A11). The silo appears to be similar to those constructed in the mid-twentieth century and is a ubiquitous piece of farming infrastructure.



Plate A11 Lysaght silo. (Source: RPS 2015)

North of the outbuildings, and opposite the Lysaght silo, is a water tank on a stand. The stand is constructed of pole timber. This is a vernacular tank stand arrangement (Plate A12).



Plate A12 Water tank on stand; outbuildings behind. (Source: RPS 2015)

North of the Lysaght silo is a collapsed and overgrown byre (Plate A13). The byre appears to be contemporaneous with the shed.



Plate A13 View west toward byre. (Source: RPS 2015)

Across the north eastern part of the property are five clusters of poultry sheds, in varying states of decay. These appear to be of mid-twentieth century construction (Plate A14).



Plate A14 One of several sets of poultry sheds on the site. (Source: RPS 2015)

Immediately opposite the shed are a series of extremely overgrown outbuildings. These are primarily timber framed buildings with corrugated iron cladding, aligned to the north of the cottage. These were unable to be accessed at the time of inspection, and it is presumed they are contemporaneous with the construction of the shed (Plate A15).



Plate A15 View south toward outbuildings. (Source: RPS 2015)

West of the cottage is a residence which was built on the property in 1963 when Woods was first married (Plate A16).



Plate A16 View north east toward 1960s house. Sleep-out visible at rear. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	The Gardiner Road farm complex contains a number of buildings of various styles, ages and fabric. The original timber slab building is still standing and is of historic interest, as is the adjoining weatherboard cottage. The farm outbuildings also vary in ages, fabric and styles. Collectively they reflect the growth of a farming complex from a single building to a substantial agricultural enterprise.	Commonwealth
Rarity	The Gardiner Road farm complex has a number of buildings which demonstrate early construction techniques including the use of slab timber, and pole construction. It is also important because of its demonstration of the rural practice of incorporating older structures into new structures, as well as the re-use and re-purposing of the outbuildings as the need arose. Whilst likely to have once been common in the area, it is now one of the few remaining examples of this type of complex. The timber slab building is a rare example of the types of early farm buildings that would have been built in the area in the early years of European settlement. Although many would have been built, this building is one of the very few to survive. It has been somewhat adapted as an extension to a later adjoining dwelling, but is still relatively intact.	Commonwealth
Research	Gardiner Road farm complex has several buildings which have the potential to yield information relating to early construction techniques. There is high potential for the remains of former outbuildings and other structures associated with the use of the farm. Due to the limited information available about the use of the farm between 1860 and 1920, such information has the potential to contribute to our understanding of the use and significance of the farm prior to the use of the farm for poultry.	Commonwealth

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Principal characteristics of a class of place	The Gardiner Road farm complex is an excellent example of a farming complex that has grown organically, which has adapted and incorporated older buildings into a new complex each time. This applies to both the residential and farming buildings.	Commonwealth
Aesthetics	Aesthetically, the timber slab building and the weatherboard cottage are relatively intact examples of such structures and have aesthetic appeal in their context. These elements therefore meet this criterion.	Commonwealth
Creative or technical achievement	Gardiner Road farm complex is the site of the first use of the California chicken cage and appears to have been an early adopter of technology to maximise efficiencies. Despite this, there is no evidence to suggest that the site meets this criterion.	None
Social value	Gardiner Road farm complex is not considered to meet this criterion.	None
Significant people	Gardiner Road farm complex is not considered to meet this criterion.	None
Indigenous values	Gardiner Road farm complex is not considered to meet this criterion.	None
Australian historic themes		
Developing local economies – developing primary production – breeding animals, developing agricultural industries. Working – working on the land. Developing Australia's cultural life – living in and around Australian homes Developing Australia's cultural life – living in the country and rural settlements		
Statement of significance		
The Gardiner Road farm complex is a typical turn-of-the-century modest farm cottage which retains its (overgrown) gardens and semi-rural context. Although once common, cottages such as this have become rare in Western Sydney in the past three decades. The group of farm outbuildings were once typical of the area but are now rare in the vicinity. They demonstrate building techniques and designs for agricultural activities. They illustrate the nature of settlement in the Badgerys Creek area in the early twentieth century.		

AS3 Badgerys Creek Public School

List	Liverpool LEP 2008
Type of item	School
Primary address	Corner of Pitt Street and Badgerys Creek Road, Badgerys Creek
DIRD ID	404685

Site description

The village of Badgerys Creek was established following the subdivision of the larger estates in the 1880s. The formal establishment of villages led to the provision of services for new settlers.

A public school was first proposed for Badgerys Creek in 1891, but it was not approved until 1894 at which time the current site was purchased and a building erected (Plate A17). This was replaced with the current building in 1914.

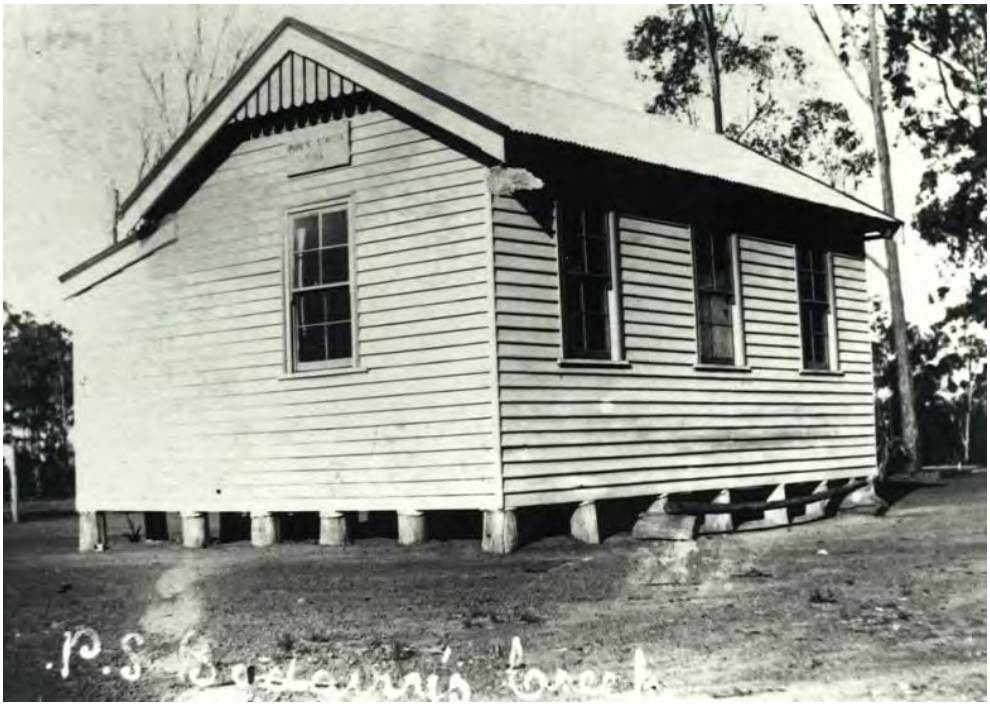

Plate A17 Badgerys Creek Public School, 1908. (Source: National Library of Australia)

Badgerys Creek Public School has seen varying levels of enrolments, but was a single teacher school until the late 1960s. During the 1970s, facilities were improved and enrolments soared to around 120 pupils, taught by five teachers and a headmaster. Uncertainty following the announcement of the airport proposal in the 1980s reduced the number of enrolments.

During the 1990s, a timber cottage from a neighbouring property, Braeburn, was moved to the school to become an art classroom. It was repaired and the timber verandah added, using second hand materials. The building was known as the “old cottage” and was used as a craft room for students.

Badgerys Creek Public School consists of a pair of single storey, weatherboard school buildings (staff room and library) with shallow gables and corrugated iron clad roofs. There were a number of more recent buildings on the site including a modern hall, and a classroom block (Plate A18) which appeared to have been constructed in the 1970s-1980s. The school had been targeted by arsonists following its closure in 2014, resulting in substantial damage to a number of the buildings.



Plate A18 View south east toward classroom block. (Source: RPS 2015)

The staff room was originally used as a classroom, and was built in 1914. This small square weatherboard building, set on brick piers, has a gabled corrugated iron roof and skillion verandah across one gabled end (front elevation, facing south) which has been half enclosed with weatherboards, and a fully enclosed skillion roof verandah at the rear (north). A simply detailed face brickwork chimney also features on the southern elevation. Windows along the side walls are generally 2 x 6 pane double hung sash windows with four paned casement to the verandah room. Internally, the building featured tongue, groove and beaded paneling to the walls and ceiling and a simple brick fireplace. This building has been substantially damaged by recent fires in 2015 and is in a very poor state of repair (Plate A19).

Facing the staff room across the central playground is a later weatherboard classroom typical of many in this style built throughout the state in the early years of the twentieth century (Plate A20). This building was used as the school library. A deep, timber framed verandah lines the front (north) elevation with one end enclosed. The windows are generally 2 x 2 pane double hung sashes.



Plate A19 View toward western wall of the staff room, note extensive fire damage. (Source: RPS 2015)



Plate A20 View south east toward library. (Source: RPS 2015)

The wash room is located to the rear (north) of the staff room (Plate A21). The western wall of the wash room is of brick construction, with the remaining three walls partially enclosed with timber slabs. The wash room has a number of drains for former wash basins along the eastern wall, and existing wash basins along the western wall.

The hall was constructed circa 2000, is of modern construction and is largely clad in corrugated iron (Plate A22). The hall appears to have a poured concrete slab foundation. At the time of inspection, the hall was boarded up, but appeared to have been targeted by vandals for copper wire.



Plate A21 View north west toward wash room. (Source: RPS 2015)



Plate A22 View north toward hall. (Source: RPS 2015)

The “old cottage” was the school’s art room (Plate A23). This building was relocated to the school site from Braeburn Homestead by Mr Parsons. The building is constructed of weatherboards, now painted, with a corrugated iron gable roof and bull nosed verandah. The building was affectionately known as “Slanty” by the Braeburn residents as it slanted. The core of the building is of a very traditional construction and form, but overall, it shows a mixture of materials from different periods. The building verandah was added to the building by Ray Freestone using a mixture of recycled building materials, including timber from the original Braeburn homestead, following its relocation (Badgerys Creek Public School 1995). The building is mounted on modern brick piers. School assemblies were held in front of the old cottage until the school’s closure in 2014.



Plate A23 View south toward the old cottage. (Source: RPS 2015)

Formerly located to the west of the school buildings and east of the courts, was a small, c. one metre high, red brick monument capped with a square sandstone slab. A plaque on the monument dedicated it to the pioneering Badgery family, reading:

> *James Badgery Pioneer with his wife Elizabeth landed at Sydney from England in 1799 and settled at Badgerys Creek in 1803*

The rear of the monument reads:

> *This monument is built from the original home-made bricks and contains relics from the home*

Following a number of arson attacks at the school in late 2014 and early 2015, the monument was relocated to Luddenham Primary School for safekeeping.

The Badgerys Creek Public School site generally features asphalt playgrounds surrounded by grass and numerous, largely native trees. Some introduced species including jacarandas feature on the site. A small school orchard was situated between the staff room and the wash room, however, the trees were removed following the school's closure. Multi purpose sports courts are located at the south west corner of the site (Plate A24).



Plate A24 View west across former monument location to courts. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	Badgerys Creek Public School demonstrates the history of education and settlement in the Badgerys Creek area.	Commonwealth
Rarity	Badgerys Creek Public School is not considered to meet this criterion.	None
Research	Badgerys Creek Public School has buildings of timber slab construction (the staff room and old cottage). Both have the potential to yield information relating to early construction techniques.	Commonwealth
Principal characteristics of a class of place	Badgerys Creek Public School is not considered to meet this criterion.	None
Aesthetics	Badgerys Creek Public School is a fine (albeit now vandalised) example of a late semi-rural nineteenth to early twentieth century school and is aesthetically pleasing.	Commonwealth
Creative or technical achievement	Badgerys Creek Public School is not considered to meet this criterion.	None

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Social value	Badgerys Creek Public School was in use as a school for over 100 years. The school is located in the vicinity of two early churches and a community hall and served as an epicenter for the widely dispersed community. The school is considered to have strong social associations for the Badgerys Creek community.	Commonwealth
Significant people	Badgerys Creek Public School is not considered to meet this criterion.	None
Indigenous values	Badgerys Creek Public School is not considered to meet this criterion.	None
Australian historic themes		
Building settlements, towns and cities – developing institutions Educating – establishing schools		
Statement of significance		
Badgerys Creek Public School is a fine and representative example of a small rural school which contains original elements that date to the turn of the century. The school has historic significance as an element in the development of the area, and aesthetic qualities in its historic buildings and setting. It has social significance for the local community and for past students and residents of the area. The integrity and intactness of the school has been compromised by vandalism and arson which has occurred since the school's closure in 2014. Badgerys Creek Public School site demonstrates the history of education and settlement in the area. It is located in the vicinity of two early churches and a community hall and serves as an epicentre for a widely dispersed community.		

AS4 Badgerys Creek butchery

List	-
Type of item	Archaeological
Primary address	Lot 51A Badgerys Creek Road, Badgerys Creek
DIRD ID	404659

Site description

Badgerys Creek butchery site is located at the corner of Badgerys Creek Road and Longleys Road. The butchery was one of two shops in Badgerys Creek. Oral histories collected by Donald and Gulson (1996) relate the origins of the butchery to the Shadlow family, specifically Thomas Shadlow, born 1833. Shadlow purchased 1 rood 26 perches (approximately 1518m^2) at St Mary's in the district of Evans near South Creek on 24 June 1842 (Donald and Gulson 1996:21). According to Lorraine Nobbs of Badgerys Creek, her father had related a story about Thomas Shadlow owning a butchers shop in the South Creek area in the mid-1800s. Thomas' son, Robert "Bobbie" Shadlow (1869-1959), was also a butcher, and due to his longevity was still remembered by some local residents when they were interviewed by Donald and Gulson. Bobbie's daughter-in-law, Gladys Shadlow (nee Weiss) suggested that the butchery on Badgerys Creek Road was established by Bobbie Shadlow in 1886 (Donald and Gulson 1996:116). Bobbie's son, Jack was also a butcher, and allegedly took up the trade because his mother did not want him to become a soldier (Donald and Gulson 1996:116). Badgerys Creek butchers served the local area until 1994, at which time it was run by Trevor Roots (Tovey 2009). A personal communication from Roots to Godden Mackay during their European cultural sites survey (Godden Mackay 1997) suggested that the butchery had only been owned by three families, of which the Shadlows were one. Land ownership details only mention Frances Annie Shadlow and Trevor Root.

After Root left the butchery, the building was sold to industrial hire company, Atomic Hire, which used it as a depot. Atomic Hire was acquired by National Hire in December 1997, and the decision was made to keep all offices including the Badgerys Creek branch.

In 1997 and prior to the demolition of the butchery building, Godden Mackay described the butchery as follows:

> *A small brick building, now painted blue with a white painted central horizontal stripe. The site consists of the original butchery building and two later additions. All the building sections have corrugated iron roofing, with the earliest addition, on the south side, also being constructed of corrugated iron. There is a relatively recent pressed-brick addition to the rear of the structure. The main building has a hipped roof, and both additions are skillion roofed. There are two pane sash windows, one on the original structure and one on the brick wing. There is also a short verandah with three supporting posts on the north side of the building.* (Godden Mackay 1997:Appendix B) (Plate A25)
>
> *It has features that are typical in a small township, such as its detachment from the town centre, its setting within an open paddock and its compact, brick-walled form.* (Godden Mackay 1997:5-15)

Godden Mackay considered the butchery to be an example of a typical semi-rural retail facility, dating from before World War II, which demonstrated "the form and extent of a retail butchery in this context" (Godden Mackay 1997:5-15).



Plate A25 Former butchers at Badgerys Creek. (Source: Godden Mackay 1997)



Plate A26 Aerial view of the Badgerys Creek butcher site, 1965. (Source: Land and Property Information)

At the time of inspection the butchery site was only able to be viewed from the road (Plate A27). The site was overgrown and it was impossible to determine the location of the former butchery from the road.



Plate A27 Badgerys Creek butchery site, viewed from Badgerys Creek Road. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	The butchery had been operating at the site for over a hundred years before its demolition in the 1990s. It therefore has historical significance.	Commonwealth
Rarity	The butchery was one of two shops in Badgerys Creek, the other being a general store. This would have made both the operation and the shop itself of considerable local rarity. However, the shop and business are now gone. The site does not fulfil this criterion.	None
Research	The butchery has now been demolished, however given its long use, it may still retain some archaeological evidence to add to the history of the site. It therefore fulfils this criterion.	Commonwealth
Principal characteristics of a class of place	The butchery was demolished in the 1990s. It therefore does not fulfil this criterion.	None.
Aesthetics	The butchery was demolished in the 1990s and therefore does not fulfil this criterion.	None
Creative or technical achievement	The butchery was demolished in the 1990s and therefore does not fulfil this criterion.	None

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Social value	As one of the two retail outlets in the Badgerys Creek area, it is assumed that the butchery had significant social value for the residents. It was also connected with the Shadlow family and therefore would have had additional social significance due to the Shadlows' long history in Badgerys Creek (see below). It would have fulfilled this criterion prior to its demolition, however as the families and the butchery have gone, it no longer retains that social significance.	Commonwealth
Significant people	The butchery was connected with the Shadlow family, who had roots in the Badgerys Creek area since the early nineteenth century. Their descendants still lived in the area and therefore were prominent in many of the ventures and activities undertaken in Badgerys Creek. This connection therefore fulfils this criterion.	Commonwealth
Indigenous values	There are no known indigenous values attached to the butchery. It therefore does not fulfil this criterion.	None
Australian historic themes		
Developing local, regional and national economies – Feeding people – Retailing foods and beverages		
Statement of significance		
The Badgerys Creek butchery site is considered to be significant for its associations with the Shadlow family, and for its social significance as one of two retail outlets in Badgerys Creek.		

AS5 Badgerys Creek post office

List	-
Type of item	Archaeological
Primary address	Lot 52 Badgerys Creek Road, Badgerys Creek
DIRD ID	404660

Site description

This is the site of the former Badgerys Creek post office which was opened in 1894 and operated until 1989. The first receiving officer was Mr Williams, who also ferried the post between Luddenham Post Office and Badgerys Creek Post Office. The post office was a central hub for residents of the area who would call in to collect their mail and newspapers.

At the time of inspection, the site was overgrown and no surface evidence of the post office remained. The property was more recently the site of the general store, which was boarded up at the time of inspection (Plate A28). It is likely that subsurface evidence of the Badgerys Creek post office remains on the site.



Plate A28 Badgerys Creek post office location, general store at the left. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	The post office represented the recognition of Badgerys Creek as its own area, rather than an outlying post of Luddenham, St Marys (South Creek) or Bringelly.	Commonwealth
Rarity	The post office site is not rare and does not meet this criterion.	None

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Research	Subsurface evidence of the post office is likely to contribute an understanding to rural postal history, particularly in the development of the post office as Badgerys Creek grew.	Commonwealth
Principal characteristics of a class of place	Badgerys Creek post office site is not considered to meet this criterion.	None
Aesthetics	Badgerys Creek post office site is not considered to meet this criterion.	None
Creative or technical achievement	Badgerys Creek post office site is not considered to meet this criterion.	None
Social value	The post office provided a connection for its residents outside of Badgerys Creek and was an important centre of personal and official communication prior to the advent of the telephone. It therefore was of important social value.	Commonwealth
Significant people	Badgerys Creek post office site is not considered to meet this criterion.	None
Indigenous values	Badgerys Creek post office site is not considered to meet this criterion.	None
Australian historic themes		
Developing local, regional and national economies – establishing communications – establishing postal services Building settlements, towns and cities – developing institutions, making settlements to serve rural Australia Governing – administering Australia – providing services and welfare Governing – establishing regional and local identity		
Statement of significance		
Badgerys Creek post office site is considered to be significant for its historic and social values. The establishment of a post office at Badgerys Creek signified its independence as a village, rather than as an outpost of Luddenham, St Mary's or Bringelly. The post office provided an important connection and central hub for the local community. It was an important centre of personal and official communication.		

AS6 Saw pit

List	-
Type of item	Archaeological
Primary address	61 Badgerys Creek Road, Badgerys Creek
DIRD ID	404656

Site description

The dam on this property is thought to be the site of a former saw pit marked on an 1859 map of Luddenham. The shape and location of the dam generally corresponds with that marked on the map.

This property was inspected from the road as it was fenced and very overgrown at the time of inspection (Plate A29).



Plate A29 View of saw pit location from Longleys Road. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	There is little surviving information regarding the saw pit other than the 1859 Luddenham Estate map.	Commonwealth
Rarity	The saw pit is not rare. It therefore does not fulfil this criterion.	None
Research	The saw pit has been filled in with water and as such the research values of the site are unable to be determined.	Unknown

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Principal characteristics of a class of place	The saw pit is not considered to meet this criterion.	None
Aesthetics	The saw pit is not considered to meet this criterion.	None
Creative or technical achievement	The saw pit is not considered to meet this criterion.	None
Social value	The saw pit is not considered to meet this criterion.	None
Significant people	The saw pit is not considered to meet this criterion.	None
Indigenous values	The saw pit is not considered to meet this criterion.	None
Australian historic themes		
Developing local, regional and national economies – utilising natural resources – making forests into a saleable resource		
Statement of significance		
The saw pit is considered to be significant for its historic values. There is very little surviving information relating to the site except an early map of the Badgerys Creek area. The site is currently full of water and as such the research values of the site are unable to be determined.		

AS7 Badgerys Creek Uniting Church and cemetery

List	-
Type of item	Archaeological, burials
Primary address	15 Pitt Street, Badgerys Creek
DIRD ID	404773

Site description

Badgerys Creek Uniting Church and cemetery site is located at 15 Pitt Street, Badgerys Creek.

The Methodist Mission Hall, as the Church was first known, was opened for public worship on 26 January 1898, an event celebrated by 200 people with a tea, sporting contests and a concert. A correspondent reporting on the opening celebrations noted that the hall was "a neat little weatherboard structure" and although built by the Primitive Methodist Society, it was to be used interdenominationally (*Nepean Times*, 1898). The correspondent hailed the day as a "red letter day in the annals of Badgery's Creek history". In the opening ceremony, the Reverend T Davies spoke of his hope that the hall would be "used in every way possible for the advancement of moral and religious culture" (*Nepean Times* 1898:3).

The Church was built to service the small rural community of Badgerys Creek. In 1927, an application by the Church to use the ground as a cemetery was approved by the Nepean Shire Council. Prior to this, parishioners were buried at Luddenham Methodist Church, including members of the Longley family, however it appears that burials were taking place from an earlier time:

> *Badgerys Creek: The newcomers at Mr W Longley's late home here are having their share of trouble. Mrs Briggs had her sister down from Bathurst, and while there she died, leaving two children. The funeral was very largely attended, and much sympathy was shown towards the bereaved ones. Mr F Emery had charge of the funeral arrangements, and the remains were interred in the new cemetery – the first burial there* (*Nepean Times* 13 July 1912).

An article in the *Nepean Times* on 6 February 1958 reports on the sixtieth anniversary of the Church, meaning that the church was constructed in 1898. It was initially constructed for use by all denominations, but predominantly used by the Methodists (now the Uniting Church) and Anglicans until 1912, when the Anglican Church was built. The article states that "(P)rior to the erection of the church, services were held in the homes of Messrs Wye and Swan..." (*Nepean Times* 1958).

The site appears to have housed a simple weatherboard church building and a hall building at the rear of the site. This is visible in historical photographs and aerial imagery of the site (Plates A30, A31)

The church was removed in the early 1990s following acquisition of the site by the Australian Government. A sign at the gate describes the site as "The Uniting Church in Australia, Badgerys Creek" (Plate A32).

Inspection of the site confirmed the general layout and description as presented in Australian Museum Consulting 2014. Possible presence of unmarked graves at this site were noted. Evidence of the church and hall structures including building rubble, glass, and ceramics were noted centrally on the site. Cultural plantings were noted at the rear of the property. Two marked graves are enclosed within a small white picket fence north-west of the church's original position. One of the graves has a sandstone headstone with marble name plate, dated December 1936; the other has an uncut piece of rock as a headstone and a steel place with "1972" engraved on it. Another space contains a depression in the ground indicating an unmarked grave. Fresh flowers were noted on the grave of Daphne Howe (Plate A33).



Plate A30 Badgerys Creek Uniting Church and cemetery site, undated. Note hall building at rear. (Source: Donald and Gulson 1996)



Plate A31 Aerial photograph of Badgerys Creek Uniting Church and cemetery site, note hall building at rear of church, 1965. (Source: Land and Property Information)



Plate A32 Badgerys Creek Uniting Church and cemetery, view from Pitt Street. (Source: RPS 2015)



Plate A33 Badgerys Creek Uniting Church cemetery, view toward former Church site. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	Badgerys Creek Uniting Church was the first consecrated place of worship in the Badgerys Creek area, built in 1898. It was used by both Methodists and Anglicans for worship until the construction of St John's Anglican Church in 1912. It also became a regular meeting place and venue for many social activities for the Badgerys Creek community. The church was demolished in the 1990s however two marked graves remain in the cemetery.	Commonwealth
Rarity	Badgerys Creek Uniting Church and cemetery is consistent with other small, rural church and cemetery sites. It is not considered a rare item and therefore does not meet this criterion.	None
Research	There is a high potential for unmarked burials within this property. The site has the potential to yield valuable information regarding informal burial practices in rural communities. This may provide further information on the pastoral role of the church in small rural communities aside from the formal spiritual model.	Commonwealth
Principal characteristics of a class of place	Badgerys Creek Uniting Church was demolished in the 1990s following acquisition of the land by the Australian Government. The cemetery was approved by the Nepean Shire Council in 1927 and has two marked graves, both believed to be from the Howe family. More graves may be present. It is probable that the cemetery was being used from an earlier time, given media reports detailed the first burial in 1912, but permission from the local council was not given until 1927.	Commonwealth
Aesthetics	Badgerys Creek Uniting Church and cemetery is located in a picturesque site overlooking Badgerys Creek. Structural features at the site are not considered to have any aesthetic significance.	None

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Creative or technical achievement	Badgerys Creek Uniting Church was demolished in the 1990s. The cemetery does not display any features that could be considered to be of creative or technical significance. It therefore does not meet this criterion.	None
Social value	Badgerys Creek Uniting Church was the first place of worship in the Badgerys Creek area. It was used by both Methodists and Anglicans, with clergy from each faith preaching on alternate weeks. Local worshippers, however, attended church every week, regardless of personal affiliations or which denomination was preaching. This demonstrates the church's high social value for past communities. However, current attitudes to the Church and cemetery's social values would need to be established via community engagement.	Commonwealth
Significant people	Badgerys Creek Uniting Church and cemetery were constructed by the local Methodist population wanting a place of worship. There are no people of local, State or National significance connected with the Church. It therefore does not meet this criterion.	None
Indigenous values	There are no indigenous values connected to the Badgerys Creek United Church and cemetery site.	None
Australian historic themes		
Developing Australia's cultural life – worshipping – worshipping together, making places for worship Marking the phases of life – dying – dealing with human remains, mourning the dead, remembering the dead		
Statement of significance		
Badgerys Creek Uniting Church and cemetery is considered to be of significance primarily for its historic, research and social values. The Church was the first formal place of worship in Badgerys Creek, and despite being used by both Methodists and Anglicans, local worshippers attended every week regardless of personal affiliations. The cemetery has two marked graves, and is likely to have unmarked graves which may reveal evidence about early burial practices in Badgerys Creek.		

AS8 St John's Anglican Church and cemetery

List	Liverpool LEP 2008
Type of item	Archaeological, burials
Primary address	30 Pitt Street, Badgerys Creek
DIRD ID	404689

Site description

The St John's Anglican Church Group is located near the intersection of Pitt Street and Badgerys Creek Road adjacent to an important early settlement centre with the Public School, former Methodist Church site and cemetery (now Uniting Church) and early cottages. All that remains on the site is the cemetery. The Church was removed or demolished at same stage since 1992.

St John's Anglican Church was built in the early 1900s to service the Anglican community in rural area (Plate A34). The site currently consists of a churchyard and cemetery with numerous graves, an open lawn and mature tree planting, generally native Eucalyptus species and pines, oleanders, pittosporum and other exotic shrubs, around the perimeter.



Plate A34 St John's Anglican Church, Badgerys Creek. (Source: Office of Environment and Heritage)

The cemetery consists of three rows of graves, facing east, containing at least 37 graves (Plate A35). The grave furniture is predominantly twentieth century concrete 'desks' with granite or marble plaques, kerbing and gravel or tile infil. There is also one war grave at the site. The main families represented at the site are Nobbs and Cox.

A small monument is located within the church yard. This is shown in Plate A34 above, however, has since been truncated and the bell tower removed. It has a brick base with corrugated iron roof, and a plaque which reads "In memory of CJ and A Swan. Erected by their daughter, 1955".

At the time of inspection, the neighbour informed RPS that bones had been identified during civil (possibly drainage) works behind the cemetery site. There is a high potential for unmarked graves at this site.



Plate A35 Rows of graves at St John's Anglican Church and cemetery site. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	There is a high potential for unmarked burials within this property. The site has the potential to yield valuable information regarding informal burial practices in rural communities. This may provide further information on the pastoral role of the church in small rural communities aside from the formal spiritual model.	Commonwealth
Rarity	St John's Anglican Church was demolished in the 1990s following acquisition of the land by the Australian Government. The cemetery is consistent with other cemeteries in small communities both in the local area and across New South Wales.	None
Research	There is potential for further burials to be present within the cemetery. Local residents informed the survey team that bones were noted on the surface on properties near the cemetery following civil works.	Commonwealth
Principal characteristics of a class of place	St John's Anglican Church and cemetery is not considered to meet this criterion.	None

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Aesthetics	The site has a semi rural setting with mature (albeit overgrown) planting.	Commonwealth
Creative or technical achievement	St John's Anglican Church and cemetery is not considered to meet this criterion.	None
Social value	The church site and cemetery represent high social value for worshippers of the Anglican faith.	Commonwealth
Significant people	The cemetery contains the remains of a World War 1 veteran (Edward Cox) and a number of Badgerys Creek pioneer families, such as the Nobbs, the Coxs and the Shadlows.	Commonwealth
Indigenous values	St John's Anglican Church and cemetery is not considered to meet this criterion.	None
Australian historic themes		
Developing Australia's cultural life – worshipping Marking the phases of life – dying – dealing with human remains, mourning the dead, remembering the dead		
Statement of significance		
St John's Anglican Church Group demonstrates the foundation and development of the Anglican Church in a small settlement, Badgerys Creek, in the environs of Liverpool. Many early families of the area are buried in the cemetery. The site also provides evidence of early native vegetation species of the area and introduced exotic plantings. The plantings are representative of late nineteenth and early twentieth century trends in cemetery landscaping. There is the potential to gain more information on the site from further architectural, archaeological and documentary research.		

AS9 Braeburn homestead

List	-
Type of item	Archaeological
Primary address	55 Longleys Road, Badgerys Creek
DIRD ID	404600

Site description

Braeburn is located at 55 Longleys Road, Badgerys Creek. Braeburn was a c.1910 homestead and associated land holdings.

The farm occupied land originally within the Eastern Division of John Blaxland's farm, Luddenham Estate. Lot 38 of the Eastern Division of Luddenham Estate was purchased by William Longley in 1912. Lot 38 is shown on the original plan of subdivision as being 145 acres and bounded to the north by a road and to the south by Badgerys Creek.

Braeburn was owned by the Longley family for a large part of the nineteenth century. Newspaper reports from April 1912 note that William Longley had been an orchardist at Badgerys Creek for nearly 50 years. He had also been a councillor with the Nepean Shire since 1908 and therefore had achieved local standing. William was the eldest son of James Longley, orchardist, who resided at Orange Hill, Badgerys Creek. William and several of his brothers also had their residence listed in electoral records as 'Orange Hill, Bringelly'.

The cottage comprised a single storey farm homestead of timber construction built on brick piers. The main house had brick chimneys, long wide verandahs on all sides and a hipped roof. The bull nosed verandah roofs were supported on square chamfered posts. External walls were clad with weatherboard – some rusticated, some splayed. A simple separate weatherboard shed was located close to the house (Plate A36). In 1991, Braeburn had been vacant for several years and was in derelict condition (Godden Mackay 1997). The homestead was still standing in 1997, but was demolished in the late 1990s.

The most recent leaseholders for the property were in residence at the time of Australian Museum Consulting's inspection of the site in 2014. The leaseholder provided a location for the Braeburn homestead site and advised that the original homestead – Orange Hill – was located at the top of a nearby hill.

Braeburn homestead was located on a relatively flat area set in a garden with mature trees, overlooking a dam (Australian Museum Consulting 2014). Plantings including kurrajong, African olive, a mature yucca, and violet nightshade were present in the vicinity of the homestead (Plate A38). Approximately 200 metres south of the homestead site was an overgrown area with pandanus trees marking the rubbish dump for the homestead. The site had been subject to extensive disturbance by recent farming activities, and the homestead site was under long grass. The concrete remains of the garage with poured concrete slab and corrugated iron impressions were visible. Extensive construction rubble was noted about the site, including broken bricks.



Plate A36 Braeburn homestead, c.1991. (Source: Liverpool City Library)



Plate A37 1965 aerial photograph of Braeburn homestead site. (Source: Land and Property Information)



Plate A38 View of Braeburn homestead site, note plantings. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	Although Braeburn was a well known property in the Badgerys Creek area, there were no events or processes that meet the threshold of significance under this criterion.	None
Rarity	Structural evidence at Braeburn is no longer standing, and subsurface evidence is thought to have been substantially destroyed by modern farming. Braeburn does not meet this criterion.	None
Research	There may be some archaeological potential associated with the Braeburn homestead site, however it has been subject to extensive and intensive farming in recent years which may have destroyed all archaeological evidence. In the event that archaeological evidence is extant on the property it may reveal something of the use of the property by the Longley family.	Commonwealth
Principal characteristics of a class of place	Braeburn homestead site is not considered to meet this criterion.	None
Aesthetics	Braeburn is positioned on an elevated site overlooking Badgerys Creek.	Commonwealth

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Creative or technical achievement	Braeburn homestead is not considered to meet this criterion.	None
Social value	Braeburn was owned by the Longley family and was part of its Orange Hill estate until the Longleys left the area. It retains its social value with the remaining residents of Badgerys Creek. Braeburn is located on Longleys Road, named for the family.	Commonwealth
Significant people	Braeburn belonged to the Longley family who were residents of Badgerys Creek from the mid nineteenth century. Members of that family were instrumental in lobbying for both a church and a school for Badgerys Creek, and were later involved in local government.	Commonwealth
Indigenous values	Braeburn homestead site is not considered to meet this criterion.	None
Australian historic themes		
Developing Australia's cultural life – Living in and around Australian homes Developing Australia's cultural life – Living in the country and rural settlements		
Statement of significance		
Braeburn had a long time association with the Longley family of Badgerys Creek. The property is assessed as being of significance on the basis of its aesthetic, research and social values and association with the Longley family.		

AS10 Orange Hill homestead

List	-
Type of item	Archaeological
Primary address	5 Jagelman Street, Badgerys Creek
DIRD ID	404610

Site description

Orange Hill is thought to be the name of the earlier homestead site at Braeburn, identified by the most recent leaseholder of the property (Australian Museum 2014). Orange Hill is located on a prominent hill approximately 450 metres east of the Braeburn homestead site. The site is small, and is readily identified by stands of cape honeysuckle (Plate A39).

William Longley's father, James Longley was an orchardist who resided at Orange Hill, Badgerys Creek. James' holding was described in an 1885 Parliamentary Return of Landholders as being 583 acres, holding seven horses, 13 cattle, 127 sheep and two pigs (NSW Legislative Assembly 1885). James died at Luddenham in 1895. In 1912, William Longley sold 55 acres of his Braeburn property to Alexander Biggs. On the land were "old houses, lights, fences, rights of way, paths, passages, water and watercourses" (Deed Registers Book 973 No. 618). It is thought that the old houses may have included Orange Hill.

According to Australian Museum Consulting (2014:44), the leaseholder was aware that there was a well at the earlier homestead site. Two wells were identified on the site by Australian Museum Consulting, they were described as "quite overgrown and each had modern rubbish tossed across the openings."



Plate A39 Cape honeysuckle trees marking the location of Orange Hill homestead. (Source: RPS 2015)

A number of sandstock bricks with rectangular frogs were identified at the site. It was noted by Australian Museum Consulting that there was no mortar on the bricks, indicating that they should predate the

introduction of Portland cement in the 1870s (Australian Museum Consulting 2014:44). A line of trees on the adjacent property 404600 may have marked access to the site.

Orange Hill homestead site was test excavated to determine the location of the dwelling at the property. A 2 x 1 metre trench was excavated over a feature comprising bricks embedded into the ground surface and partially overgrown with grass. This trench initially revealed a scatter of bricks, some whole, but most broken. Following removal of the bricks, a course of sandstone blocks was uncovered (Plate A40). These are likely to have been stone flagging. Artefacts uncovered include an iron hinge, an iron door key, ceramic pieces, glass and nails.



Plate A40 Sandstone flagging identified at Orange Hill homestead site. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	"Orange Hill" was the original home of the Longley family, who were tenants of the farm prior to their purchase following the subdivision. The road to its north is named "Longley's Road" after that family.	Commonwealth

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Rarity	Orange Hill is a locally rare example of an early homestead site in the Badgerys Creek area.	Commonwealth
Research	Test excavations revealed the footings of a structure associated with Orange Hill. It has the potential to yield further information regarding a long-used, single-family residential complex.	Commonwealth
Principal characteristics of a class of place	Orange Hill homestead site is not considered to meet this criterion.	None
Aesthetics	Orange Hill homestead site is located in an elevated position overlooking the Badgerys Creek area and with views to the Blue Mountains.	Commonwealth
Creative or technical achievement	Orange Hill homestead site is not considered to meet this criterion.	None
Social value	Orange Hill homestead site is not considered to meet this criterion.	None
Significant people	The Longley family played a large part in the development of Badgerys Creek into a settlement, and were involved in the establishment of the school and the Methodist church. William Longley was a long-serving member of the Nepean Shire Council.	Commonwealth
Indigenous values	Orange Hill homestead site is not considered to meet this criterion.	None
Australian historic themes		
Developing Australia's cultural life – living in and around Australian homes Developing Australia's cultural life – living in the country and rural settlements		
Statement of significance		
Orange Hill was the original home in the area of the Longley family, who were well known and influential in the Badgerys Creek area. Orange Hill is considered to be significant for its historic and research values, and associations with significant people.		

AS11 Vicary's Winery

List	Liverpool LEP 2008
Type of item	Complex/group
Primary address	1935 The Northern Road, Luddenham
DIRD ID	404757

Site description

Vicary's Winery group is located at 1935 The Northern Road. The property was originally part of Blaxland's Luddenham Estate. In 1842, Blaxland transferred a mortgage for the Estate to the Australian Trust Company, excluding 300 acres bounded on the east by The Northern Road, and by Gore's, Wentworth's, and Piper's land.

From the 1880s, the property operated as a working farm. The site features a c.1860 slab homestead, and a c.1880s woolshed and shearer's quarters.

In 1916, Cecil Vicary purchased the property for the purposes of establishing a dairy and vineyard. Vicary converted the woolshed to a dairy, the vineyards were planted in 1917 and commercial production began in 1923. In 1947, Vicary was granted a licence to sell wine from his cellar door at Luddenham:

> *Cecil Wilfred Vicary, of "The Vineyards", Bringelly Road, Luddenham, applied for a spirit merchants licence, but Mr John Clapin (formerly of Penrith) said that his clients business was that of an old established vigneron, who would give an undertaking that he would use it for no other purpose than wine-making and the carrying on of his business.*
>
> *The licensing inspectors report stated that the applicant was a man of good character. The inspector opposed the application on the grounds that the reasonable requirements of the neighbourhood did not justify it.*
>
> *Private objectors added the objection that the premises proposed to be licensed were not suitable.*
>
> *Applicant, Cecil Vicary, said 'he bought the property about 30 years ago and commenced the vineyard about 20 years ago. People from metropolls and country bought wine (as allowed by law to vignerons) from him. His place was a quarter of a mile off the road. He had built in anticipation of carrying on his business as applied for. The building would hold 10,000 gallons. He had been producing, on an average, during the last 12 or 15 years about 1000 gallons a year. Production varied considerably, mostly owing to weather. In wine-making, it was necessary to blend light wines with standard wines. He needed to buy in large quantities for blending.*
>
> *Louis Harold Skidmore (Shire President), Mulgoa and John Armstrong Morgan, Wallacia, gave evidence in support of the application.*
>
> ***Granted in View of Undertaking***
>
> *Mr Wells, L.M (giving his decision): Applicant is a vigneron and desires to blend his wine with other wines in excess of the percentage at present. He desires to deliver his wine; he desires to buy more than five gallons from vignerons for blending and desires to sell more than 5-gallon lots. For that reason he needs a spirit merchant's licence. He had given an undertaking on oath that he will not sell beers or spirits and will deal only in wines, and not depart from that undertaking without first obtaining the permission of this court. In view of the undertaking which he has given, I grant the application.* (*Nepean Times,* 23 January 1947)



Plate A41 Advertisement for Vicary's "Vineyards". (Source: *Nepean Times*, 5 April 1951)

Vicary's is believed to be the oldest continually operating winery in Sydney with wine processing still occurring until 2015. The winery is the sole survivor of a previously flourishing viticulture industry on the south-west Cumberland Plains, established from the 1830s and 1840s. It was relocated to the Hunter Valley from the 1860s after constant outbreaks of phylloxera and other vine pests in the region. Early vineyards included Blaxland's Leeholme at Luddenham, Captain Chisholm at Gladswood, Narellan and several properties in the Mulgoa Valley (Godden Mackay 1997).

Vicary's Winery group consists of a combination of surviving earlier structures and a range of modern buildings constructed as the wine making technology at the site was progressively updated. The property includes a vineyard situated north of the major wine-making complex. The wine-making complex includes a collection of c.1950s and 1980s sheds which house modern winemaking equipment. One nineteenth century winepress is on display at the cellar door. The cellar door building was built in 1923, and is constructed of red brisk ashlar with sandstone stone work facing around the double doors and windows (Plate A42). A number of later sheds, ablutions blocks, and an old train carriage are also present within the complex (Plate A43, A44).



Plate A42 Vicary's Winery cellar door building. (Source: RPS 2015)



Plate A43 Vicary's Winery group ablutions and ancillary sheds. (Source: RPS 2015)



Plate A44 Vicary's Winery group, train carriage at right, extension to woolshed at left. (Source: RPS 2015)

Significant surviving earlier structures are the woolshed (former dairy) (Plate A45) to the west of the complex and slab homestead to the north of the complex. Since 1992, there have been a number of modifications to the complex. The woolshed has been substantially altered, including an extension to the western end of the shed to facilitate its use as a dance hall and wedding venue. Cow bails (Plate A46), presumably from the former dairy, remain at the front of the woolshed.



Plate A45 Vicary's Winery woolshed. (Source: RPS 2015)



Plate A46 Vicary's Winery group, cow bails outside the woolshed. (Source: RPS 2015)

The slab horse shed recorded in 1992 no longer remains on site. A description of the horse shed in 1997 indicated its condition was very poor and collapse was imminent.

The c.1860 slab homestead (Plate A47) remained in a garden setting at the time of inspection, albeit overgrown. The homestead was occupied at the time of the inspection and as such was largely inaccessible. The original slab house has symmetrical Georgian design with roof line and wide verandahs typical of the 1840s-1860s. The brick chimney is external, and although rendered and painted white, sandstock bricks are

visible, indicating an early date for the original structure. Later accretions, including weatherboard cladding to the east wall, fibro infilled verandahs and a fibro wing to the west of the house (Plate A48) are typical of early twentieth century Federation style architecture.



Plate A47 Vicary's Winery front of c.1860 slab homestead. (Source: RPS 2015)



Plate A48 Vicary's Winery, rear of c.1860 slab homestead, fibro wing at right. (Source: RPS 2015)

At the time of inspection, Chris Niccol continued to make wine, crushing around 40 tonnes per year for his own and other wineries in the area. The Sydney basin is classified as a phylloxera quarantine area, and as such, local grapes cannot be processed outside this area. Inspection of the site confirmed the general layout

and description as presented in Australian Museum Consulting 2014. The slab horse shed recorded in 1992 no longer remains on site. A description of the structure in 1997 indicated its condition was very poor and collapse was imminent. Early and winemaking machinery was also noted on the site.

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	From the 1880s Vicary's operated as a working farm and featured a slab homestead, woolshed and shearers quarters. In 1916, Cecil Vicary purchased the property for the purposes of establishing a vineyard. The property has continued to operate as a vineyard, and its surviving complex of structures demonstrate the history of a one thriving, but now diminished, industry in the area.	Commonwealth
Rarity	Vicary's Winery group is a rare complex of structures which document the agricultural use of the property from the 1880s to the present. Further, the complex represents the last remnant of the local wine industry, which is rare in the local area.	Commonwealth
Research	The property as the potential to contain archaeological evidence of former outbuildings. Due to the limited information available about early use of the property as a farm, such information has the potential to provide further information about the use and significance of the property.	Commonwealth
Principal characteristics of a class of place	The use of the property is consistent with other farms and vineyards in the local area. The complex of structures demonstrates the use of the property as a farm and vineyard.	Commonwealth
Aesthetics	Vicary's Winery group is an intact example of a complex of structures associated with the use of the property as a farm and a vineyard from the 1880s. The structures have aesthetic significance within a rural setting.	Commonwealth
Creative or technical achievement	Vicary's Winery group is not considered to meet this criterion.	None
Social value	Vicary's Winery group is not considered to meet this criterion.	None
Significant people	Vicary's Winery group is associated with Cecil Vicary, a significant person in the local area.	Commonwealth

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Indigenous values	Vicary's Winery group is not considered to meet this criterion.	None
Australian historic themes		
Developing local, regional and national economies – developing primary production – grazing stock, developing agricultural industries Developing local, regional and national economies – feeding people – preserving food and beverages Developing Australia's cultural life – living in the country and rural settlements, living in and around Australian homes		
Statement of significance		
Vicary's Winery group is an intact set of structures which document the agricultural change in the Luddenham area since the original granting of land to Blaxland in the early nineteenth century. The group includes structures such as a slab house, slab hut and former dairy (woolshed) which relate to the small scale agricultural industry of the late nineteenth century. Since the twentieth century, the group has been predominantly in use as a winery and its surviving vineyard and complex demonstrate the history of a once thriving, but now diminished, wine industry in the Luddenham, Badgerys, Mulgoa area. It is Sydney's oldest continually operating winery.		

AS12 Well

List	-
Type of item	Archaeological
Primary address	1972 The Northern Road, Luddenham
DIRD ID	404774

Site description

1972 The Northern Road formed part of Blaxland's Luddenham Estate. In October 1859, the *Sydney Morning Herald* published a description of Luddenham Estate, noting No 24 of the Eastern Division, of which this property was part, as "Uncleared". The property was purchased by Philip and John Anschau in 1860, on the proviso that they pay £362, 18 shillings and 3 pence by 1 January 1867, an arrangement on which it appears they defaulted. As a result, the property was resold to Andrew and Mary McGarrity on 31 October 1870.

In 1876, the property was sold to Isaac Earlam who ran it and adjacent properties as an orchard and vineyard. In 1960, the property left the Earlam family and was purchased by Yero Bautovich, an immigrant from Yugoslavia.

At the time of the site inspection, the field team was informed that the house on this property had been constructed about a sandstone well. Bautovich appears to have constructed the present house (Plate A49) about the sandstone well (Plate A50). The well is likely to have been constructed by the Earlam family as part of their development of the property as an orchard and vineyard.



Plate A49 House at 1972 The Northern Road. (Source: RPS 2015)



Plate A50 Internal sandstone lined well at 1972 The Northern Road, capped with fibro and timber. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	This property was utilised throughout the second half of the nineteenth and first half of the twentieth century as an orchard and vineyard. Such agricultural practices were common in the area and there are some structures which have not been assessed on the property which may be associated with these agricultural practices. A sandstone-lined well, undated, remains intact inside the current residence.	Commonwealth
Rarity	The presence of a sandstone lined well on the site is rare in the local context.	Commonwealth
Research	This item is not considered to meet this criterion.	None
Principal characteristics of a class of place	This item is not considered to meet this criterion.	None
Aesthetics	This item is not considered to meet this criterion.	None
Creative or technical achievement	This item is not considered to meet this criterion.	None
Social value	This item is not considered to meet this criterion.	None

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Significant people	This property is associated with the Earlem family, specifically Isaac Earlam, who originally purchased the land from Nicholson and his son Victor Earlam, who were significant people in the local area.	Commonwealth
Indigenous values	This item is not considered to meet this criterion.	None
Australian historic themes		
Developing local, regional and national economies – developing primary production – developing agricultural industries Developing Australia's cultural life – living in the country and rural settlements, living in and around Australian homes		
Statement of significance		
The well at 1972 The Northern Road appears to have been associated with the Earlam family's use of the site from the late nineteenth century. The site is considered to be significant for its historical and rarity values, as well as its associations with the Earlams.		

AS13 The Northern Road alignment

List	-
Type of item	Archaeological
Primary address	The Northern Road, Luddenham
DIRD ID	-

Site description

Within the airport site, The Northern Road alignment has been modified a number of times, including opposite St Francis Xavier Church, and near the site of Lawson's Inn. The Northern Road is a very early road alignment and has been known by other names, including "North Road" and "the Bringelly Road". The Northern Road was initially used to connect Camden and Windsor. A notice in the *Sydney Gazette* by W. Oxley made the following statement:

> *In consequence of numerous Applications as to the Line of Road to be followed by Persons travelling to Windsor, and the Parts adjacent, to the Southern settlements of Minto, Airds, and Appin. - NOTICE is hereby given that the road from Windsor, which was marked by Order of Governor BLIGH, to Frogmore Estate in Melville District, is the Road to be followed from Windsor and from thence the Public Road continues, as at present used, to Minto, Cooke, Airds and Appin. This Cross Road from Windsor ends in the new Bringelly Road, about three-quarters of a mile West of the Cow-pasture Road.* (*Sydney Gazette and New South Wales Advertiser*, 15 September 1821)

The Northern Road is noted on a map of the Bringelly area in 1834 as North Road (Plate A51).

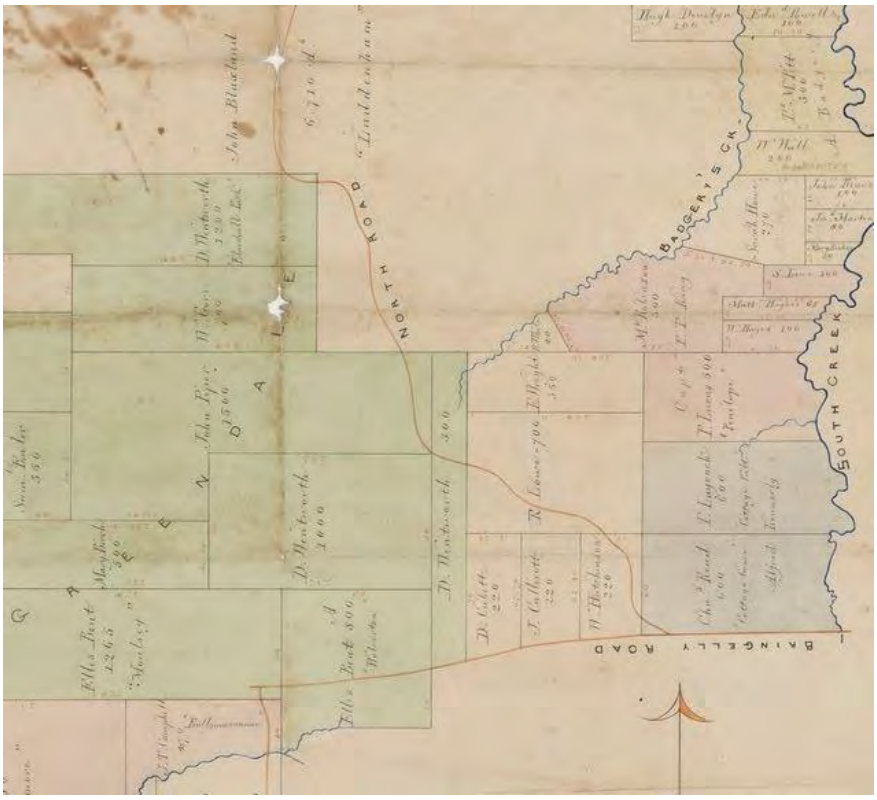

Plate A51 Cadastral plan of the Parish of Bringelly, 1834, note North Road. (Source: State Library of NSW)

The alignment of The Northern Road has changed a number of times. Notable deviations within the airport site include those immediately south of Luddenham and near St Francis Xavier Church and cemetery site.

Significance assessment		
Criterion	**Discussion**	**Heritage significance within the airport site**
Events and processes	The Northern Road has been an important historic thoroughfare linking the nascent communities of Camden and Windsor. Although it has been upgraded and alignments in some sections have changed, it has followed the same basic route since the early nineteenth century.	Commonwealth
Rarity	The Northern Road is not considered to meet this criterion.	None
Research	The alignment of the road has been well mapped since its construction. However there may be areas of the original alignment that demonstrate early road building techniques and materials.	Commonwealth
Principal characteristics of a class of place	The Northern Road is not considered to meet this criterion.	None
Aesthetics	The Northern Road is not considered to meet this criterion.	None
Creative or technical achievement	The Northern Road is not considered to meet this criterion.	None
Social value	The Northern Road is not considered to meet this criterion.	None
Significant people	The Northern Road is not considered to meet this criterion.	None
Indigenous values	The Northern Road is not considered to meet this criterion.	None
Australian historic themes		
Developing local, regional and national economies – moving goods and people – building and maintaining roads, moving goods and people on land Building settlements, towns and cities – supplying urban services		
Statement of significance		
The Northern Road alignment is considered to be significant as one of the earliest roads in the area, predating the subdivision of early land grants in the area.		

AS14 Anschau Vineyard, Steinberg and grave(s)

List	-
Type of item	Archaeological, burials
Primary address	1845-1875 The Northern Road, Luddenham
DIRD ID	404800

Site description

The former Anschau Vineyard site is located on the eastern side of The Northern Road south of Luddenham. Anschau Vineyard was one of a number of small vineyards operating in the region from the late 1800s. The Parish Map for Bringelly of 1953 shows Lot 25 of the Eastern Division of Luddenham Estate as containing "Anchau" trigonometry station. The property measures 247 acres, 1 rood 16 perches and is bounded on its western side by The Northern Road.

Franz Johann Anschau arrived in Sydney on 4 April 1849 onboard the *Beluah* with his wife, Elizabeth, and their children Philip, Franz Jnr, Elizabeth, Apollonia and Joseph. Anschau's occupation was listed as wine cooper, with Philip, Franz Jnr and Johann listed as vine dressers. It is likely that Anschau was brought to Australia from Germany by Macarthur for his Camden estates (Australian Museum Consulting 2014). Many of the German vintners brought to Camden later established vineyards in the local area, and the Anschau family may be among the earliest vignerons to venture into Badgerys Creek (Australian Museum Consulting 2014). In the 1850s, Franz Anschau established a tannery and a vineyard near Luddenham (Sydney Vignerons Association 1995).

In 1877, Franz Anschau established a winery on his property, Steinberg, near Luddenham (Paul Davies Pty Ltd 2007:153). Little information is known regarding the winery, however the Anschau family appear to have prospered. Franz Anschau died at Luddenham in 1876. Following his death, the property passed to his son Francis and the family continued to run the vineyard and other interests in the area. Following Francis' death in 1896, he granted a life estate to his wife Elizabeth, and devised that it would pass to his sisters following the death of his wife.

In 1896, only two people in the Penrith Licensing District had wine licenses, being Elizabeth Anschau of Luddenham and Beaumont Wilson of Badgerys Creek. The following year, Elizabeth Anschau and Frederick Petith, both of Luddenham, each had a wine license along with William F Emert of Mount Druitt. *Sands Directory* of 1903 lists Mrs F Anschau as being at the "Wine Shop, Luddenham".

In 1908, Elizabeth, Apollonia and Margaretha Anschau sold part of their land on The Northern Road at Luddenham to the trustees of the Roman Catholic diocese. St Francis Xavier Church was constructed on this land in 1912 (Catholic Archdiocese of Parramatta, undated).

In 1927, Elizabeth Anschau was still at Steinberg, and was recorded as having five horses and 22 cattle on 196 acres (Sands Directory 1927). Elizabeth died in December of that year, and left her estate to her sisters, Apollonia and Margaretha. Margaretha died in 1933, leaving her portion of the estate to Apollonia. Apollonia died in 1954, leaving the estate to FL and KJ Harvey.

A newspaper article in 1954 reported the death of 94 year old Appelona (sic) Anschau, who had lived her whole life at Steinberg. The following is noted about the vineyard:

> *Mr and Mrs Franz Anschau... came out from Germany years before and married here. At Luddenham, on 200 acres, he industriously conducted a farm, vineyard and wine cellars.* (*Nepean Times*, 15 July 1954)

At the time of Godden Mackay's inspection of the site for the 1997 *Draft EIS*, the following commentary was made:

> *There appears to be no building remaining from this property, however, the outline of a structure and the vineyard to its north are distinguished by a square imprint and by variations in the colour and density of the grass now growing over the area. There are visible lines of furrows across the west-sloping ground where the vines were once planted.* (Godden Mackay 1997)

These furrow lines are clearly visible in an aerial photograph of the site, taken in 1965 (Plate A52). There is no remaining evidence of the vineyard (Plate A53).

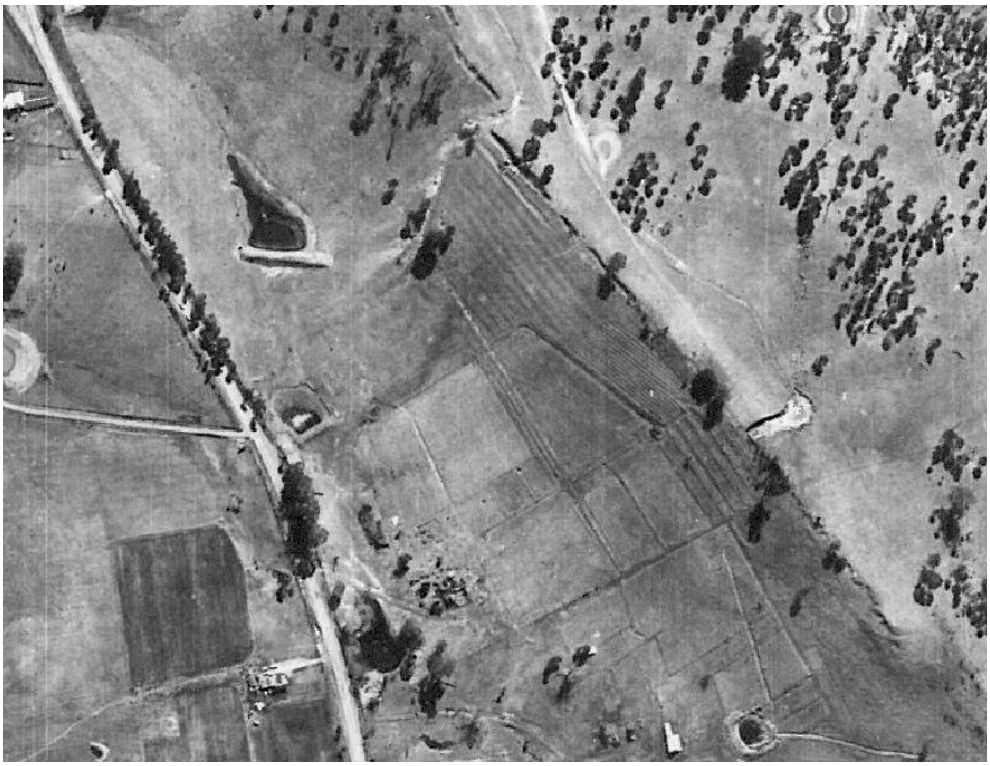

Plate A52 1965 aerial photograph of Anschau Vineyard site, note furrows on western slope and structures on the site. (Source: Land and Property Information, NSW 1404 5166 Cumberland 1965 series, Run 22, 29/08.1965).

During the 2015 site inspection of the former Anschau Vineyard and Steinberg site, the former owner of the property, Julia Palmer, advised that there were ruins of a homestead and some blacksmith's tools located approximately 100 metres behind the current house complex. Several sandstock bricks, iron and other building materials were noted, as well as the overgrown ruin of Steinberg (Plate A54, A55). Owing to several warnings from the occupier regarding snakes at the site, the building material was photographed and mapped, however the extensive vegetation covering did not allow for a comprehensive assessment. It was clear that this was the site of a substantial dwelling of mid to late nineteenth century construction. The presence of a number of tools used for blacksmithing located at the rear of the homestead indicated the possibility of subsurface footings for other outbuildings. Four large timber posts forming a square around the homestead site were also recorded, possibly demarcating a residential precinct for the homestead.

In late June 2015, around the time the property was due to be vacated, Palmer reported the site of a suspected grave to Pam Kennison, property manager of the airport site. At the time of reporting, the grave had not been subject to inspection, however, this is likely to be the grave of an Anschau family member.



Plate A53 View toward Anschau Vineyard site from The Northern Road. (Source: RPS 2015)



Plate A54 View east to the ruin of Steinberg, thickly covered in vegetation. (Source: RPS 2015)



Plate A55 Collected iron thought to be evidence of a smithy near Steinberg. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	The Anschau vineyard was one of the earliest vineyards in the Luddenham area. Aerial photographs show furrows consistent with the vineyards. Steinberg was the name of the homestead and property. It is listed as the address of many individuals from Luddenham's Anschau family through to the death of Apollonia Anschau in 1954.	Commonwealth
Rarity	The Luddenham and Badgerys Creek area was known for its orchards and vineyards and was actively promoted as such in the late nineteenth and early twentieth century. The vineyard was not a rare pursuit in the local area, however, the presence of blacksmithing tools adjacent to the remains of Steinberg homestead may represent a rare example of a mid nineteenth century self-sufficient family property.	Commonwealth

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Research	The property is considered likely to have subsurface integrity. As an early vineyard site, this place has the potential to provide an insight into the lives and activities of the people who lived and worked in the local wine industry that would not be available from other sources. Any archaeological evidence of Steinberg homestead and the associated smithy is likely to add to the current information relating to the Anschau family and their vineyard business.	Commonwealth
Principal characteristics of a class of place	The vineyard is consistent with other ventures undertaken in the Badgerys Creek and Luddenham area. The area was actively promoted by real estate agents as land ideal for orchards and vineyards, and used Anschau's vineyard as demonstration of this.	Commonwealth
Aesthetics	Steinberg is located on a west facing slope of a dominant ridgeline which runs roughly north-south adjacent to The Northern Road alignment. The property has views to the Blue Mountains and meets this criterion.	Commonwealth
Creative or technical achievement	Anschau Vineyard is the location of one of the earliest vineyards in the Badgerys Creek area.	Commonwealth
Social value	The property was a cornerstone of early agriculture and viticulture in the area, and was often held up as an example of success.	Commonwealth
Significant people	Anschau Vineyard and Steinberg site was associated with the Anschau family. The Anschau family was locally prominent, donating land to the Catholic Church for the establishment of a Church, called St Francis Xavier after Francis Anschau.	Commonwealth
Indigenous values	Anschau Vineyard and Steinberg is not considered to meet this criterion.	None

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Australian historic themes		
Peopling Australia – migrating – changing the face of rural and urban Australia through migration Developing local, regional and national economies – developing primary production – developing agricultural industries Developing local, regional and national economies – feeding people – preserving food and beverages Marking the phases of life – dying – dealing with human remains Developing Australia's cultural life – living in and around Australia homes Developing Australia's cultural life – living in the country and rural settlements		
Statement of significance		
Anschau Vineyard and Steinberg is assessed as being of significance for its historic associations with the prominent Anschau family, who had close connections with the development of a Catholic presence in Luddenham.		

AS15 St Francis Xavier Church and cemetery

List	-
Type of item	Archaeological
Primary address	1966 The Northern Road, Luddenham
DIRD ID	404607

Site description

St Francis Xavier Church and cemetery site is located at 1966 The Northern Road, Luddenham.

St Francis Xavier Church was constructed in 1912 on land variously described as sold or donated by the Anschau family to the Roman Catholic diocese in 1908.

Some sources mention a cemetery present at the site prior to the construction of the Church, however the scope of this information is limited. An article in the *Nepean Times* in 1911 stated:

> *Beside the road leading from Luddenham, on an elevated position, there was a cemetery for many years only; but recently a new Catholic Church has been built within the fence of "God's acre". Originally the ground for this cemetery was donated by the late Mr Francis Anschau, whose daughters live at 'Steinberg' Luddenham. The Catholics of Luddenham had no church wherein to worship until the happy thought occurred to them to build one, and have journeyed to Mulgoa for many years to attend worship. That thought has been realised with an accomplished fact, in as much as the church has been completed, thanks to the special efforts of the Misses Anschau who made a special appeal to all their friends and especially their own relatives. Although the church is only weatherboard, it will serve its purpose for many years. This structure was built by Mr F. Petith and Sons, who agreed that the labor* [sic] *of erection at the church was to be their contribution, and it was no small contribution*. (*Nepean Times,* 21 October 1911)

A newspaper article in 1954 reporting the death of Apollonia Anschau at age 94 reveals further details about the Anschau family's involvement in the Church:

> *It is worthy of note that portion of the Catholic Cemetery at Luddenham was a gift from the family to the Church.... The funeral* [of Apollonia] *took place on Wednesday, July 7, when the remains were interred in the Catholic Cemetery at Luddenham with those of her two sisters. Nearby is a grave in which her father and mother were buried. Miss Appelona* [sic] *Anschau, some years ago, prepared inscriptions for the one headstone for the grave of her two sisters and herself, the inscription relating to herself to be added at the appropriate time.* (*Nepean Times*, 15 July 1954)

Apollonia's parents died well before the establishment of the church and it seems the earlier date for the cemetery is probable. Their remains were moved from St Francis Xavier at Luddenham to the Roman Catholic cemetery at Greendale in the 1990s. As the church was not consecrated until 1912, Franz Snr's burial at the site in 1876 raises the possibility of other unrecorded burials dating from the intervening period.

Aside from the Anschau and Petith families, other families known to have been buried at St Francis Xavier cemetery include the Dorahy, Salmon, Neiss and Flynn families. These surnames have long been associated with the Luddenham and Badgerys Creek areas.

Burials in the cemetery were exhumed and reinterred at St Francis Xavier Church at Greendale, including many members of the Anschau family. The contents of the original St Francis Xavier Church were also removed to the Greendale church.

At the time of inspection, the property was largely abandoned and overgrown, with large open areas of grass central to the property (Plate A57). Neighbours from both adjoining properties told of how they have found pieces of coffins and grave furniture throughout the paddock, mentioning that the exhumation of graves from the site appeared to have been rushed and messy.

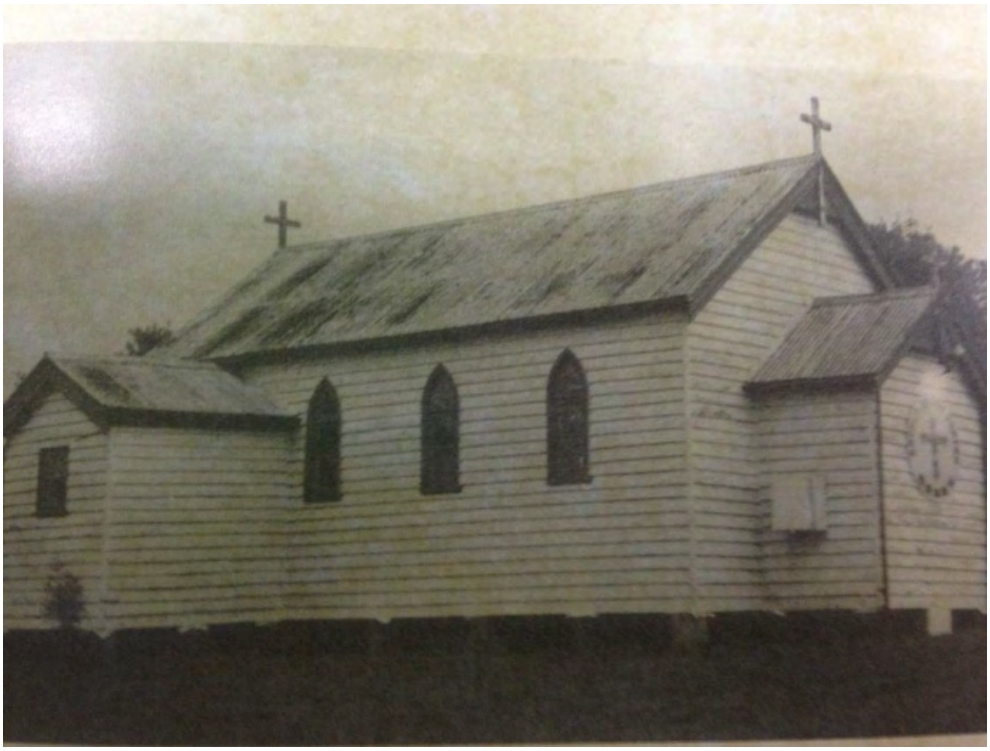

Plate A56 Undated photograph of St Francis Xavier Church. (Source: Wilmington 2013:35)



Plate A57 Open areas within St Francis Xavier Church and cemetery site. (Source: RPS 2015)

The ruins of a structure including timber and a concrete slab were identified east of the Church and cemetery (Plate A58). The provenance of this structure is currently unknown.



Plate A58 Ruins of unknown structure, St Francis Xavier Church and cemetery. (Source: RPS 2015)



Plate A59 St Francis Xavier Church Greendale, with relocated headstones from the original site. (Source: RPS 2014)



Plate A60 Plaque at St Francis Xavier Greendale. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	The church and cemetery are historically significant as the first Catholic church in the vicinity. There are also reports that the cemetery predated the church, indicating the potential for unmarked and/or unrecorded graves.	Commonwealth
Rarity	The church and cemetery site is consistent with others in rural areas. The item does not meet this criterion.	None
Research	There is scope for further research on the cemetery, particularly in regard to early burial practices in the Luddenham area.	Commonwealth
Principal characteristics of a class of place	St Francis Xavier Church and cemetery site is not considered to meet this criterion.	None
Aesthetics	St Francis Xavier Church and cemetery site is located in an elevated position overlooking the Luddenham area, with views to the Blue Mountains.	Commonwealth
Creative or technical achievement	St Francis Xavier Church and cemetery site is not considered to meet this criterion.	None

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Social value	The church and cemetery site is likely to have high social value to Catholics in the area, particularly those whose family were first buried there.	Commonwealth
Significant people	The church and cemetery site is located on land donated by the Anschau family, who owned the nearby "Steinberg" homestead and were involved in early winemaking.	Commonwealth
Indigenous values	St Francis Xavier Church and cemetery site is not considered to meet this criterion.	None
Australian historic themes		
Developing Australia's cultural life – worshipping – worshipping together, making places for worship Marking the phases of life – dying – dealing with human remains, mourning the dead, remembering the dead		
Statement of significance		
St Francis Xavier Catholic Church and Cemetery is considered to be significant for its historic and social values, and for its associations with the Anschau family. The site is also considered to be significant for its research values, as it is the site of one of the earliest churches in the Luddenham area, and may be the site of much earlier burials.		

AS16 Jackson Road cottage

List	-
Type of item	Cottage and farm buildings
Primary address	Lot 2 Jackson Road, Luddenham
DIRD ID	404804

Site description

Lot 2 Jackson Road is located at the intersection of Jackson and Anton Roads, Luddenham

The property was once part of Blaxland's Luddenham Estate, and was offered for sale in the late 1880s as part of the Luddenham Farms. Luddenham Farms were advertised as "orchard and vineyard land" with "local residents who have turned their attention to orchard planting and grape culture [having' met with wonderful success" (Swyny 1900).

The property has a c.1890 house and several ancillary farming structures. The house is of simple rectangular form with skillion additions to the rear, and bullnose verandah about three sides on chamfered posts (Plate A61, A62). The brick walls are internally plaster rendered. The exterior of the house is rendered and painted.

At this time, it is unclear who built the house at Lot 2 Jackson Road, however, the property was owned by Ebenezer Vicary and transferred to James Manton, blacksmith of Woolloomooloo in 1887. In 1891, Manton sold the property, and it is unclear whether it was improved at the time of sale.



Plate A61 Undated photograph of house at Lot 2 Jackson Road. (Source: Donald and Gulson 1996)



Plate A62 Lot 2 Jackson Road house. (Source: RPS 2015)

The original part of the house has two rooms with an internal fireplace. The kitchen is housed within the skillion addition, which appears to have replaced an earlier skillion structure with fireplace to exterior wall (Plate A62). There is a fibro bathroom and laundry addition at the rear of the kitchen.



Plate A63 Lot 2 Jackson Road farm shed with accretions. (Source: RPS 2015)

The ancillary farming buildings include a series of corrugated iron clad sheds with accretions (Plate A63). These were in use at the time of inspection and as such, full examination was not permitted. Infrastructure including services and septic were present within the property.

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	There are no known events or processes associated with this place.	None
Rarity	The c. 1890 dwelling is a rare example in the local landscape. Though a number of others are known to have been built in the local area, it is one of the few remaining examples.	Commonwealth
Research	Potential archaeological remains of former outbuildings and other structures associated with the use of the farm. Due to the limited information available about the use of the farm from 1870 onwards, such information has the potential to further our understanding of the use and significance of the farm.	Commonwealth
Principal characteristics of a class of place	The c. 1890 dwelling demonstrates the principal characteristics of an early cottage including a gable roof with a medium pitch and a bullnose verandah.	Commonwealth
Aesthetics	Intact example of a c. 1890 dwelling which has aesthetic significance due to its rural setting.	Commonwealth
Creative or technical achievement	Jackson Road cottage is not considered to meet this criterion.	None
Social value	Jackson Road cottage is not considered to meet this criterion.	None
Significant people	Jackson Road cottage is not considered to meet this criterion.	None
Indigenous values	Jackson Road cottage is not considered to meet this criterion.	None
Australian historic themes		
Working – working on the land Developing Australia's cultural life – living in the country and rural settlements Developing Australia's cultural life – living in and around Australian homes		
Statement of significance		
The Jackson Road cottage is considered to be a representative example of a late nineteenth century farming cottage. The site is considered to be significant for its rarity, research potential, principal characteristics and aesthetic values.		

AS17 Badgerys Creek Road alignment

List	-
Type of item	Archaeological
Primary address	Badgerys Creek Road, Badgerys Creek
DIRD ID	-

Site description

Badgerys Creek Road has been noted on maps since the 1850s and was known variously as Badgerys Creek Road and Cox's Road. The alignment has altered little since that time.

It is believed that James Badgery may have been responsible for the road alignment from a charge of trespass against him by Sir John Jamison. According to the *Sydney Gazette*:

> *In 1815 the defendant, to save himself the trouble of prosecuting the highway from his own residence to his Nepean farm, made a road across Lord's Folly farm, by which he lessened the distance about 1½ miles. This cross-road, which had received the name of 'Badgery's Road' had been open for the last seven years. This farm (Lord's Folly) became the property of the plaintiff, who had the whole, for many miles round, securely fenced in; in accomplishing which object, Badgery's road was necessarily shut up. A few months since, the defendant, with his family, on their return from Richmond thought proper to pursue his favourite and, what he esteemed, his* own *road. When he came to the fence upon the side nearest to his farm, it was discovered to be closed up by a strong railing. Without the least hesitancy, Mr Badgery dismounted and broke down the fence, having previously offered a government servant of the plaintiff two dollars for an axe, to enable him to destroy the fence; at the same time affirming he would take it down as fast as Sir John could put it up.* (*Sydney Gazette and New South Wales Advertiser*, 8 November 1822)

However, there are no maps to confirm that "Badgery's Road" is indeed the same as "Badgerys Creek Road". Both Badgery's and Jamison's holdings were located on the northern side of Elizabeth Drive (Orphan School Road) and it is probable that the subject of the trespass was in that locality.

The 1859 Eastern Division of the Luddenham Estate names the road "Cox's Road", presumably as the road led to the property owned by the Cox family.

Significance assessment		
Criterion	**Discussion**	**Heritage significance of Badgerys Creek Road within the airport site**
Events and processes	Badgerys Creek Road has followed roughly the same alignment since its construction and has been used as the main road in Badgerys Creek ever since.	Commonwealth
Rarity	Badgerys Creek Road alignment is not considered to meet this criterion.	None
Research	Investigation of the Badgerys Creek Road alignment may reveal evidence about early road construction methods in the area.	Commonwealth
Principal characteristics of a class of place	Badgerys Creek Road alignment is not considered to meet this criterion.	None

Significance assessment		
Criterion	**Discussion**	**Heritage significance of Badgerys Creek Road within the airport site**
Aesthetics	Badgerys Creek Road alignment is not considered to meet this criterion.	None
Creative or technical achievement	Badgerys Creek Road alignment is not considered to meet this criterion.	None
Social value	Apart from its extensive use by local residents, it is unlikely that the road has any social value from a heritage perspective.	None
Significant people	There is some suggestion that the road was originally laid down and used by James Badgery.	Commonwealth
Indigenous values	Badgerys Creek Road alignment is not considered to meet this criterion.	None
Australian historic themes		
Developing local, regional and national economies – moving goods and people – building and maintaining roads, moving goods and people on land Building settlements, towns and cities – supplying urban services		
Statement of significance		
The Badgerys Creek Road alignment is considered to be historically significant as one of the earliest roads in the area, predating the subdivision of the early land grants. This item is strongly associated with James Badgery, who allegedly selected the route as a short cut to his property.		

AS18 Spredenberg

List	-
Type of item	Archaeological
Primary address	55 Longleys Road, Badgerys Creek
DIRD ID	404600

Site description

This site was the area marked “Spredenburg” on the Eastern Division of the Luddenham Estate map (1859). A house was noted in the general area of Spredenburg on the 1947 aerial photograph of the area.

On inspection, the site was completely overgrown with blackberries, however a number of modern bricks and other builders refuse were observed on the surface and atop the blackberry bushes (Plate A64). No heritage building material was observed. The heritage significance of this site cannot be assessed until vegetation has been cleared from the site.



Plate A64 View west across the site of Spredenburg. (Source: RPS 2015)

AS19 Howe residence

List	-
Type of item	Archaeological
Primary address	Corner Badgerys Creek Road and Longleys Road, Badgerys Creek
DIRD ID	404363

Site description

This site was shown to the excavation team by the property's leaseholder. It was located on a property on the south western intersection of Badgerys Creek Road and Longleys Road, with an access from Badgerys Creek Road, opposite the former Badgerys Creek post office site leading to a flattened area. According to the leaseholder, this property was once owned by the Howe family, members of whom had lived in the area since the early nineteenth century.

Analysis of the 1947 aerial photograph shows a residence at this site. A number of features consistent with the remains of a homestead were identified during the survey, including a rectangular perimeter of exotic trees, marking the residential area, a number of wooden posts, bricks and corrugated iron (Plate A65). A brick-lined circular depression was noted at the west of the residential area, most likely the remains of a well (Plate A66). Some fence posts, both metal and timber, were still in place.



Plate A65 View west across the site of the Howe residence. (Source: RPS 2015)



Plate A66 Circular, brick lined depression (well) at Howe's residence. (Source: RPS 2015)

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Events and processes	This site is associated with the Howe residence and meets this criterion.	Commonwealth
Rarity	The Howe residence is not considered to meet this criterion.	None
Research	Investigation of the Howe residence may reveal evidence of early residential occupation in Badgerys Creek area.	Commonwealth
Principal characteristics of a class of place	The Howe residence is not considered to meet this criterion.	None
Aesthetics	The Howe residence is not considered to meet this criterion.	None
Creative or technical achievement	The Howe residence is not considered to meet this criterion.	None
Social value	The Howe residence is not considered to meet this criterion.	None
Significant people	This site is associated with the Howes, a prominent family who lived in the Badgerys Creek area from the early nineteenth century.	Commonwealth
Indigenous values	The Howe residence is not considered to meet this criterion.	None
Australian historic themes		
Developing Australia's cultural life – living in the country and rural settlements, living in and around Australian homes		

Significance assessment		
Criterion	**Discussion**	**Heritage significance**
Statement of significance		
The site of the Howe residence is considered to be of heritage significance for its historical and associative values. The Howes were a prominent family who lived in Badgerys Creek from the early nineteenth century.		

VOLUME 4

Appendix N
Planning and land use

Western Sydney Airport

Planning and Land Use Impact Assessment

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IMPORTANT NOTE

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Contents

EXECUTIVE SUMMARY 1
TERMS AND ABBREVIATIONS 3
1 INTRODUCTION 4
1.1 Methodology 5
1.2 Limitations and assumptions 5
2 EXISTING ENVIRONMENT 6
2.1 Airport site description 6
2.2 Existing land uses 8
2.3 Surrounding existing land uses 10
3 LAND USE AND PLANNING 13
3.1 Australian Government 13
3.2 NSW Government 18
3.3 Local Government 26
3.4 Industry guidelines 29
4 AIRPORT PROPOSAL 30
4.1 Summary of the proposal 30
4.2 Airport Plan 30
5 IMPACT ASSESSMENT 33
5.1 Land use impacts 33
5.2 Airport operations 35
6 RECOMMENDED MITIGATION MEASURES 39
7 CONCLUSION 41
8 REFERENCES 42

Tables

TABLE 1 SITE DESCRIPTION 6
TABLE 2 SECTION 117 DIRECTIONS 19
TABLE 3 SUMMARY OF AIRPORT PLAN PROPOSED LAND USES 31
TABLE 4 BUILDING SITE ACCEPTABILITY BASED ON ANEF ZONE (AS2021) 36
TABLE 5 MITIGATION MEASURES 39

Figures

FIGURE 1 AIRPORT SITE (GHD, 2015) 7
FIGURE 2 REGIONAL SITE PLAN AND TRANSPORT MAP (GHD, 2015) 12
FIGURE 3 WESTERN SYDNEY INFRASTRUCTURE PLAN (DIRD, 2015) 17
FIGURE 4 INFRASTRUCTURE AND LAND USE PLANNING UNDER THE METROPOLITAN PLAN (DP&E, 2015) 21
FIGURE 5 SOUTH WEST PRIORITY GROWTH AREA PRECINCTS (DP&E, 2015) 22
FIGURE 6 WESTERN SYDNEY EMPLOYMENT AREA LOCATION MAP (DP&E, 2015) 23
FIGURE 7 SOUTH WEST RAIL LINK EXTENSION (TRANSPORT FOR NSW, 2015) 24
FIGURE 8 OUTER SYDNEY ORBITAL INVESTIGATION AREA, SHOWN IN PURPLE (TRANSPORT FOR NSW, 2015) 25
FIGURE 9 AIRPORT SITE AND SURROUNDING LANDS ZONING MAP (GHD, 2015) 27

Plates

PLATE 1 HORTICULTURE GREENHOUSES 8
PLATE 2 POULTRY SHED 8
PLATE 3 EXISTING CEMETERY (ST JOHNS ANGLICAN CHURCH CEMETERY, PITT STREET) 8
PLATE 4 FORMER BADGERYS CREEK PRIMARY SCHOOL 8
PLATE 5 EXISTING LOCAL ROAD 9
PLATE 6 CLEARED CATTLE GRAZING LANDS 9

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Executive Summary

Western Sydney Airport proposal

The Australian Government is undertaking detailed planning and investigations for the proposed Western Sydney Airport (the airport) at Badgerys Creek. The airport is to service both domestic and international air traffic, with development staged in response to passenger demand.

The initial development (Stage 1) of the airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation. Initially it would be capable of facilitating the safe and efficient movement of up to 10 million passengers per year. In the longer term, approximately 40 years after the initial airport development, the airport could include parallel runways and additional passenger and ground transport facilities to service around 82 million passengers per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis.

Methodology

This planning and land use report has been prepared as a component of an environmental impact statement (EIS) which addresses the environmental impacts of the airport in accordance with the Environment Protection and Biodiversity Conservation Act 1999 and the Australian Department of the Environment's guidelines for the EIS. Planning for a second airport for Sydney has been undertaken since 1946. This land use and planning assessment builds upon previous studies and addresses the potential planning and land use impacts of the proposed airport, and recommends mitigation measures to minimise impacts.

Land use and planning

Over the last two decades, planning by the Australian and NSW governments, and surrounding local councils for land use change in the South West Priority Growth Area and the Western Sydney Employment Area has taken into account the likely impacts of the proposed airport. The majority of land for the construction and operation of the proposed airport has been acquired by the Australian Government. Some additional minor acquisitions may be undertaken prior to operations.

Impact assessment

The report considers how the proposed airport would affect rural, agricultural, employment and recreational lands. Development controls are considered for the management of aircraft safety and noise. Lighting and air quality impacts from airport operations are considered in the context of surrounding planning and land use. The need for local traffic and transport improvements are identified, and considerations for future land acquisition are recommended.

Recommendations and mitigation measures

The Commonwealth Airports Act 1996 has been amended to provide for an Airport Plan which is a transitional planning instrument for the initial development of the airport as a greenfield airport site. The Airport Plan, once determined by the Infrastructure Minister will authorise the carrying out of specific developments detailed in the plan. It is anticipated the Minister would have regard to potential neighbouring employment land uses in exercising this authority, and in determining any future airport master plans and major development plans prepared for the airport site.

Prior to the commencement of Stage 1 operations, it is recommended that the Department of Infrastructure and Regional Development (DIRD) liaise with the NSW Department of Planning and Environment (DP&E) and local councils to seek:

- to ensure Local Environment Plans (LEPs), have regard to any new noise exposure forecasts prepared for the proposed airport based on the Australian Noise Exposure Forecast (ANEF) system and include relevant provisions for considering noise mitigation in the assessment of development applications. Whilst the EIS provides preliminary predictions of future aircraft noise exposure, an official ANEF contour map is expected to be prepared prior to the commencement of operations, taking account of detailed airspace design and airport operations planning. This process should be undertaken in accordance with the National Airports Safeguarding Framework (NASF) guidelines for noise management. A State environmental planning policy may be the most efficient and effective means to ensure consistency across local government planning instruments;
- to ensure LEPs incorporate relevant obstacle limitation surfaces (OLS) and procedures for air navigation systems operations surface (PANS-OPS), to restrict development heights and other potentially incompatible activities (such as exhaust plumes from vent outlets) for proposed developments within the vicinity of the airport; and
- rezoning of all land which forms part of the airport site to a uniform zone such as Special Uses 1 – Commonwealth under the NSW Standard Instrument LEP.

In addition, it is recommended that DIRD continue to consult with Transport for NSW, Roads and Maritime Services (RMS), local councils and affected landowners to undertake corridor protection for proposed future road and rail corridors and fuel pipelines, well in advance of their forecast need to ensure the growth of the airport is not constrained in the future.

Terms and abbreviations

Airports Act	Commonwealth *Airports Act 1996*
airport site	The airport site is the total of all properties that may become part of the proposed Western Sydney Airport. The airport site includes existing Commonwealth land and land that may be acquired by the Commonwealth, such as The Northern Road.
DIRD	Australian Department of Infrastructure and Regional Development
DP&E	NSW Department of Planning and the Environment
EIS	environmental impact statement
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
initial development	The initial stage in the development of the airport, including a single runway and capacity to handle 10 million annual passenger movements (nominally occurring in 2030). Also referred to as Stage 1 development
LEP	local environmental plan
LGA	local government area
Liverpool LEP	*Liverpool Local Environmental Plan 2008*
longer term development	The longer term development potential of Western Sydney Airport includes two runways and would facilitate approximately 82 million annual passenger movements. The Western Sydney Airport EIS forecasts that this patronage level may be reached around 2063. Any future stages of development beyond the initial (Stage 1) development would be subject to the relevant approvals process of the Commonwealth *Airports Act 1996*.
NSW	New South Wales
OLS	obstacle limitation surface
PANS-OPS	procedures for air navigation systems operations surface
Penrith LEP	*Penrith Local Environmental Plan 2010*
PSZ	public safety zone
RAAF	Royal Australian Air Force
RMS	NSW Roads and Maritime Services
SEPP	State environmental planning policy
Stage 1	Refer to ‘initial development’.

1 Introduction

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the proposed airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.1 Methodology

This planning and land use report has been prepared as a technical study for the preparation of an EIS which addresses the overall environmental impacts of the proposed airport as required by the EPBC Act. The purpose of this report is to address key necessary planning and land use considerations of the proposed airport, and to recommend any necessary mitigation measures to minimise impacts during construction and operation.

This report responds to and has been prepared in accordance with the Department of the Environment's assessment guidelines (EPBC 2014/7391) for the preparation of an EIS for the proposed Western Sydney Airport. This report considers two key stages of airport development and operations:

- construction and operation of the initial phase with one runway (Stage 1, nominally in 2030); and
- operation with two runways (nominally in 2063), referred to as the longer term development.

This report considers land use and planning impacts not only for Stage 1 but also for the longer term, to ensure opportunities and constraints are identified early for consideration of early implementation measures where reasonable and feasible.

In preparing this land use and planning report RPS has:

- inspected and analysed the key characteristics of the airport site and surrounding land;
- reviewed existing Commonwealth and NSW legislation applying to the airport site and surrounding land;
- reviewed strategic land use plans relevant to the airport site and surrounding land to identify NSW Government objectives for development of the area;
- consulted planning staff in local councils within the vicinity of the airport site to confirm applicable land use plans, policies and assessment considerations;
- reviewed relevant sections of other technical reports prepared for the EIS;
- assessed the likely impacts of the airport proposal on surrounding land uses; and
- recommended mitigation measures to reduce the impacts of the proposal.

1.2 Limitations and assumptions

This technical report has been prepared in accordance with the scope of work set out in the contract between the Australian Government and GHD. In preparing this technical report, RPS has relied on concept plans and data provided by GHD and the Australian Government, and an understanding of the scope of other technical studies (but not access to the actual studies) relating to noise and vibration, air quality, hazard and risks, traffic and transport, flooding and visual impact undertaken as part of the preparation of the EIS.

This report is part of a broader EIS and should be read in conjunction with other parts of the EIS where detailed analysis of specific issues are presented.

2 Existing environment

2.1 Airport site description

The airport site is located within the suburbs of Badgerys Creek and Luddenham, within the Liverpool local government area (LGA). The northern boundary of the airport site adjoins the Penrith LGA boundary. The study area is situated about 60 kilometres west-southwest of the Sydney CBD and about 50 kilometres west of Sydney Airport. The site terrain comprises low lying hills with several watercourses and dams.

Over the period 1986 to 1991 the Australian Government acquired approximately 1,700 hectares of land for the airport site. The current Australian Government land holding comprises over 20 lots, with the majority of the land located on a consolidated land title (1,667 hectares). A map of the airport site is provided in Figure 1. The following table provides the legal description of the lots and their size followed by a figure of the airport site.

Table 1 Site description

Legal Description	Description	Area (ha)	Ownership
Lot 1 DP 838361	Main site	1,667.3	Commonwealth
Lot 1 DP 851626	2215 The Northern Road	11.9	Commonwealth
Lot 22 DP 258581	400 Willowdene Ave	10.0	Commonwealth
Lot 17 DP 258581	335 Willowdene Ave	10.0	Commonwealth
Lot 23 DP 259698	355 Willowdene Ave	10.1	Commonwealth
Lot 33 DP 259698	5 Vicar Park Lane	10.1	Commonwealth
Lot 32 DP 259698	15 Vicar Park Lane	10.1	Commonwealth
Lot 15 DP 229293	221 Greendale Road	4.7	Commonwealth
Lot 2 Sect. C DP 1451	10 Jackson Road	4.8	Commonwealth
Lot 8 DP 3050	105 Lawson Road	4.7	Commonwealth
Lot 7DP 3050	95 Lawson Road	2.0	Commonwealth
Lot 9 DP 226448	45 Martin Road	2.0	Commonwealth
Lot 9 DP 226448	20 Martin Road	2.1	Commonwealth
Lot 11 DP 226448	1932 Elizabeth Drive	0.1	Commonwealth
Lot 1 DP 129674	Elizabeth Drive property 1	0.1	Commonwealth
Lot 1 DP 129675	Elizabeth Drive property 2	0.1	Commonwealth
Lot 1 DP 996420	Elizabeth Drive property 3	0.1	Commonwealth
Lot 2 DP 996420	Elizabeth Drive property 4	0.1	Commonwealth
Lot 28 DP 217001	Elizabeth Drive property 5	0.1	Commonwealth
Lot 1 DP 996379	Elizabeth Drive property 6	0.1	Commonwealth
Lot 2 DP 996379	Elizabeth Drive property 7	10.4	Commonwealth
To be determined	The part of The Northern Road which bisects the site. See survey description next to this table.	2.5	Liverpool Council & NSW Government

Prior to commencement of Stage 1 operations, the Australian Government may consider acquisition of additional land or interests in land (such as easements) for properties which are located within the footprint of the airport proposal and are yet to be acquired (or where otherwise appropriate for airport operational matters such as for aircraft navigational safety).

The requirement for additional land acquisition/easements is discussed further in Section 5 of this report.

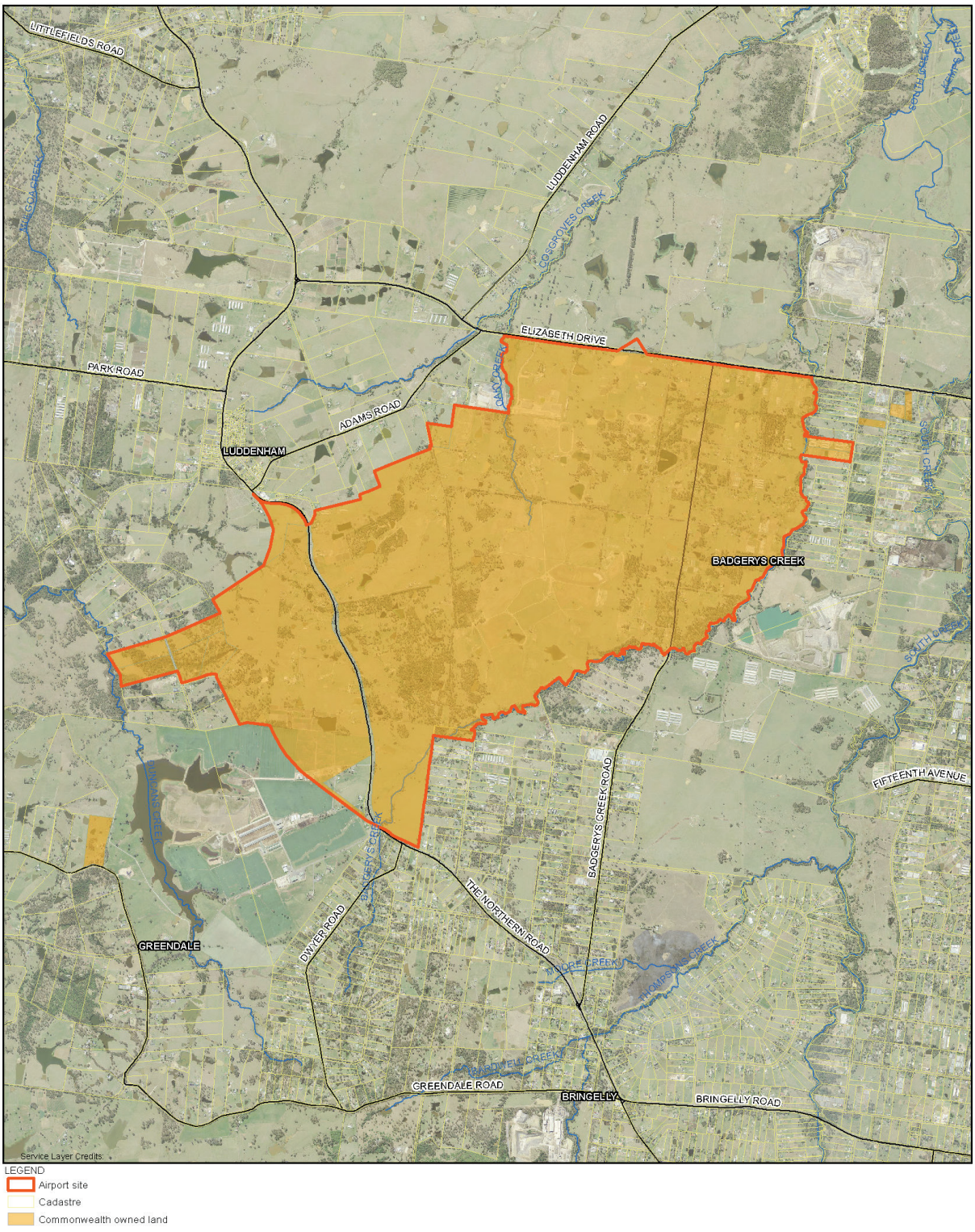

Figure 1 Airport site (GHD, 2015)

2.2 Existing land uses

The majority of the airport site comprises low density rural residential and agricultural land uses. Rural residential tenancies range from approximately 1–40 hectares in area. Agricultural land uses include cattle grazing and horticulture.

In addition to rural residential and agricultural land uses, the built features that are also found on the airport site include:

- Former Badgerys Creek Primary School (closed in December 2014)
- Badgerys Creek Park
- Four gravesites (St Johns Anglican Church, Badgerys Creek Uniting Church, Anschau family grave (Luddenham), and St Francis Xavier Church);
- Quarry (Blue Sky Mining)
- Scout hall

The following photos provide examples of existing built features and existing land uses on the airport site.



Plate 1 Horticulture greenhouses



Plate 2 Poultry shed



Plate 3 Existing cemetery (St Johns Anglican Church cemetery, Pitt Street)



Plate 4 Former Badgerys Creek Primary School



Plate 5 Existing local road



Plate 6 Cleared cattle grazing lands

Flora and Fauna

The flora and fauna on the site have been assessed in detail in the Biodiversity technical study prepared by GHD.

In summary, the airport site supports a variety of vegetation types on the Cumberland Plain. The airport site is contained within the 'Cumberland Plain' Mitchell Landscape. This landscape comprises low rolling hills and valleys in a rain shadow area between the Blue Mountains and the coast, with vegetation characterised by grassy woodlands and open forest dominated by Grey Box (*Eucalyptus moluccana*) and Forest Red Gum (*Eucalyptus tereticornis*) and poorly drained valley floors with forests of Cabbage Gum (*Eucalyptus amplifolia*) and Swamp Oak (*Casuarina glauca*).

Badgerys Creek flows along the southern and eastern boundary of the airport site, and Oaky Creek originates in the centre of the site and flows northwards. Both creeks drain to South Creek and the Hawkesbury River.

Road and transport network

The existing road and transport network have been assessed in detail in the Traffic and Transport technical study prepared by GHD.

In summary, the airport site contains a number of internal roads, all of which (except for The Northern Road) were compulsorily acquired by the Australian Government in July 1991. The following roads within the site are currently maintained by Liverpool Council under an agreement with the Australian Government:

- Anton Road
- Badgerys Creek Road
- Ferndale Road
- Fuller Street
- Gardiner Road
- Jackson Road
- Jagelman Road
- Leggo Street
- Longleys Road
- Pitt Street
- Taylors Road
- Vicar Park Lane
- Winston Close

It is noted that Willowdene Avenue also crosses the site in part. This road is not owned by the Commonwealth or proposed to be acquired.

The major roads in the vicinity of the site are:

- Elizabeth Drive – which runs along the northern border of the airport site
- The Northern Road – which intersects the airport site north to south in the western part of the site; and
- Badgerys Creek Road – which intersects the airport site north to south in the eastern part of the site.

2.3 Surrounding existing land uses

The airport site is located within Liverpool LGA, with the northern airport site boundary coinciding with the Penrith LGA southern boundary at Elizabeth Drive. Beyond the immediate LGAs, Blue Mountains LGA lies to the west; Wollondilly, Camden and Campbelltown LGAs lie generally to the south; and Bankstown, Fairfield and Blacktown LGAs lie generally to the east of the airport site.

The regional context of the airport proposal is identified in Figure 2 and surrounding land uses are discussed briefly below.

Liverpool local government area

The village of Luddenham is located 3 kilometres west of the airport site, generally straddling The Northern Road between Park Road and Adams Road. As of 2012, Luddenham Village contained 224 properties with a population of 819 (Liverpool Council). Luddenham village comprises neighbourhood retail shops and low density residential housing with average lots sizes of around 500 square metres.

Luddenham also has two large recreation reserves (Luddenham Showground and Sales Park) and two primary schools (Holy Family Primary School and Luddenham Public School). The Hubertus Cultural Club directly adjoins the north-western boundary of the airport site. Rural residential properties of up to 10 hectares surround the village.

To the east of the airport site are the localities of Badgerys Creek and Kemps Creek. The Badgerys Creek riparian corridor defines the eastern boundary of the site. The land to the east of Badgerys Creek is largely used for agriculture, including the Ingham's Multiplication Farm (poultry farm). The recreational areas of Kemps Creek Nature Reserve and the Western Sydney Parklands are also located to the east of the airport site.

Southwest of the airport site in the locality of Greendale land use is predominantly large lot rural residential. Some agricultural activities are present, including the Leppington Pastoral Company and the University of Sydney Research Farms. The area contains the largest landholdings within Liverpool LGA with many properties exceeding 40 hectares in area (Liverpool Council, 2012).

Five kilometres south of the airport site is the town of Bringelly. Bringelly is largely characterised by large lot residential properties. The 2012 Liverpool Rural Lands Study recommended 775 hectares of land be converted from Rural – RU1 – Primary Production (east and west) to Rural – RU4 – Primary Production Small Lots (south east) in order to further limit fragmentation of the land in Bringelly, with a minimum lot size of 10 hectares. A decommissioned Royal Australian Air Force Telecommunications facility and the Boral Bringelly Brickworks are also located in Bringelly.

Penrith local government area

Land uses are predominantly rural residential in the vicinity of Badgerys Creek to the north of the site. Adjoining the northern boundary of the airport site, north of Elizabeth Drive, is a cattle grazing farm adjacent to a landfill facility. The area north of the airport is drained by two creeks – Cosgroves Creek and Badgerys Creek which are identified as 'Environmental Conservation' areas in the Penrith Local Environmental Plan 2010 (Penrith LEP).

About 3 kilometres north of the airport site is the proposed Sydney Science Park. The area was rezoned in July 2015 from RU2 Rural Landscape to B7 Business Park, B4 Mixed Use and RE1 Public Recreation. The objectives of the rezoning are to accommodate research and development employment, education and supporting retail, and residential uses. The area is proposed to provide for 440,000 square metres of employment and education floor space, 30,000 square metres of retail space, 3,000 dwellings and accommodation for up to 400 students.

About 5 kilometres north of the airport site is the Twin Creeks estate. The 340 hectare estate comprises an 18 hole golf course, function centre, restaurant and more than 200 dwellings.

The localities of Kemps Creek and Mount Vernon are located to the northeast of the airport site. These localities largely comprise rural residential dwellings with average lot sizes of about 10 hectares. Lot sizes decrease in the eastern part of Mount Vernon, east of Mamre Road. These localities are drained by two creeks, South Creek and Kemps Creek, which are identified as an 'Environmental Conservation' area in the Penrith LEP.

The Defence Establishment Orchard Hills is located approximately 9 kilometres north of the airport site. The RAAF utilises this site for storage and distribution and Defence Explosive Ordnance Training.



Figure 2 Regional site plan and transport map (GHD, 2015)

3 Land use and planning

Land use planning in Western Sydney for the last two decades has incorporated considerations for an airport at Badgerys Creek. This chapter considers the applicable legislation, plans and strategies at the Australian, NSW and local government levels as they apply to land use and planning for the airport site and surrounding land.

3.1 Australian Government

Legislation and related frameworks

Environment Protection and Biodiversity Conservation Act 1999

The Department of Infrastructure and Regional Development submitted a referral under the EPBC Act for the development of the airport on 4 December 2014. The Department of the Environment invited public comment on the referral for 12 business days.

On 23 December 2014, a delegate of the Minister for the Environment determined the proposed Western Sydney Airport to be a controlled action. The referral decision instrument identifies the following controlling provisions under the EPBC Act as being relevant for this proposal:

- world heritage properties (sections 12 and 15A);
- national heritage places (sections 15B and 15C);
- listed threatened species and communities (sections 18 & 18A); and
- Commonwealth action (section 28).

At the same time the delegate decided that the proposed airport development would be assessed by preparation of an EIS. As a result of recent amendments to the *Airports Act 1996* (Airports Act), approval for the proposed airport under Part 9 of the EPBC Act is not required. However an EIS for the proposed airport must be prepared and an Airport Plan for the proposed airport must be determined before the proposed airport can proceed.

Airports Act 1996

Western Sydney Airport will be developed and operated under the Airports Act. An airport lease will in due course be granted by the Commonwealth to an airport lessee company which will then become responsible for the Airport Site.

A Master Plan is a 20 year strategic vision for the airport site which is renewed every five years. The Master Plan includes future land uses, types of permitted development, and noise and environmental impacts. The Master Plan must also address the likely effect of the proposed development on the local and regional economy and community. This includes an analysis of how the proposed development fits within the planning schemes for commercial and retail development in the area that is adjacent to the airport.

The Environment Strategy sets out the airport's strategy to manage environmental issues within a five year period and beyond. It is the basis on which the Commonwealth measures the environmental performance of airports and the document by which airport tenants will determine their environmental responsibilities.

The Airports Act has been amended to provide for an Airport Plan which is a transitional planning instrument for the initial development of Western Sydney Airport as a greenfield airport site. This amendment provides a single and transparent environment and development approval for the Western Sydney Airport project. The Airports Act amendment provides for the preparation of an Airport Plan which is determined by the Minister for Infrastructure and Regional Development.

In determining the Airport Plan the Minister for Infrastructure and Regional Development must accept any environmental conditions proposed by the Minister for the Environment, taking into account the EIS. Leased federal airports are subject to a planning framework set out in the Airports Act. As part of the planning framework, airports are required to prepare a Master Plan that incorporates an Environment Strategy.

Convention Concerning the Protection of the World Cultural and Natural Heritage

Australia is a member of the World Heritage Convention which aims to promote cooperation to protect heritage around the world that is of outstanding universal value. The World Heritage Convention is administered by a World Heritage Committee, which among other functions, establishes a list of properties that have outstanding universal value, called the World Heritage List.

The Greater Blue Mountains World Heritage Area (GBMWHA) was listed on the World Heritage List in 2000. Nations that are parties to the World Heritage Convention agree to use their own resources to protect their World Heritage properties as far as possible.

Australian Standard 2021

The Australian Standard 2021:2015 – Acoustics – Aircraft noise intrusion – Building siting and construction (AS 2021) provides guidance on the siting and construction of buildings in the vicinity of airports to minimise aircraft noise intrusion. The guidance provided by AS2021 is based on the level of potential aircraft noise exposure at a given site using the Australian Noise Exposure Forecast (ANEF) system.

The NSW Government and local councils give effect to AS 2021 in land use planning for new development in environmental planning instruments, and as a necessary consideration in building siting and design as part of the assessment of new development applications within the noise impact zone of airports.

Airservices Australia provides air traffic control, aviation rescue and fire fighting as well as other related services to the aviation industry. This includes maintaining technology used by the industry for navigation and surveillance and aircraft noise monitoring.
Actions and processes under Airservices Australia's policy on aircraft noise management are aligned to the International Civil Aviation Organization's Balanced Approach to Noise Management. Four key elements of this approach are:

- reduction of noise at source – e.g. quieter planes, noise standards;
- land use planning and management – e.g. zoning, easements and building standards;
- noise abatement operational procedures – e.g. noise-preferred flight routes and runways; and
- operating restrictions on aircraft – e.g. flight curfews and quotas.

National Airport Safeguarding Framework

The National Airports Safeguarding Framework (NASF) is a national land use planning framework, agreed to by Commonwealth, State and Territory Ministers in 2012. The NASF recognises that responsibility for land use planning rests with State and local governments, but that a national approach can assist in improving planning outcomes on and near airports and flight paths. The framework aims to:

- improve community amenity by minimising aircraft noise-sensitive developments near airports including through the use of additional noise metrics and improved noise-disclosure mechanisms; and
- improve safety outcomes by ensuring aviation safety requirements are recognised in land use planning decisions through guidelines being adopted by jurisdictions on various safety-related issues.

The NASF comprises seven key planning principles:

- Principle 1: The safety, efficiency and operational integrity of airports should be protected by all governments, recognising their economic, defence and social significance;
- Principle 2: Airports, governments and local communities should share responsibility to ensure that airport planning is integrated with local and regional planning;
- Principle 3: Governments at all levels should align land use planning and building requirements in the vicinity of airports;
- Principle 4: Land use planning processes should balance and protect both airport and aviation operations as well as community safety and amenity expectations;
- Principle 5: Governments will protect operational airspace around airports in the interests of both aviation and community safety;
- Principle 6: Strategic and statutory planning frameworks should address aircraft noise by applying a comprehensive suite of noise measures; and
- Principle 7: Airports should work with governments to provide comprehensive and understandable information to local communities on their operations concerning noise impacts and airspace requirements.

The NASF guidelines provide comprehensive information and recommendations relating to six airport safeguarding matters. The NASF guidelines are:

- Guideline A: Measures for Managing Impacts of Aircraft Noise;
- Guideline B: Managing the Risk of Building Generated Windshear and Turbulence at Airports;
- Guideline C: Managing the Risk of Wildlife Strikes in the Vicinity of Airports;
- Guideline D: Managing the Risk of Wind Turbine Farms as Physical Obstacles to Air Navigation;
- Guideline E: Managing the Risk of Distractions to Pilots from Lighting in the Vicinity of Airports; and
- Guideline F: Managing the Risk of Intrusions into the Protected Airspace of Airports.

Additional guidelines for the protection of Public Safety Zones and Communication, Navigation and Surveillance infrastructure are proposed to be developed by National Airports Safeguarding Advisory Group in the near future.

Protection of Operational Airspace Surfaces

Protecting immediate airspace around airports is essential to ensuring and maintaining a safe operating environment and to provide for future growth.

Obstacle Limitation Surfaces (OLS) are a series of surfaces in the airspaces established by the international Civil Aviation Organisation. The OLS defines the airspace to be protected for aircraft operation during the initial and final stages of flight. The OLS are generally the lowest surfaces and are designed to provide protection for aircraft flying into or out of the airport when the pilot is flying by sight.

Procedures for Air Navigation Services - Aircraft Operations (PANS-OPS) provide for the establishment of surfaces to protect stages of flight during take-off, landing or manoeuvring and when aircraft is operating in non-visual conditions. The PANS-OPS surfaces are generally above the OLS and are designed to safeguard an aircraft from collision with obstacles when the aircraft's flight may be guided solely by instruments, in conditions of poor visibility. Structures, trees or other activities that intrude into these surfaces are potential obstacles to aircraft, and therefore a potential safety hazard, and must be controlled. Both OLS and PANS-OPS will be prepared for the proposed airport.

Infrastructure projects

Western Sydney Infrastructure Plan

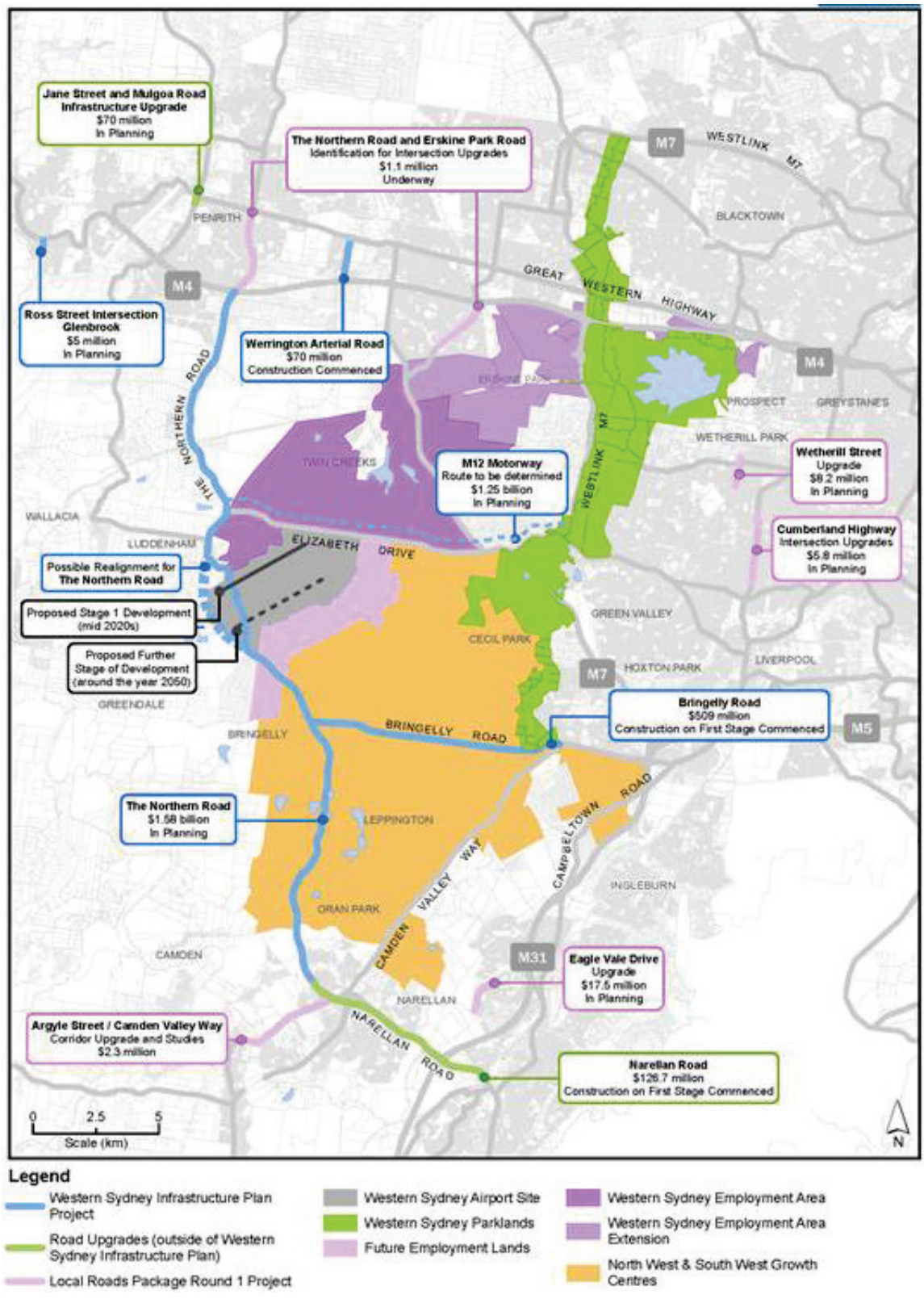

Figure 3 Western Sydney Infrastructure Plan (DIRD, 2015)

The Australian and NSW governments are currently delivering a plan to improve transport infrastructure in Western Sydney. The Western Sydney Infrastructure Plan seeks to ensure that the proposed Western Sydney Airport would be supported by high quality transport infrastructure to ensure the efficient movement of passengers, employees and freight. The Western Sydney Infrastructure Plan includes consideration of the following works:

- upgrade of The Northern Road to a minimum of four lanes from Narellan to Jamison Road, including realignment of the road around the western boundary of the airport site;
- construction of a new four-lane motorway between the M7 Motorway and The Northern Road, generally along the Elizabeth Drive corridor;
- upgrade of Bringelly Road to a minimum of four lanes from Camden Valley Way to The Northern Road;
- construction of the Werrington Arterial Road between the M4 Motorway and the Great Western Highway;
- improvement of interchanges connecting The Northern Road and a new motorway at Elizabeth Drive and Bringelly Road;
- upgrade of Ross Street and Great Western highway intersection at Glenbrook; and
- a $200 million local roads package.

Refer to Figure 3 for the Western Sydney Infrastructure Plan summary.

3.2 NSW Government

Legislation

The NSW planning legislative framework consists primarily of *the Environmental Planning and Assessment Act 1979* (the EP&A Act) and the *Environmental Planning and Assessment Regulation 2000*. Within this structure are the following three key instruments:

- State environmental planning policies (SEPPs): which outline the NSW Government's approach to dealing with more specific planning issues. These can be either site or issue specific, and may control land zoning and development controls, or establish a development process.
- Local environmental plans (LEPs): each local government area has an LEP to guide development and protect natural resources within local government areas. LEPs are prepared by local councils.
- Local planning directions, issued by the Minister for Planning under section 117 of the EP&A Act provide direction on matters which planning proposals need to address.

State Environmental Planning Policies

State Environmental Planning Policy (Sydney Region Growth Centre) 2006

State Environmental Planning Policy (Sydney Region Growth Centres) 2006 aims to coordinate the release of land for residential, employment and other urban development in the North West and South West Growth Centres of Sydney. The proposed airport site is located adjacent to the South West Growth Centre.

The Growth Centres SEPP provides development controls for the area in the vicinity of the site. This is further explored within Chapter 3.2 South West Priority Growth Areas.

State Environmental Planning Policy (Infrastructure) 2007

State Environmental Planning Policy (Infrastructure) 2007 (Infrastructure SEPP) aims to facilitate the effective delivery of infrastructure across the State.

Under clause 22 of the Infrastructure SEPP, development for the purposes of an airport may be carried out by or on behalf of a public authority without consent within the project area. It is noted however that the proposal is to be assessed under Commonwealth legislation, and therefore the process for approval is not subject to the Infrastructure SEPP.

State Environmental Planning Policy (Western Sydney Employment Area) 2009

This policy establishes the Western Sydney Employment Area (WSEA) to provide businesses in Western Sydney with land for industry and employment generating uses, including transport and logistics, warehousing and commercial office space. The WSEA lies to the north of the airport site.

Local planning directions

Under section 117(2) of the Act the NSW Government issues directions which the relevant consent authority should consider when preparing a planning proposal for a new (or amending) LEP. Relevant section 117 Directions are listed in Table 2.

Table 2 Section 117 directions

Direction	Objective	What a relevant planning authority must do if this direction applies
3.5 Development near Licenced Aerodromes (issued July 2009)	The objective of this Direction is to ensure the effective and safe operation of aerodromes, uncompromised by development. It is also to ensure development for residential purposes incorporates appropriate mitigation measures so that the development is not adversely affected by aircraft noise.	A planning proposal that rezones land in the vicinity of an airport must include a provision to ensure that development meets AS 2021 regarding interior noise levels. The planning authority must also consult with the Commonwealth and take into account relevant development standards such as height limitations. Development which is compatible with the operation of an aerodrome must be permissible with consent.
5.8 Second Sydney Airport: Badgerys Creek (issued in 2005 and reissued in July 2009)	The objective of this direction is to avoid incompatible development in the vicinity of any future second Sydney Airport at Badgerys Creek.	Planning proposals must not contain provisions that enable the carrying out of development, either with or without development consent, which could hinder the potential for development of a Second Sydney Airport.

Strategic Documents

A Plan for Growing Sydney

The DP&E publication *A Plan for Growing Sydney* (the Metropolitan Plan) is a 20 year strategic development plan for the Sydney Metropolitan Area. It provides direction for Sydney's productivity, environmental management, and liveability. To deliver upon these directions, the Metropolitan Plan identifies the location of future housing, employment, infrastructure and open space areas. An element of the Metropolitan Plan outlines how the proposed airport will transform Western Sydney.

Action 1.4.1 of the Metropolitan Plan aims to improve transport links and create a new services centre and industrial precinct to support the growth of the proposed Western Sydney Airport. The proposed airport will transform and drive future investment and jobs growth in Western Sydney. In order to protect and promote the proposed airport, the NSW Government plans to:

- protect the future operating capacity of the proposed Western Sydney Airport by ensuring adequate buffers for areas affected by aircraft noise and airspace to provide for future aviation needs.
- preserve land for complementary airport-related activity including a jet fuel pipeline to service the proposed airport and freight-related uses, and
- identify and preserve future transport and infrastructure corridors and related sites in the Western Sydney Airport precinct.

As part of employment growth with the proposed airport development, the NSW Government seeks to develop strategic employment corridors to service the proposed airport. The airport would be the single largest infrastructure catalyst for employment in Western Sydney. In order to promote employment growth, under Action 1.4.2 of the Metropolitan Plan the NSW Government will:

- facilitate an enterprise corridor from Leppington to Western Sydney Airport along Bringelly Road, potentially linked to a future extension of the South West Rail Link. A flexible and innovative regulatory environment will be developed to enable a wide range of commercial activities to take advantage of transport access to this precinct and its proximity to the airport, Leppington and the population growth of the South West Growth Centre.
- facilitate development opportunities that can leverage off improved transport connections, including improvements to Elizabeth Drive, The Northern Road and Bringelly Road.
- investigate how improved transport connections, associated with the proposed South West Rail Link extension between the proposed Western Sydney Airport to the western line will influence land use planning, and
- preserve the land needed for a major intermodal terminal and for a related Western Sydney Freight Line between Port Botany and the Western Sydney Employment Area.

South West Priority Growth Area

The NSW Government established the South West Growth Centre in 2005 to encourage a sustainable plan for Sydney's greenfield land development on its urban edge. Planning for the South West Growth Centre is delivered primarily through State Environmental Planning Policy (Sydney Region Growth Centres) 2006 (Growth Centres SEPP). It is now referred to as the South West Priority Growth Area.

The South West Priority Growth Area is located directly to the southeast and east of the airport site, with Badgerys Creek as the border. The area is about 17,000 hectares in size and incorporates land in Liverpool, Camden and Campbelltown LGAs. The South West Priority Growth Area comprises 18 precincts that are being progressively released for urban development. Seven of these precincts have already been rezoned since 2005 (refer to Figure 5). The Growth Area will ultimately provide 110,000 new dwellings and capacity for at least 22,000 jobs. The possible future extension of the South West Rail Link from Leppington to the airport and further north to the Western Line will also pass through the Growth Area.

The area directly south and southeast of the airport site is identified in the South West Priority Growth Area Structure Plan as future industrial/employment lands. Further detailed planning for this area is being undertaken by DP&E and detailed precinct plans are yet to be publicly released.

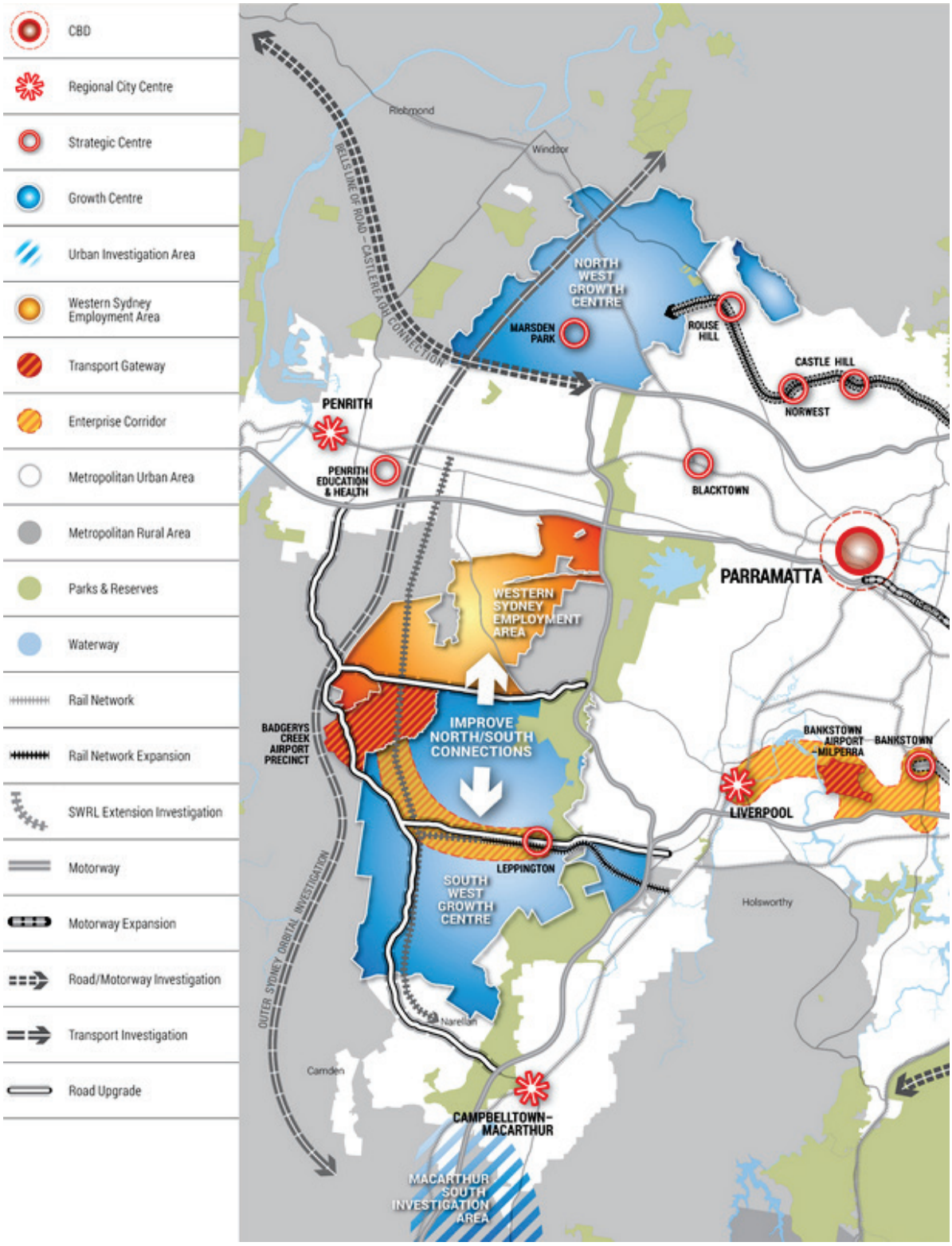

Figure 4 Infrastructure and land use planning under the Metropolitan Plan (DP&E, 2015)

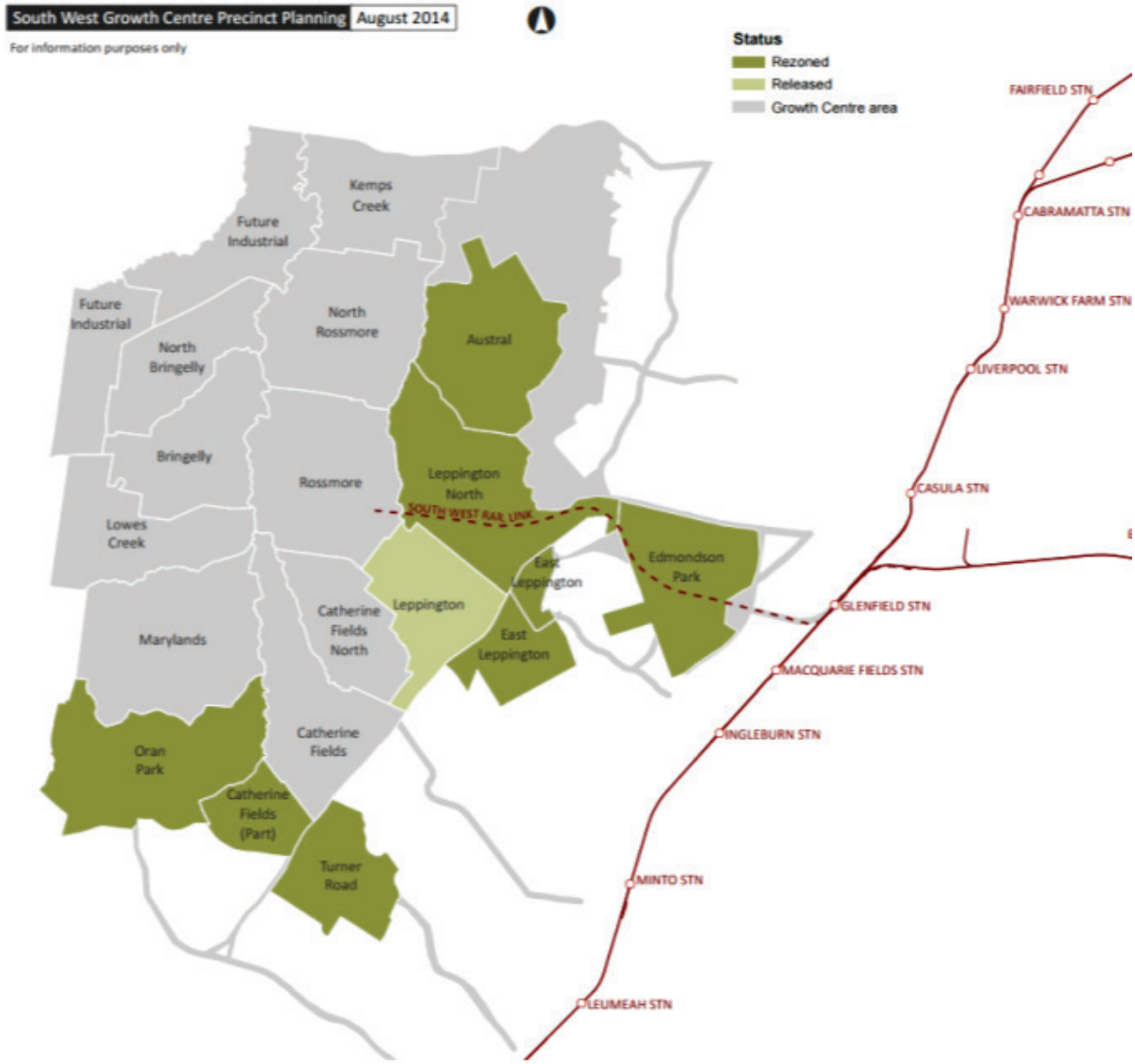

Figure 5 South West Priority Growth Area precincts (DP&E, 2015)

Western Sydney Employment Area

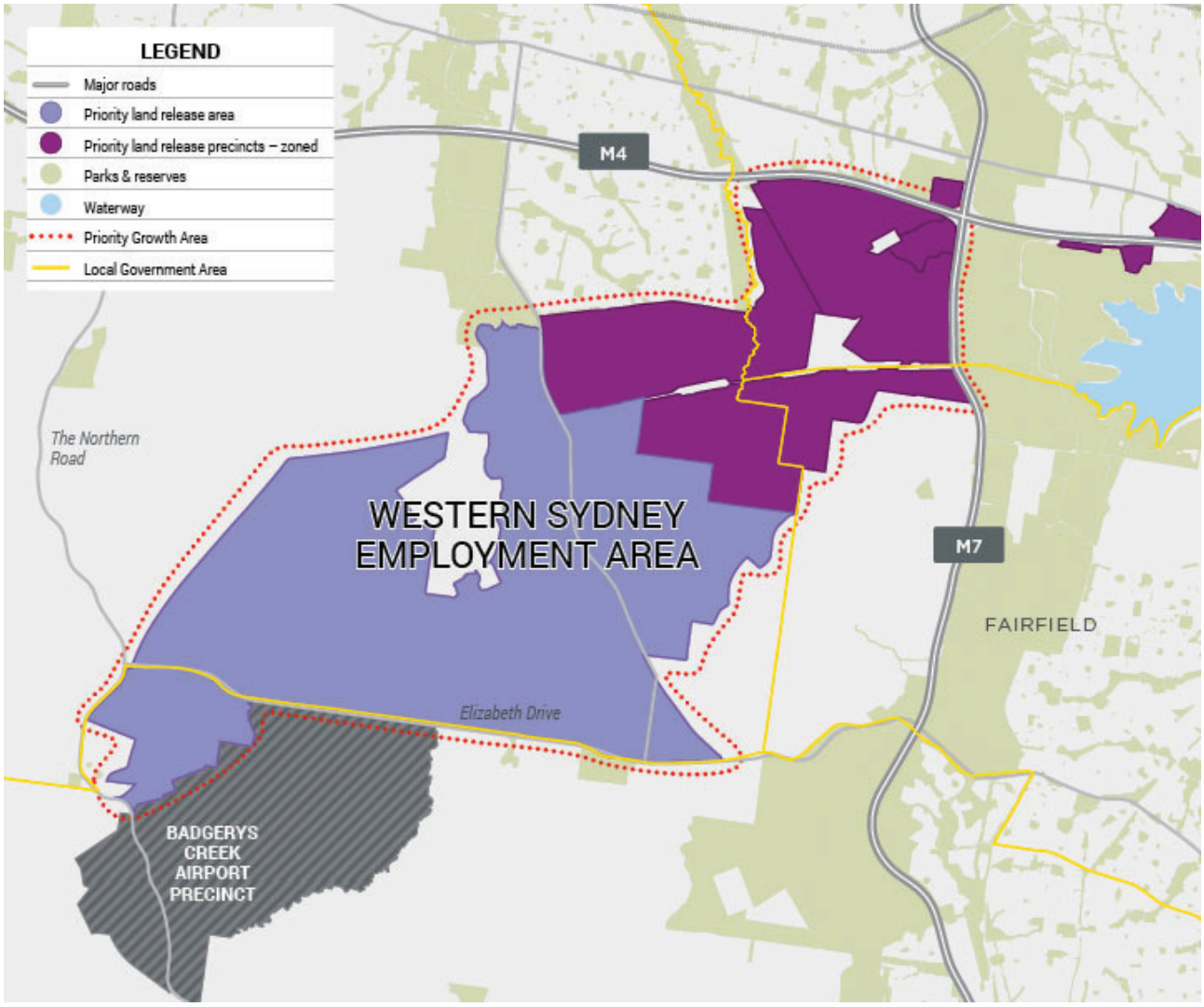

Figure 6 Western Sydney Employment Area Location Map (DP&E, 2015)

NSW Government established the Western Sydney Employment Area (WSEA) to provide businesses in Western Sydney with land for industry and employment generating uses, including transport and logistics, warehousing and commercial office space. The NSW Government forecasts the population of Western Sydney to rise from 2.1 million in 2011 to 2.9 million in 2031. The WSEA has been developed to help provide employment opportunities to support this growth. The WSEA is identified in Figure 6.

State Environmental Planning Policy (Western Sydney Employment Area) 2009 (WSEA SEPP) is the environmental planning instrument which outlines development controls for WSEA. In January 2015, the WSEA SEPP was amended to extend the boundaries to include land adjacent to the airport site (known as the Broader WSEA). The Broader WSEA amendment allows for even closer linkages between employment generating land uses and the proposed airport. The amendment identifies a further 4,573 hectares of land for future employment uses, and the Broader WSEA area is expected to deliver more than 36,000 industrial jobs and 21,000 office jobs over the next thirty years.

The Broader WSEA now comprises over 10,690 hectares of land, spanning four LGAs: Penrith, Blacktown, Liverpool and Fairfield. Most of the land in the newly identified Broader WSEA is currently zoned rural allowing rural residential and/or agricultural uses. Other zoning in the area includes special uses for the Australian Department of Defence and environmental conservation areas.

Land within the more established northern portion of WSEA has already been rezoned to industrial. The Broader WSEA confirms the NSW Government's intention for additional future employment land uses and provides certainty for infrastructure agencies, landowners and businesses of intended future development objectives.

Infrastructure projects

South West Rail Link Extension

The NSW Government is in the process of protecting a future public transport corridor that would extend the South West Rail Link which was opened for operation in February 2015. The proposed corridor extends from Leppington to Bringelly and then heads in two directions: south to Narellan and north to the Western Line near St Mary's. As part of the northern extension, the corridor is expected to provide a station at the airport site.

A specific alignment or station location for the airport rail link is yet to be confirmed, however planning for the airport preserves flexibility to accommodate several possible rail alignments. This would be resolved as part of the future design and planning for the proposed airport in conjunction with Transport for NSW and DP&E. The indicative South West Rail Link Extension alignment is identified in Figure 7.

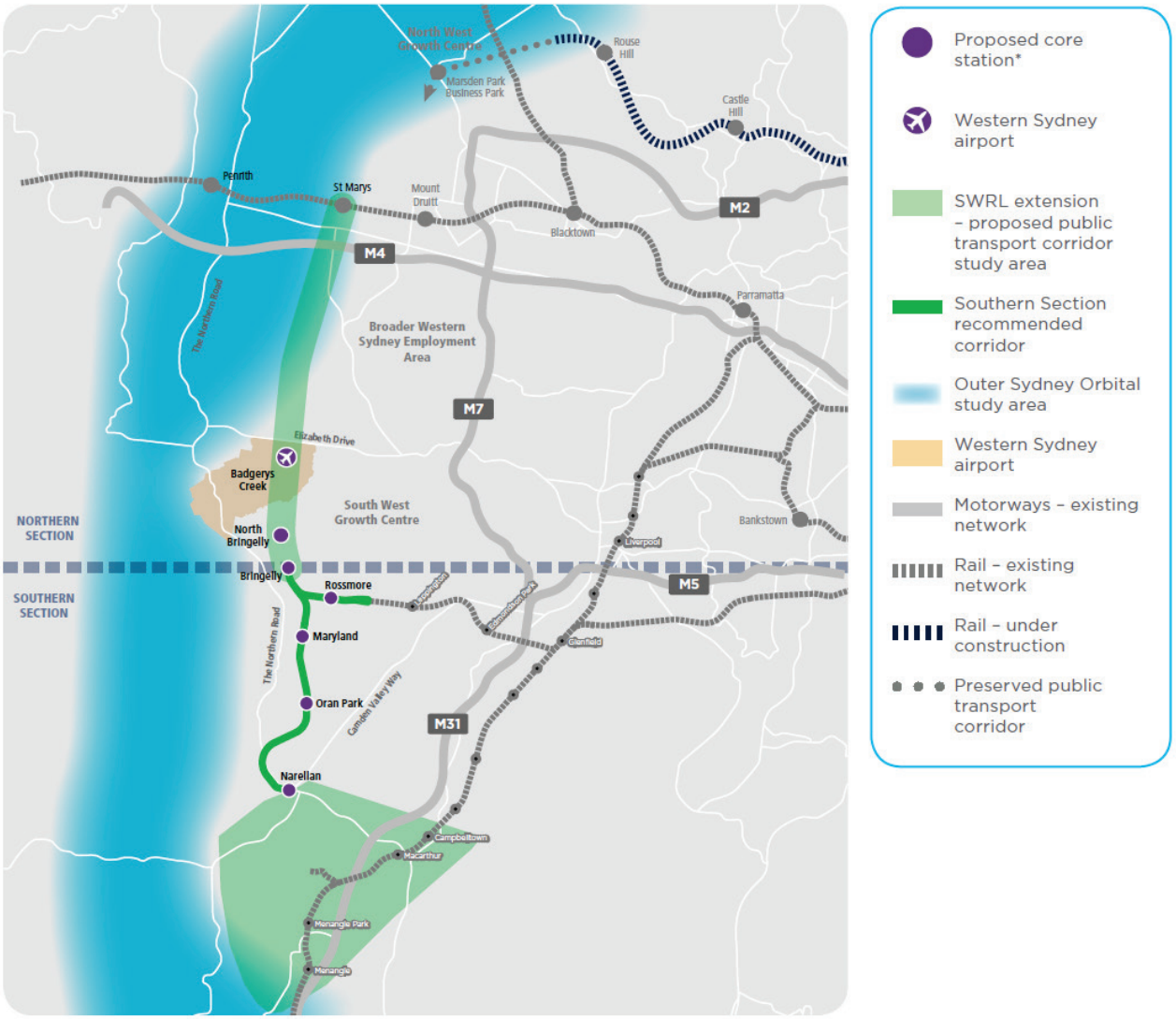

Figure 7 South West Rail Link Extension (Transport for NSW, 2015)

Outer Sydney Orbital

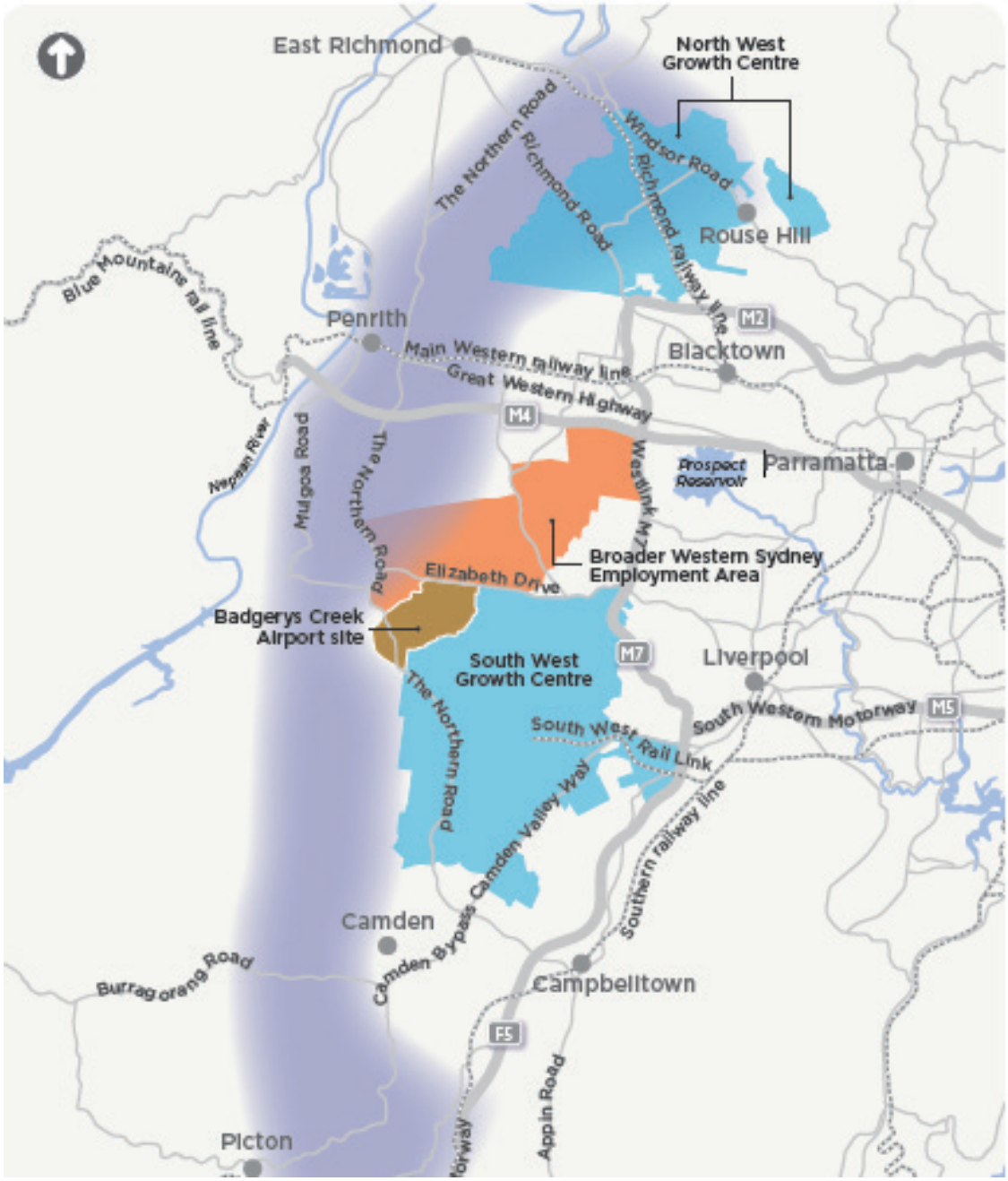

Figure 8 Outer Sydney Orbital investigation area, shown in purple (Transport for NSW, 2015)

Transport for NSW is investigating suitable corridors for the Outer Sydney Orbital (OSO). The OSO will provide a north-south connection for a future motorway, freight rail, and where practical, may be co-located with the South West Rail Link Extension. The proposed alignment will be located to the west of the airport site, possibly connecting the M5 South West Motorway to the M4 Western Motorway. The OSO investigation area is identified in Figure 8.

The proposed airport development is to the immediate east of the corridor investigation area. Transport for NSW has committed to take into consideration the development of the future airport by coordinating and working closely with relevant government agencies in assessing corridor options for the OSO. The corridor provides the opportunity for multimodal linkages to employment, freight and passenger movements directly related to the proposed airport.

3.3 Local Government

Liverpool

Land use zones

The airport site is located within the Liverpool LGA. The Liverpool Local Environmental Plan 2008 (Liverpool LEP) sets out the land use controls and matters for consideration for development within its council boundaries.

The majority of the airport site is zoned SP1 – Special Activities (Commonwealth) under the Liverpool LEP. Surrounding land zones are Rural – RU1 – Primary Production (east and west) and RU4 Primary Production Small Lots (south east). The applicable land use zones are identified in Figure 9.

Noise management

When Liverpool Council adopted the Standard Instrument LEP in August 2008, it included a provision (clause 7.18) for development in areas subject to potential aircraft noise from the proposed airport. Under clause 7.18 of the Liverpool LEP:

- development consent is required for the erection of a building on land where the ANEF shown on the Liverpool LEP Airport Noise Map exceeds 20 if it is erected for residential purposes or for any other purpose involving regular human occupation.
- the following development is prohibited unless it meets the requirements of AS 2021 with respect to interior noise levels:
  - residential accommodation on land where forecast noise exposure levels exceed 20 ANEF,
  - business premises, entertainment facilities, office premises, public administration buildings, retail premises and tourist and visitor accommodation on land where forecast noise exposure levels exceed 25 ANEF.
- the following development is prohibited:
  - educational establishments, hospitals and places of public worship on land where forecast noise exposure levels exceed 20 ANEF,
  - dwellings on land where forecast noise exposure levels exceed 25 ANEF (other than development consisting of the alteration, extension or replacement of an existing dwelling house where the development is consistent with the objectives of this clause), and
  - business premises, entertainment facilities, office premises, public administration buildings, retail premises and tourist and visitor accommodation on land where forecast noise exposure levels exceed 30 ANEF.

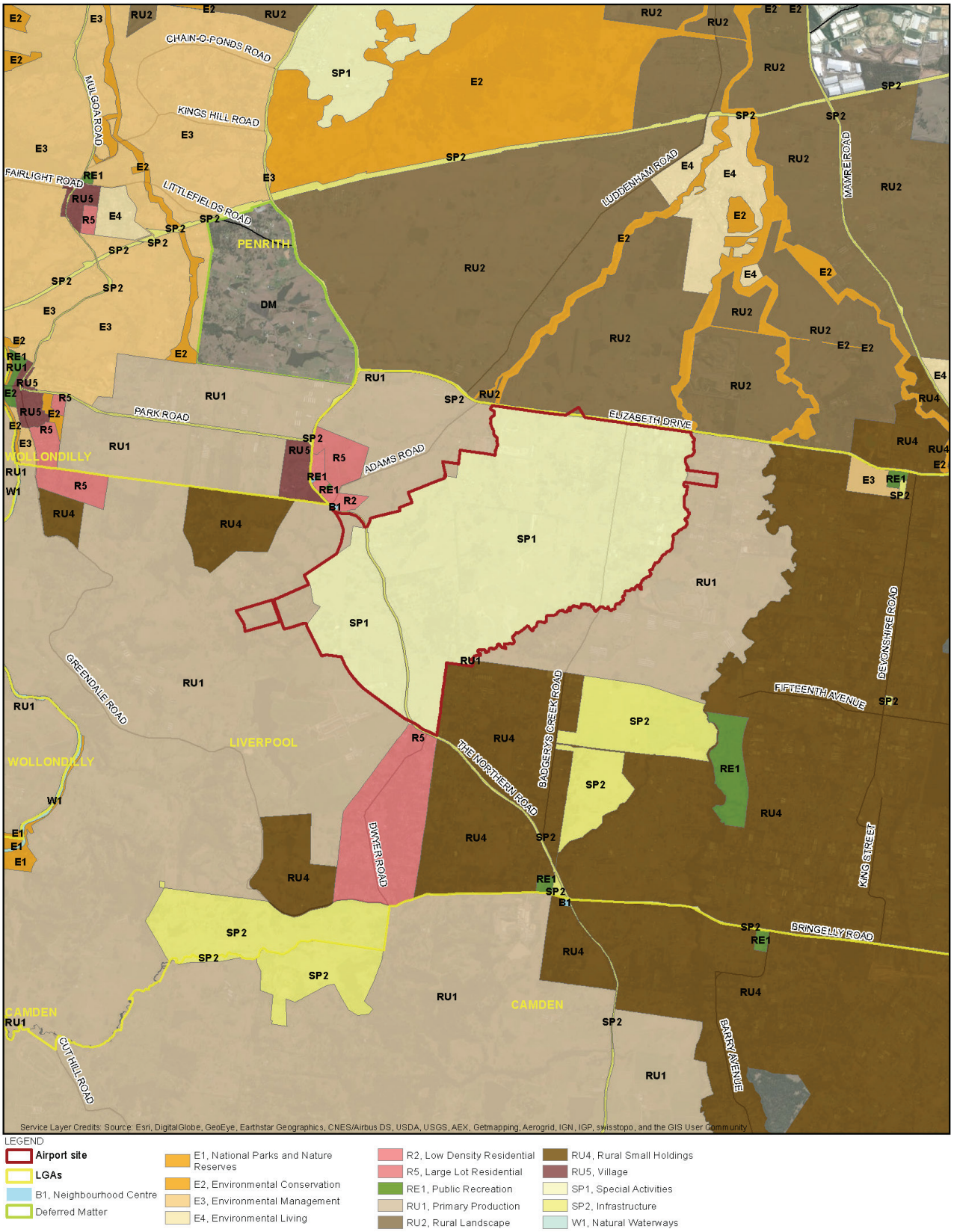

Figure 9 Airport site and surrounding lands zoning map (GHD, 2015)

Penrith

Land use zoning

Penrith Council adopted the Standard Instrument LEP in 2010. Surrounding land to the north of the airport site is zoned RU2 Rural landscape under the Penrith LEP.

There are three urban settlements in close proximity to the project area within the Penrith LGA. These are at Luddenham, Twin Creeks and Kemps Creek.

To the west of the site is Luddenham village, which spans Penrith and Liverpool LGAs. The applicable land use zones for the Luddenham village under the Penrith LEP are:

- R5 Large Lot Residential
- R2 Low Density Residential
- RU5 Village
- B1 Neighbourhood Centre
- RE1 Public Recreation

North of the site is Twin Creeks Golf and Country Club, which is zoned E4 Environmental Living. This locality comprises 200 large lot residential dwellings and a golf course.

Kemps Creek is to the north/northeast of the site, with a small village cluster within the RU4 Rural Small Holdings zoned land and a cluster of smaller lot rural residential properties in the E4 Environmental Living zone at Mount Vernon.

Oaky Creek and Badgerys Creek to the north of the site are zoned E2 Environmental Conservation.

Noise management

Clause 7.9 of Penrith LEP adopts provisions for noise management (similar to the Liverpool LEP). Under this clause development in the vicinity of the airport site must have regard to the use or potential future use of the site as an airport, and must not have an adverse impact on the development or operation of an airport. Clause 7.9 applies to development that is on land near the airport site and is in an ANEF contour of 20 or greater. Prior to determining a development application to which this clause applies, Penrith Council:

- must consider whether the development will result in an increase in the number of dwellings or people affected by aircraft noise;
- must consider the location of the development in relation to recommended development types within ANEF zones, as outlined in the AS 2021 (see Table 4 below); and
- must be satisfied that the development will meet AS 2021 with respect to interior noise levels for the purposes of:
  - if the development will be in an ANEF contour of 20 or greater—child care centres, educational establishments, entertainment facilities, hospitals, places of public worship, public administration buildings or residential accommodation
  - if the development will be in an ANEF contour of 25 or greater—commercial premises, hostels or hotel or motel accommodation.

Fairfield

Noise management

Whilst Fairfield City Council is yet to adopt any LEP controls for the management of aviation noise, Council adopted an interim policy in May 2014. The interim policy sets out 'deemed to comply' requirements for acoustic proofing measures for residential development in Horsley park and Cecil Park.

These requirements apply to all forms of new residential accommodation (as defined under the Fairfield LEP 2013) permitted in zones RU1 – Primary Production, RU2 – Rural Landscape, RU4 – Primary Production Small Lots, RU5 – Village. The requirements also apply to alterations and additions to existing residential accommodation.

3.4 Industry guidelines

Australian Airports Association Practice Notes

The Australian Airports Association (AAA) is a national representative group for airports in Australia.

Practice Note 5 – Planning around Airports provides guidance for planning around airports. It includes consideration of NASF, Public Safety Zones and broader planning considerations of surface access to airports.

4 Airport proposal

4.1 Summary of the proposal

The airport is proposed to be developed on approximately 1,700 hectares of land which was acquired by the Australian Government in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s. The airport would service both domestic and international air traffic, with development staged in response to passenger demand.

The initial development of the airport would include a single 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year.

In the longer term, approximately 40 years after operations commence and in accordance with relevant assessment processes, the airport development could include parallel runways and additional passenger and rail transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the site.

Further details relating to the scope of works of the airport proposal is available in Chapter 5 of the EIS.

4.2 Airport Plan

Accompanying the EIS as a companion document is a draft Airport Plan which described the Stage 1 development and also includes proposals for land use and related development of the airport site.

The categories of development associated with the initial and longer term land use plans for the proposed airport are shown in Table 3. Note, these proposed land uses are indicative only and may be altered prior to determination of the Airport Plan.

Table 3 Summary of Airport Plan proposed land uses

Land use Area	Proposed permissible uses	Stage 1 area (hectares)	Longer term area (hectares)
Aviation Activity	Agriculture, aviation activity, detention pond, earthworks, environmental protection works, extractive industry, liquid fuel depot and distribution facility, navigational aids, public administration facility, public utility undertaking, road, signage (other than an advertisement), telecommunications facility, temporary structure, and works depot.	322	672
Terminal and Support Services	Agriculture, amusement centre, animal boarding, aviation activity, aviation support facility, business premises, car park and parking spaces, childcare centre, convenience store, detention pond, earthworks, environmental protection works, extractive industry, food and drink premises, freight handling and transport facility, hotel or motel accommodation, kiosks, liquid fuel depot and distribution facility, markets, navigational aids, office premises, passenger transport facility, public administration facility, public utility undertaking, road, shop, signage, telecommunications facility, temporary structure, terminal, transfer corridor, vehicle hire premises, and works depot.	204	527
Aviation Logistics and Support	Agriculture, animal boarding, aviation activity, aviation support facility, business premises, car park and parking facilities, detention pond, earthworks, extractive industries, food and drink premises, freight handling and transport facility, light industry, liquid fuel depot and distribution facility, navigational aids, office premises, public administration facility, public utility undertaking, retail – low intensity, road, signage, telecommunications facility, temporary structure, transport depot, and works depot.	221	231
Aviation Reservation	Agriculture, animal boarding, aviation activity, aviation support facility, detention pond, earth works, environmental protection works, extractive industry, navigational aids, passenger transport facility, public utility undertaking, public administration facility, retail – low intensity, road, shop, signage, telecommunication facility, temporary structure, terminal, waste or resource management facility and works depot.	530	–
Business Development	Agriculture, animal boarding, aviation activity, aviation educational facility, aviation support facility, business premises, car park and parking spaces, child care centre, earth works, extractive industry, freight handling and protection works, hotel or motel accommodation, medical centre, navigational aids, office premises, passenger transport facility, public utility undertaking, public administration facility, recreational facility (indoor), retail premises, road, service station, shop, signage, telecommunication facility, temporary structure, vehicle hire premises, warehouse and distribution centre, and works depot.	167	170

Land use Area	Proposed permissible uses	Stage 1 area (hectares)	Longer term area (hectares)
Business Development (Reservation)	Agriculture, animal boarding, aviation activity, aviation education facility, aviation support facility, business premises, car park and parking spaces, child care centre, earth works, extractive industry, freight handling and transport facility, hotel or motel accommodation, medical centre, navigational aids, office premises, passenger transport facility, public utility undertaking, public administration facility, recreational facility (indoor), retail premises, road, service station, shop, signage, telecommunication facility, temporary structure, vehicle hire premises, warehouse and distribution centre, and works depot.	148	–
Environmental Conservation	Environmental protection works, public utility undertaking and permissible land uses determined as part of the Environmental Impact Statement.	129	129

5 Impact assessment

Having regard to the existing environment, strategic planning at the local and regional scale, and the scope of the proposal, RPS has assessed the following likely impacts on land use and planning arising from the proposed airport.

5.1 Land use impacts

Rural residential lands

Since the mid-1990s, land use planning controls in the Badgerys Creek area have been implemented with regard to the likely impacts of a potential airport. The likely impacts of the airport on sensitive land uses would be reduced by the considered application of land use zones and development controls that are largely already in place through existing planning instruments for the South West Sydney Priority Growth Area, Western Sydney Employment Area and local council planning controls.

The development of the proposed Western Sydney Airport is a key part of the transformation of Western Sydney. If the proposal proceeds, what is currently a, semi-rural area would change into an urban landscape as the frontier of suburban Western Sydney is extended. The airport would generate passenger traffic and increase freight road traffic, and result in increased aircraft noise and air quality impacts. The Social Impact Assessment undertaken by GHD in the EIS provides further details on these types of impacts.

Agricultural lands

The construction and operation of the proposed airport and associated urban expansion in Western Sydney will necessitate the loss of some land currently being used for agricultural purposes.

The 1999 Supplement to the 1997 Draft EIS identified the loss to agricultural production from an airport at the site as relatively small (being up to 0.23 percent of total regional agricultural production), with any production losses likely to be replaced by agricultural activity elsewhere in the region or State.

The Liverpool Rural Lands Study 2012 considered the pressures affecting Liverpool's rural areas. The study reflected the growth of development in the South West Priority Precincts and in relation to planning at that time for a second Sydney airport (for which Badgerys Creek had been ruled out). At that time the majority of the study area was not being used for economic agricultural production. Relevant findings of the report include:

- Prominent agricultural industries in Liverpool generally included those relating to poultry, dairy, market gardening and horse activities.
- Between the 1994 and 2007, agriculture was in decline – re-investment of capital into farming machinery and structures had reduced and therefore so had efficiency of operation.
- Recreational activities, particularly equestrian, were an increasing trend.

Whilst acknowledging the importance of agricultural production close to the Sydney market, the Metropolitan Plan confirms the NSW Government's support for the delivery of the Western Sydney Airport as it would transform and drive future investment and jobs in Western Sydney. The Metropolitan Plan identifies other rural lands within the Sydney metropolitan area which may be used as alternate agricultural sites.

Employment lands

The New South Wales Government established the Western Sydney Employment Area (WSEA) to provide the region with substantial land for industry and employment growth, catering for transport and logistics, warehousing and office space. WSEA capitalises on access to roads and utility services close to the proposed airport. The Western Sydney Employment Area Extension is proposed to extend the current Western Sydney Employment Area boundary south to Elizabeth Drive and includes some land west of the airport site. A draft Structure Plan was released in June 2013. It outlines a broad framework for the area including the location of future employment land and centres, a road network, potential freight and transport corridors and staging scenarios. The NSW Government is revising the draft Structure Plan to take into account of the proposed airport. This revision is anticipated to be completed by the close of 2015.

The proposed airport development also supports the future development of the adjacent South West Priority Growth Area employment lands. The proposed airport would be a mutually beneficial land use, creating demand for employment generating activities and facilitating the provision of transport infrastructure required for freight and logistics. Extend

The land use plan contained in the draft Airport Plan identifies land use areas for retail and commercial development within the airport site. Though specific activities are yet to be confirmed, the impacts of these proposals on the airport and surrounding lands will be assessed in accordance with the requirements of the Airports Act, including the preparation of major development plans for major proposed developments.

Recreational lands

Badgerys Creek Park would be removed as part of the Stage 1 development of the airport.

There are extensive recreational areas located within the vicinity of the site. Aircraft flight paths may result in visual and noise impacts on the following recreational reserves:

- North – Twin Creeks Golf Course, Ropes Creek Reserve (Erskine Park), Eastern Creek Raceway, Sydney International Equestrian Centre (Horsley Park), Western Sydney Parklands (Horsley Park), Calmsley Hill City Farm (Abbotsbury),
- South – Sales Park (Luddenham), Bents Basin State Conservation Area (Greendale), Burragorang Recreation Area (Silverdale)

The proximity of aircraft accompanied by loud noise may be audible by people engaged in recreational activities such as organised sport, walking, cycling, boating or camping. It is understood the noise impact assessment technical report prepared by Wilkinson Murray assesses the predicted impact on these areas.

It is noted that impacts on recreational lands are not currently addressed under ANEF/AS 2021 requirements.

Impacts on recreational lands are also addressed in Chapters 10, 11, 31 (noise) and 26 (Greater Blue Mountains) of the EIS.

Consolidation of Commonwealth land holding

As discussed in section 2.1, much of the land required for the proposed construction of the airport has already been acquired by the Australian Government. Despite this, a small amount of additional land may be required.

The Australian Government may consider acquiring the portion of land that is within the identified public safety zone (PSZ). Alternatively, opportunities to include the PSZ within the existing site boundary will be further explored during detailed design.

Airport site land use zone

The use of the site as an airport is permissible under the current SP1 – Special Activities (Commonwealth) zoning for the majority of the site.

Additionally, the Airports Act was recently amended to clarify that the land owned by the Commonwealth at Badgerys Creek is a declared airport site; but also to clarify that even where the Commonwealth does not own the land it may be declared part of an airport site for the purposes of the Airports Act. This means that the Airport Master Plan, Major Development Plan and building approvals process set out under the Airports Act will be required for development of the proposed airport.

Nevertheless it is recommended that to provide clarity and certainty for the future use of the land, DIRD liaise with DP&E and Liverpool Council to ensure that all land which is to be incorporated into the airport site be rezoned to a consistent zone under the relevant LEP (such as the existing SP1 – Special Activities (Commonwealth) zone).

5.2 Airport operations

Airspace development controls

Protecting airspace on and around airports is essential to maintaining a safe operating environment. The Airports Act provides for the Commonwealth to take steps under the Airports (Protection of Airspace) Regulations 1997 to regulate certain incursions in the airspace around airports. These incursions include breaches of the Obstacle Limitation Surfaces (OLS) and the Procedures for Air Navigation Systems Operations Surface (PANS-OPS) which would be identified for the proposed airport as part of ongoing operations planning.

OLS are a series of theoretical surfaces in the airspaces established under International Civil Aviation Organisation guidelines. The OLS defines the airspace to be protected from protrusion by natural or man-made structures which might cause a safety hazard for aircraft during the initial and final stages of flight.

PANS-OPS are established to protect aircraft during take-off, landing or manoeuvring and when aircraft are operating in non-visual conditions. OLS and PANS-OPS are discussed in more detail in Section 3.1.

DIRD will need to liaise with DP&E and relevant local councils to ensure OLS and PANS-OPS requirements are applied in applicable environmental planning instruments.

Public safety zones

The Australian Government is working with the states and territories on the development of a national standard for public safety zones to be incorporated into the NASF. Public safety zones (PSZs) are an area of approximately 1,000 metres x 250 metres at the ends of runways in which development is constrained. They are based on runway use statistics correlated against international crash data. PSZs minimise the risk of damage by aircraft during landing or take off by ensuring any development within the zone does not add unduly to existing levels of risk.

Where a PSZ is identified, additional scrutiny might be considered for new developments that:

- increase residential use and population density in the zone;
- attract large numbers of people, such as retail or entertainment developments;
- involve institutional uses, such as schools and hospitals;
- involve the manufacture or depot storage of noxious and hazardous materials; and

- attract significant static traffic.

Aircraft noise

Land use planning by the NSW Government and local councils over the last two decades has had a high regard to the potential for aircraft noise from a proposed airport. Planning for the South West Priority Growth Area anticipated the potential impacts of aircraft noise by locating a substantial buffer of employment generating development areas against the airport site's south-eastern boundary.

Liverpool Council's Rural Lands Strategy 2012 recommended not to expand Luddenham village beyond its current extent as it may be impacted by aircraft noise from the future Western Sydney Airport.

In Australia aircraft noise exposures for land use planning are derived using the Australian Noise Exposure Forecast (ANEF) measure. The noise technical report provides noise exposure contour maps which depict the aircraft noise levels forecast to exist as a result of the assumed airport operations.

The Australian Noise Exposure Concept (ANEC), which is based on indicative data on aircraft types, aircraft operations and flight zones, is used to provide a measure of aircraft noise impacts in an EIS. The methods used to derive an ANEC are exactly the same as that used to derive an ANEF, but the ANEC is indicative and not endorsed by Airservices Australia.

Table 4 identifies the recommended development types within ANEF zones, as outlined in the AS 2021.

Table 4 Building Site Acceptability Based on ANEF Zone (AS2021)

Building Type	ANEF zone of site		
	Acceptable	Conditionally acceptable	Unacceptable
House, home unit, flat, caravan park	Less than 20 ANEF	20 to 25 ANEF	Greater than 25 ANEF
Hotel, motel, hostel	Less than 25 ANEF	25 to 30 ANEF	Greater than 30 ANEF
School, university	Less than 20 ANEF	20 to 25 ANEF	Greater than 25 ANEF
Hospital, nursing home	Less than 20 ANEF	20 to 25 ANEF	Greater than 25 ANEF
Public building	Less than 20 ANEF	20 to 30 ANEF	Greater than 30 ANEF
Commercial building	Less than 25 ANEF	25 to 35 ANEF	Greater than 35 ANEF
Light industrial	Less than 30 ANEF	30 to 40 ANEF	Greater than 40 ANEF
Other industrial	Acceptable in all ANEF		

We are advised that the Wilkinson Murray report prepared as part of this EIS includes predicted aircraft noise impact mapping. Areas around the airport, including those generally aligned with the proposed runways and GBMWHA will be subjected to varying levels of aircraft noise depending on factors such as time of day, number of aircraft movements and wind speed.

It is recommended that DIRD liaise with DP&E and relevant local councils to ensure applicable environmental planning instruments have regard to the noise exposure forecasts presented in the EIS and supporting AS 2021 building siting and development controls.

The implementation of *Guideline A: Measures for Managing Impacts of Aircraft Noise* under the NASF will be instrumental in managing potential future operational noise impacts for future land use planning and development around the airport.

Lighting

The proposed runway orientation has limited the possible areas that could be affected by the approach lighting and runway lighting. The proposed location of buildings between the two runways also provides a buffer for the potential impact of the buildings' lighting. LED apron lighting and directional external lighting would minimise potential impacts to surrounding land. The Visual Impact Assessment technical report by RPS concludes that the proposed airport lighting would likely have minimal impact to the surrounding lands.

Air quality

It is understood that the EIS air quality assessment undertaken as part of this EIS has provided a forecast of the air quality impacts on surrounding areas.

Land use zoning for employment generation and other less sensitive land uses is recommended as a means of reducing local air quality impacts on sensitive receivers in the vicinity of the airport site. Reference should be made to that report for detail of areas likely to be affected.

The regional impact on air quality from the airport operations are a cumulative effect of aircraft operations, road traffic, industrial emissions and other regional sources. Again, the air quality assessment report should be referred to for details of areas affected.

Fuel pipeline

A jet fuel pipeline may service the proposed airport in the future. It is important to note that a fuel pipeline corridor has not yet been identified. Consultation is underway between the Department of Infrastructure and Regional Development and the NSW Department of Planning and Environment to identify a potential future corridor and seek to preserve the corridor through relevant planning controls. Arrangements for access to the fuel pipeline, which may involve an easement, are required along the pipeline corridor alignment to ensure maintenance access and as a public safety measure. This may include planning controls restricting development on and adjacent to the pipeline.

It is recommended that DIRD facilitate liaison between commercial parties operating the airport and DP&E to identify potential future corridors and seek to preserve the corridor alignment well in advance of the need through relevant planning controls, both to ensure public safety and that future fuel supply is not a constraint to airport development.

The timing of the fuel pipeline will be based on a number of factors however is not currently proposed as part of the initial development of the airport.

Traffic and transport

As outlined in the EIS Traffic and Transport Assessment, several local road improvements are required in the vicinity of the airport site. Badgerys Creek Road is also expected to be partially closed as part of the initial development of the airport site. The current alignment of The Northern Road is to be acquired for construction of the proposed airport. Investigations are underway Plan to upgrade and realign The Northern Road to outside the western boundary of the proposed airport. In addition, RMS and Transport for NSW are undertaking corridor studies for a new motorway along the general alignment of Elizabeth Drive between The Northern Road and the M7 Westlink Motorway.

Local roads within the Commonwealth landholdings, not within the Stage 1 construction footprint, are expected to remain open for public access. As longer term development proceeds, these roads would progressively be decommissioned.

The proposed South West Rail Link Extension is expected to provide a railway station for the airport site. A specific alignment or station location is yet to be confirmed. Although the rail line may not be constructed for some years after the opening of the airport, opportunities for corridor protection should be pursued with Transport for NSW, DP&E and local councils.

6 Recommended mitigation measures

Having regard to the planning and land use impact assessment, Table 5 summarises the recommended mitigation measures identified in this report for implementation prior to commencement of operation of Stage 1 of the airport site.

Table 5 Mitigation measures

Issue	Recommended mitigation measure	Primary Party for DIRD to liaise with	Comment
Land use zoning	1. Liaise with the relevant State and local government agencies to seek the appropriate adjustment to zoning of the airport site under applicable environmental planning instruments.	DP&E	Whilst most of the existing Australian Government landholdings are already zoned SP1 – Special Activities (Commonwealth), some existing/future landholdings should be zoned SP1 – Special Activities (Commonwealth) to reconcile the airport uses with planning controls.
Operational airspace	2. Liaise with the relevant State and local government agencies to implement appropriate OLS and PANS-OPS requirements in applicable environmental planning instruments to reflect protected airspace under the Airports (Protection of Airspace) Regulations 1997.	DP&E	Once the operational airspace requirements have been finalised, DIRD should liaise with Airservices, DP&E and relevant local councils to ensure OLS and PAN-OPS requirements are implemented in applicable environmental planning instruments.
Noise	3. Liaise with the relevant State and local government agencies to implement appropriate noise management controls in applicable environmental planning instruments with reference to AS2021-2000 *Acoustics: aircraft noise intrusion – Building siting and construction* and noise guidelines under the National Airports Safeguarding Framework.	DP&E	Whilst Penrith and Liverpool Councils have existing controls, these may need to be amended to reflect revised ANEF. Relevant controls also need to be considered for Wollondilly, Camden, Blacktown and Fairfield Councils.
Corridor protection – Rail	4. Liaise with the relevant State and local government agencies to identify opportunities for corridor protection for the provision of a future rail connection to the airport site.	Transport for NSW	Rail corridors are the responsibility of the State Government. Corridor protection opportunities may take the form of land acquisition, easements or zoning/development controls in relevant environmental planning instruments. Zoning and land use control outside the airport site is within State and local control.

Issue	Recommended mitigation measure	Primary Party for DIRD to liaise with	Comment
Corridor protection – road	5. Liaise with the relevant State and local government agencies regarding future access arrangements from The Northern Road and Elizabeth Drive.	NSW Roads and Maritime Services	Off site roads are the responsibility of State and local government. Corridor protection opportunities may take the form of land acquisition, easements or zoning/development controls in relevant environmental planning instruments. Zoning and land use control outside the airport site is within State and local control.
Corridor protection – fuel pipeline	6. Liaise with the relevant State and local government agencies to identify opportunities for protection of a corridor for a future fuel pipeline.	DP&E	Corridor protection opportunities may take the form of land acquisition, easements or zoning/development controls in relevant environmental planning instruments. Zoning and land use control outside the airport site is within State and local control and will require liaison between DIRD and local and State authorities.

7 Conclusion

Construction and operation of the proposed airport would change the rural character of Badgerys Creek and surrounding lands. This land use outcome has been anticipated in Commonwealth, NSW and local government strategic planning for the area over several decades. The Australian Government will continue to work closely with State government agencies and local councils to ensure regional and local land use planning complements the future operation of the proposed airport and limits incompatible land uses in the vicinity of the airport site.

The proposed airport development would be a catalyst for a range of infrastructure projects identified by the Australian and NSW governments to support Western Sydney's growth into the future. The proposed airport development would also be a key focus for employment generating development in Western Sydney, creating jobs for the new residents of the South West Priority Area.

This report has assessed the likely land use and planning impacts and makes recommendations for mitigation measures to minimise impacts. Many of these will be dependent upon the outcomes of subsequent design and regulatory processes before they can be implemented.

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VOLUME 4

Appendix O
Landscape character and visual

Western Sydney Airport EIS

Landscape Character and Visual Impact Assessment

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Name	Signature	Date
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Contents

GLOSSARY AND ABBREVIATIONS ..... **IV**
EXECUTIVE SUMMARY ..... **V**
1.0 INTRODUCTION **1**
1.1 Project Overview **1**
1.2 Purpose **2**
1.3 Limitations of the Report **2**
1.4 Scope of this Report **3**
2.0 APPROACH AND METHODOLOGY **4**
2.1 Assessment Process **4**
2.2 Visual Sensitivity **4**
2.3 Magnitude of Effect **5**
2.4 Visual Impact Grading Matrix **5**
3.0 EXISTING ENVIRONMENT **6**
3.1 Site Context **6**
3.2 Landform **11**
3.3 Vegetation **13**
3.4 Land Use **15**
3.5 Heritage items **16**
4.0 VISUAL IMPACT ASSESSMENT **18**
4.1 Visual Catchment **18**
4.2 Selection of representative viewpoints **21**
4.3 Assessment of Selected Viewpoints **24**
4.4 Flight Paths **38**
4.5 Construction **38**
4.6 Lighting and skyglow effects **40**
4.7 Cumulative Impacts **41**
5.0 MITIGATION AND MANAGEMENT MEASURES **43**
5.1 Operation **43**
5.2 Construction **44**
5.3 Residual Effects **45**
6.0 SUMMARY AND CONCLUSIONS **46**
7.0 REFERENCES **47**

Glossary and Abbreviations

AHD	Australian Height Datum
ATCT	Airport Terminal Control Tower
BWSEA	Broader Western Sydney Employment Area
CASA MOS	Australian Civil Aviation Safety Authority Manual of Standards
Cumulative Effects	Cumulative effects occur between projects, where the combination of effects created by multiple projects may be greater than the sum of the individual effects
1999 EIS	Environmental Impact Statement, Second Sydney Airport Proposal, Supplement to Draft, Volume 3 Supplement
EP&A Act	NSW Environmental Planning and Assessment Act 1979
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
Landform	The shape and form of the land surface which is the result of the action and interaction of natural and/or human factors. *
Landscape Character	A distinct recognisable and consistent pattern of elements in the landscape that makes one landscape different from another, rather than better or worse
Landscape Character Zone	An area of landscape with similar properties or strongly defined spatial qualities, distinct from areas immediately adjacent
LCVIA	Landscape Character and Visual Impact Assessment
LED	Light Emitting Diode
LIIEMA	UK Landscape Institute and Institute of Environmental Management & Assessment
Magnitude of Effect	A term that combines the judgements about the size and scale of the effect, the extent of the area over which it occurs, whether it is reversible or irreversible and whether it is short or long term in duration
OLS	Obstacle Limitation Surface - A series of surfaces that define the limits to which structures or objects may project into the airspace to ensure the safety of aircraft
Residual Impacts	Impacts that remain following the implementation of mitigation measures
RMS	New South Wales Roads and Maritime Services
Sensitivity	A term applied to visual receivers, combining judgements of the susceptibility of the receiver to the specific type of change or development proposed and the value related to that receptor
Skyglow	The brightening of the night sky above our towns, cities and countryside
SWGC	South West Growth Centre
Visual amenity	The overall pleasantness of the views people enjoy of their surroundings, which provides an attractive visual setting or backdrop for the enjoyment of activities of the people living, working, recreating, visiting or travelling through an area. *
Visibility Envelope	A map, usually digitally produced, showing areas of land within which a development is theoretically visible.
VIA	Visual Impact Assessment
Visual receiver	Individuals and/or defined groups of people who have the potential to be affected by a proposal.
WSIP	Western Sydney Infrastructure Plan

Executive Summary

The landscape in which the airport is proposed comprises a modified landscape occupying a rural and scenic area known for its undulating landform and open viewsheds within the Cumberland Plains of Western Sydney. There are scenic values associated with both the rural qualities of the area as well as the nearby Blue Mountains World Heritage Area which forms a backdrop to the airport site to the west.

The rural character that has existed for many decades in Western Sydney is changing due to the development of the South West Growth Centre (SWGC), the commitment by the Commonwealth Government for the Western Sydney Infrastructure Plan (WSIP) and the establishment of the Broader Western Sydney Employment Area (BWSEA). The proposed airport is being developed within the context of these broader projects.

Key Findings

1. The proposed airport development would involve substantial modification of the landscape and the existing rural visual quality in the area to a more urbanised and commercial landscape character.
2. The overall visual impacts of the proposed airport are reduced due to the local topography and by existing vegetation which limit the size of the visual catchment of the airport site.
3. Future surrounding urban development, as a part of government planning and implementation, will alter the existing rural character north, south and east of the airport thereby reducing visual sensitivity (and visual impacts) over time.
4. The Stage 1 airport construction and operation will likely have the most visual impacts on areas to the north such as Luddenham and Elizabeth Drive due to their relatively close proximity to the airport.
5. There will be some relatively minor construction activity in the southern portion of the site in Stage 1 to accommodate water retention basins and other ancillary infrastructure and longer term construction and airport operations in the southern portion of the airport site will increase visual impacts in the areas south of the airport such as Bringelly, Greendale and Bents Basin with the possibility of overflights or aircraft being seen in the sky. Distant views of airport construction and operation from surrounding rural residential areas at higher elevations, such as Mount Vernon, Silverdale and Rossmore, are only of a moderate to low visual impact. The impact would however be increased by either aircraft taking off and landing and/or overflights.
6. Visual assessments were undertaken at selected important cultural and recreational areas including three publicly accessible locations in the Blue Mountains and Bents Basin. The assessment concluded that visual impacts will range from moderate to high due to the high sensitivity ratings of the viewpoints and the effect of aircraft taking off and landing and/or overflights.
7. Retention of existing remnant vegetation will assist in diminishing the visual impacts of the airport facilities to the surrounding areas particularly along the perimeter at Badgerys Creek.
8. Operational lighting will have a relatively low visual impact on the surrounding areas. The 05/23 (northeast/southwest) runway alignment inherently limits the populated areas that could potentially be affected by the approach lighting and runway lighting and potential impacts would be further reduced if advances in lighting technology such as light emitting diode (LED) lights are incorporated in the airport design. The impact will also reduce over time as further planned urbanisation and lighting pollution occurs in nearby areas including the BWSEA and the SWGC.

Mitigation Measures

Retention of existing trees within areas of the airport site will help to mitigate the visual impact in the short term and longer term. If site planting is undertaken, it should incorporate the use of locally endemic species.

Opportunities to retain and potentially embellish important natural features within the landscape such as the riparian zone along Badgerys Creek should be investigated and incorporated wherever possible, noting that conflicts might arise as a result of other important airport considerations such as bushfire risk minimisation and site surveillance and security

Site perimeter fencing may result in a significant visual impact during construction and operation due to the extent required. Measures such as screen planting in key locations could help diminish its overall visual impact. Any decision to incorporate screen planting will need to consider the security requirements of the airport.

Requirements for creating large level areas within the airport through balanced cutting and filling should, wherever possible, try and minimise large grade transitions near the boundaries. This is particularly important in order to avoid unnatural visual transitions or barriers in more visible areas, such as near roads. Site flood control measures, if any are required, will also need to be taken into account in any decision making.

Low angle, cut-off fittings should be used to mitigate the impact of the high intensity approach lighting and runway lighting. Detailed consideration should be given to the adoption of full cut off LED apron and external building lighting, both for the Stage 1 and longer term airport development.

1.0 Introduction

1.1 Project Overview

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Purpose

This landscape character and visual impact assessment (VIA) has been prepared in support of the EIS for the proposed airport development at Badgerys Creek in Western Sydney. The objective of this report is to the meet the requirements of the EIS Guidelines and to assess the visual impacts of the airport development in accordance with the Significance of Impact Assessment Guidelines 1.1 (MNES) and 1.2 (Environment).

The purpose of this report is to identify potential landscape and visual impacts of the proposed airport. The report will inform appropriate, contextual mitigation measures that can be incorporated in both the design and management of the proposed airport development to help offset adverse impacts from the construction and operation of the airport wherever possible and to satisfy the requirements of relevant authorities.

1.3 Limitations of the Report

RPS has prepared this report pursuant to the conditions in the Department of Infrastructure and Regional Development Deed of Standing Quotation (SON2030181), the Commonwealth RFQTS Number 2014/7540/001, the subsequent response accepted and referenced in the relevant Official Order; and the GHD Subconsultancy Agreement dated 11 May 2015 (collectively the "**Contract**"):

In particular, this report has been prepared by RPS for the Commonwealth (and to the extent expressly stated in the Contract (and for the purposes stated therein) the parties referred to in the Contract ("**Other Parties**") and may only be used and relied on by the Commonwealth and the Other Parties in accordance with the Contract for the purpose agreed between RPS, GHD and the Commonwealth as set out in the Contract.

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The opinions, conclusions and any recommendations in this report are based on assumptions made by RPS described in this report. RPS disclaims liability arising from any of the assumptions being incorrect.

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The opinions, conclusions and any recommendations in this report are based on information obtained from, and field surveys undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific survey locations. Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report. Site conditions (including the presence or abundance of threatened biota) may change after the date of this report. RPS does not accept responsibility arising from, or in connection with, any change to the site conditions. RPS is also not responsible for updating this report if the site conditions change.

This assessment is intended to be an objective report based on professional analysis of the landscape and the design proposals. It seeks to establish the anticipated visual impacts of the proposal on a wide range of existing and future viewers of the landscape, most of whom cannot be specifically identified and whose perceptions it is not possible to solicit.

The assessment has been undertaken based on conceptual level information and therefore is generally broad in its approach. As such, it has not included a detailed review of the individual ancillary airport components such as the fuel farm weather station, signage, maintenance and other airport support facilities or infrastructure upgrades in the surrounding area such as roads.

1.4 Scope of this Report

This report assesses those impacts associated with the construction and operation of the proposed airport and comprises the following sections.

- description of the context of the site in terms of the visual environment;
- description of the main visual components of the proposed airport for both Stage 1 and the longer term development;
- qualitative assessment of the potential visual impact of the changes to the visual amenity and views from key representative viewpoints for both the construction and operation phases;
- assessment of visual impact using a grading matrix;
- provision of mitigation measures where possible to address key identified visual impacts; and
- assessment of cumulative and residual effects.

In order to address the night time visual impact assessment, this report provides an update of the operational lighting impact assessment prepared by O'Hanlon Design (Commonwealth Department of Transport and Regional Services, 1999) with consideration given to current lighting standards and requirements for airports.

2.0 Approach and Methodology

2.1 Assessment Process

This report uses a well-utilised approach to visual quality assessment that is systematic, consistent and based on professional, value judgement of commonly accepted and adopted criteria within the industry.

There is currently no standard guidance on the assessment of landscape and visual impact within Australia. Methods used in this VIA are from the NSW Roads and Maritime Services (2013) *Environmental Impact Assessment Practice Note - Guideline for Landscape Character* and the *Visual Impact Assessment* and *Guidelines for Landscape Visual Impact Assessment Third edition* (2013). The methodology has been adapted and designed to address the specific issues of this project.

This assessment focuses on two main types of visual impact:

- effect on visual amenity; and
- effect on surrounding viewpoints.

An assessment of those two effects (or impacts) depends on the combination of two main factors.

1. visual sensitivity (of the visual amenity or viewpoints).
2. the magnitude of the visual change.

Using the grading matrix in Table 1 below, consideration of both of these factors is required to arrive at an overall level of effect or impact.

The assessment therefore determines the potential level of impact to the visual amenity of the site and its surrounds in general terms, as well as more specific impacts to key surrounding viewpoints such as from roads, residential and recreational locations.

2.2 Visual Sensitivity

An assessment of the landscape character was undertaken to develop an understanding of the context and the sensitivity of the area's landscape character.

Visual sensitivity refers to the character of a setting, the quality of the view, and how sensitive it is to the proposed change (RMS, 2013). An assessment of visual sensitivity refers to the qualities of an area, the type and number of receivers and how sensitive the existing character is to the proposed change. Combined with magnitude, sensitivity provides a measure of impact.

Visual sensitivity is related to the direction of view, the composition of the view and may include more than one character zone. A landscape character zone refers to an "area of landscape with similar properties or strongly defined spatial qualities, distinct from areas immediately adjacent." (RMS, 2013)

2.3 Magnitude of Effect

The magnitude of a visual effect is the degree of change the visual landscape undergoes as a result of the proposed development. It is the measurement of the overall scale, form and character of a development proposal when compared to the existing condition (RMS, 2013). Magnitude also takes into consideration the distance between the viewer(s) and the proposal.

2.4 Visual Impact Grading Matrix

Once a visual sensitivity level and magnitude are determined, they are combined into a visual impact grading matrix to identify an overall level of impact on key viewpoints.

Table 1 below is used to provide a general understanding of the level of impact and is utilised in the assessment of predicted visual impacts in section 4.0 of this report.

Magnitude

Sensitivity: Impact Rating	High	High-Moderate	Moderate	Moderate-Low	Low	Negligible
High	High Impact	High Impact	Moderate-High	Moderate-High	Moderate	Negligible
High-Moderate	High Impact	Moderate-High	Moderate-High	Moderate	Moderate	Negligible
Moderate	Moderate-High	Moderate-High	Moderate	Moderate	Moderate-Low	Negligible
Moderate-Low	Moderate-High	Moderate	Moderate	Moderate-Low	Moderate-Low	Negligible
Low	Moderate	Moderate	Moderate-Low	Moderate-Low	Low Impact	Negligible
Negligible	Negligible	Negligible	Negligible	Negligible	Negligible	Negligible

Table 1 Landscape Character and Visual Impact Grading Matrix (RMS 2013)

3.0 Existing Environment

An understanding of the visual character of the existing landscape and the type and extent of potential views acts as a baseline for the visual impact assessment. For example, a description of the visual character of the landscape would identify areas of visual enclosure where existing structures, topography and vegetation limit views, as opposed to visually open landscapes where widespread inter-visibility between communities and visual features exist.

Landscape character is generally defined as the recognisable pattern of elements that occurs in a particular landscape. Variations in geology, soils, vegetation, land use, settlement patterns, landform and building types are the physical elements that create different landscapes with distinctive characteristics and create a unique sense of place. The landscape character of the airport site was assessed in order to determine the degree of change that would occur from the result of the proposed airport in both Stage 1 and the longer term.

The landscape character provides a picture or sense of the landscape and is defined by the area of visually distinct common features. Defining the landscape character and its values aids in determining the capacity for the landscape to accommodate any changes from the introduction of development.

3.1 Site Context

The proposed airport development site is approximately 1,700 hectares in area within the Cumberland Plain region of Western Sydney. The Cumberland Plain is a broad geographical region in the Sydney metropolitan area stretching from Windsor in the north to Picton in the south, from the Hawkesbury Nepean in the west to Sydney's inner western suburbs in the east.

The site and surrounding areas include ridgelines and rolling hills within the visual context of the Greater Blue Mountains to the west which provides a backdrop to views from the east. The existing landscape is of a rural character and part of the greater South Creek Valley.

The overall landscape character surrounding the airport is open and rural with expansive views possible from surrounding hill tops and higher elevations to the west. The area's character is also defined by cleared pastureland, large lot residences (both single or double storey) set back from the road and punctuated with exotic planting. Patches of remnant vegetation exists within the airport site, particularly along creek lines, road edges and near farm dams.

The area north of Elizabeth Drive is rural pasture land with scattered remnant vegetation, farm dams and open views of the landscape. Immediately north of the site are farm buildings generally set well back from Elizabeth Drive and do not have a strong visual connection with the road. Northeast of the airport site is a landfill which is setback and screened from Elizabeth Drive and therefore has only a minor visual presence. Badgerys Creek runs south-north forming the eastern and part of the southern site boundary. The remnant vegetation along its edges provides a natural character which contrasts with the overall open rural character of the rest of the site. It also provides visual screening of views to the eastern areas of the airport site from further east.

East of the airport site there is more regular patterning of lots, homes and farm buildings with smaller lot sizes aligned perpendicular to the streets. Roads in the area have undefined edges and contribute to the overall rural character. A good example can be seen in Plate 1.



Plate 1
View south from Lawson Road

South of the site near Badgerys Creek Road, the area is characterised by large, rural residential lots and farms on undulating topography. Homes are generally setback from the road and characterised by a mix of remnant vegetation, exotic planting, farm dams and open lawn. Examples of this can be seen in Plates 2 and 3.



Plate 2
View south from Badgerys Creek Road



Plate 3
View west from Badgerys Creek Road

The Bringelly and Greendale areas south and southwest of the proposed airport site are characterised by large lot rural houses within a mix of remnant native vegetation and exotic tree plantings and mown grass areas as shown in Plate 4. The landscape opens up in areas with views west in the direction of the Blue Mountains as shown in Plates 5 and 6.



Plate 4
View north from Dwyer Road, Bringelly



Plate 5
View west from Dwyer Road, Bringelly toward the Blue Mountains



Plate 6
View northeast from Greendale Road, Wallacia

Luddenham is the most urbanised area near the proposed airport. It consists of a commercial area accessed from The Northern Road and a residential area just to the east. Dwellings in this area are closer together and set close to the road, as shown in Plate 7. The area appears to have grown minimally within the last few years with the addition of 4-5 homes on Ethan Close. Despite a more urban character at Luddenham, the area immediately surrounding is rural with open views of the landscape to the south and east as shown in Plate 8.



Plate 7 – View from Adams Road looking north west along Jamison Street, Luddenham



Plate 8 – View from Adams Road looking south west, Luddenham

Mount Vernon is a sparsely populated rural suburb approximately five kilometres north east of the proposed airport. Much of the suburb consists of undulating topography and some rural-residential properties have views over the wider area including to the west toward the proposed airport site and the Blue Mountains.



Plate 9 – View south from Mount Vernon Road, Mount Vernon

3.2 Landform

The topography of the airport site and surrounding area is typical of the Cumberland Plains, consisting of gently rolling foot hills with local relief of 10-30 metres. Slopes are generally less than 5 percent but sometimes to 10 percent and very occasionally up to 10 to 20 percent . Crests and ridges are broad (200-600 metres) and rounded with convex upper slopes grading into concave lower slopes (Bannerman and Hazelton, 1990).

A ridge line with a high point of 118 metres AHD occurs in the western portion of the site near The Northern Road. It offers views over the immediate area and the much wider landscape. Areas in the western half of the airport site are generally at a higher elevation whereas they are lower and flatter along Badgerys Creek with the lowest point being 43 metres in the north east corner of the site near Elizabeth Drive. Elevations more typically range between 60 and 90 metres throughout the central areas of the airport site, refer Figure 1.

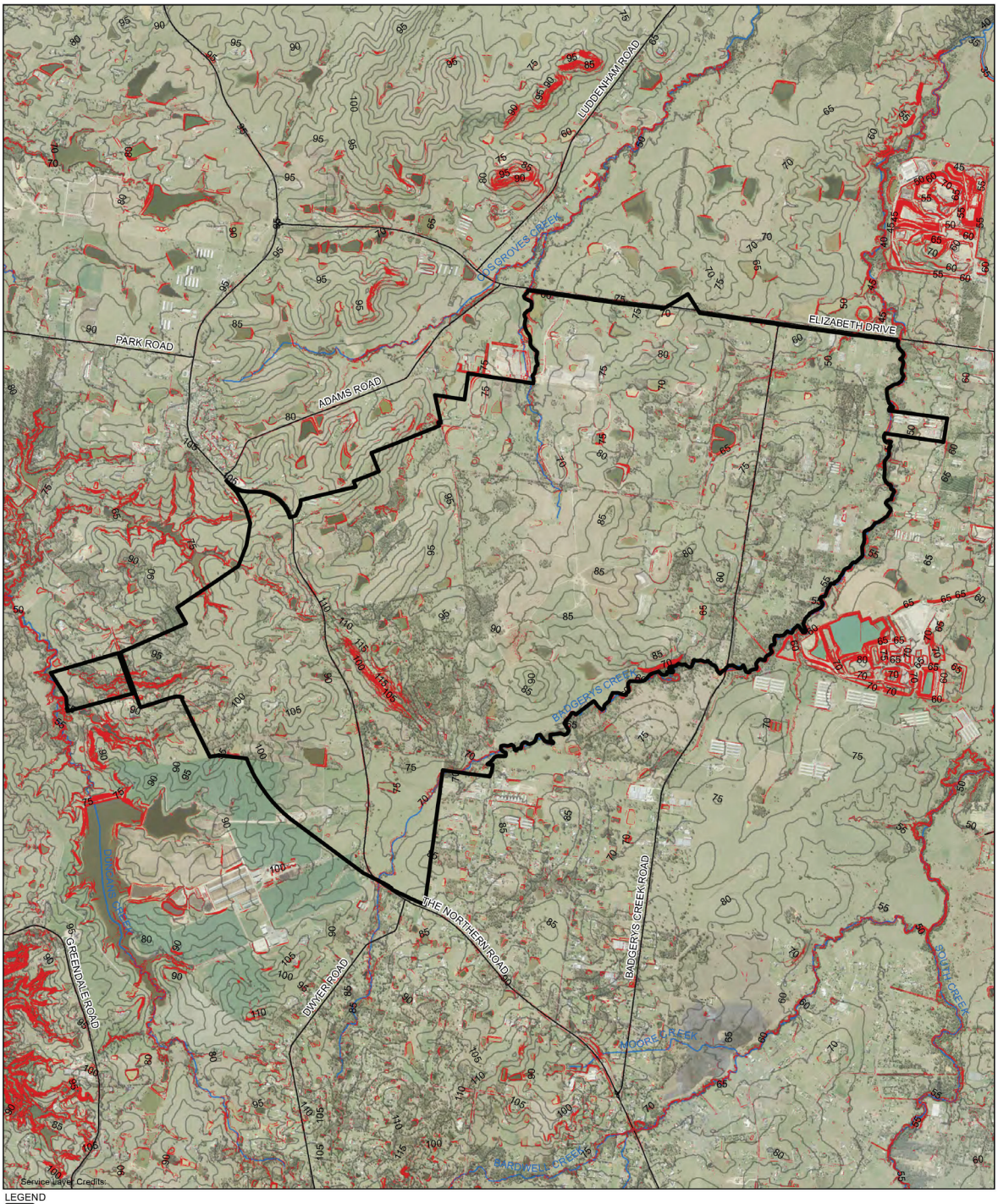


Figure 1 – Site Topography

3.3 Vegetation

The airport site contains gently undulating, low hills on shale and broad flats on alluvium on the Cumberland Plain. The vegetation comprises remnant patches of grassy woodland and narrow corridors of riparian forest within extensive areas of grassland, cropland and cleared, developed land. The main land uses are agriculture and low density rural-residential development.

The majority of the airport site contains exotic grassland with pasture species such as Kikuyu (*Pennisetum clandestinum*) and Paspalum (*Paspalum dilatatum*) along with some native species such as Kangaroo Grass (*Themeda australis*). There are occasional isolated paddock trees that are remnants of adjoining native woodland and forest.

The most extensive native vegetation type is Forest Red Gum (*Eucalyptus tereticornis*) and Grey Box (*Eucalyptus moluccana*) woodland with a grassy understorey and occasional dense patches of the shrub species Native Blackthorn (*Bursaria spinosa spinosa*). This vegetation generally occurs in small, remnant patches surrounded by grassland.

The riparian corridors of Badgerys Creek and other drainage lines through the airport site contain denser forest of Forest Red Gum, Grey Box and Cabbage Gum (*Eucalyptus amplifolia*) along with Swamp Oak (*Casuarina glauca*), Broad-leaved Apple (*Angophora subvelutina*) and paperbarks (*Melaleuca* spp.). Understorey vegetation is similar to the grassy woodland on higher ground but also contains moisture loving species such as rushes and sedges.

There are a large number of dams and flooded depressions throughout the airport site formed by the construction of barriers across small drainage lines. These water bodies contain a moderate diversity and abundance of native wetland plants such as Cumbungi (*Typha orientalis*) and Spike Rush (*Eleaocharis sphacelata*).

The condition of native vegetation varies across the airport site as a result of previous land uses and grazing intensity. Areas that have been historically cleared and/or heavily grazed now contain regrowth vegetation in poorer condition. There is moderate to severe weed infestation throughout, with linear remnants along roads and isolated patches in agricultural land the most severely affected. Notwithstanding the generally moderate to poor condition of vegetation at the airport site, it has high conservation significance as a result of the presence of threatened species and ecological communities and the generally limited extent and quality of similar vegetation in the Western Sydney region.

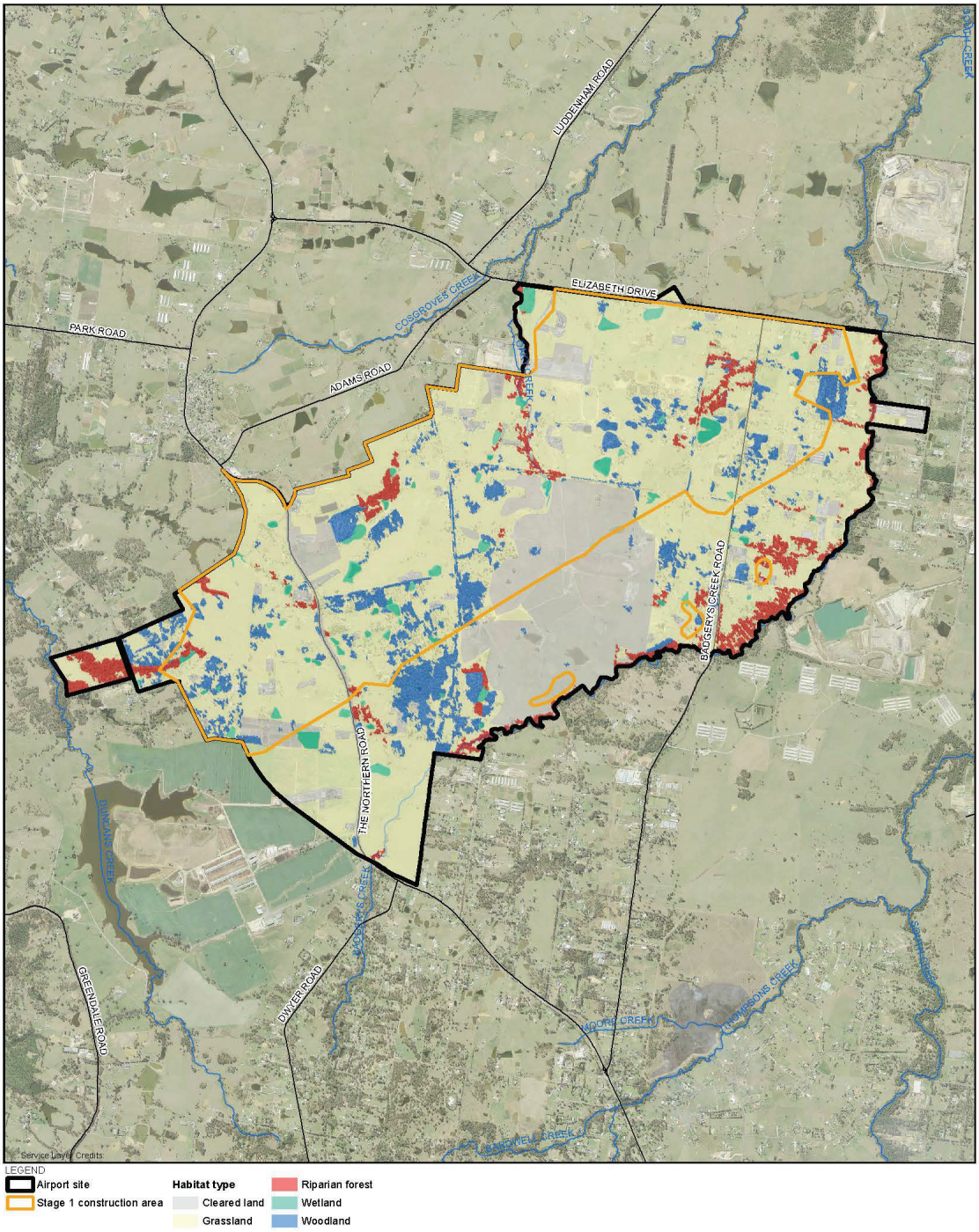


Figure 2 – Vegetation Zones

3.4 Land Use

Pastoral and horticultural land uses remain the primary land uses in the area. Large blocks of agricultural land are found to the north and west, while rural residential and agricultural properties are generally concentrated to the east and south.

Figure 3 shows the various types of land uses immediately surrounding the site. This includes the following large, land uses:

- Elizabeth Drive Landfill containing non-putrescible and industrial waste and located approximately 1 kilometre north of the airport site;
- Twin Creeks Golf & Country Club, a 200 lot residential estate and golf course approximately 5 kilometres north of the airport site;
- Boral Brickworks brick pit and production facility located approximately 1 kilometre east of the airport site;
- Inghams Multiplication Farm - a large commercial agricultural use located approximately 1 kilometre east of the airport site;
- Royal Australian Air force Telecommunications, Bringelly – This is a military base located approximately 2 kilometres southeast of the airport site;
- The University of Sydney - a rural farm located approximately 4 kilometres south west of the airport site; and
- Bents Basin State Conservation Area – a recreation area located approximately 5 kilometres south west of the airport site.

The following broad character zone map depicts adjacent land uses.

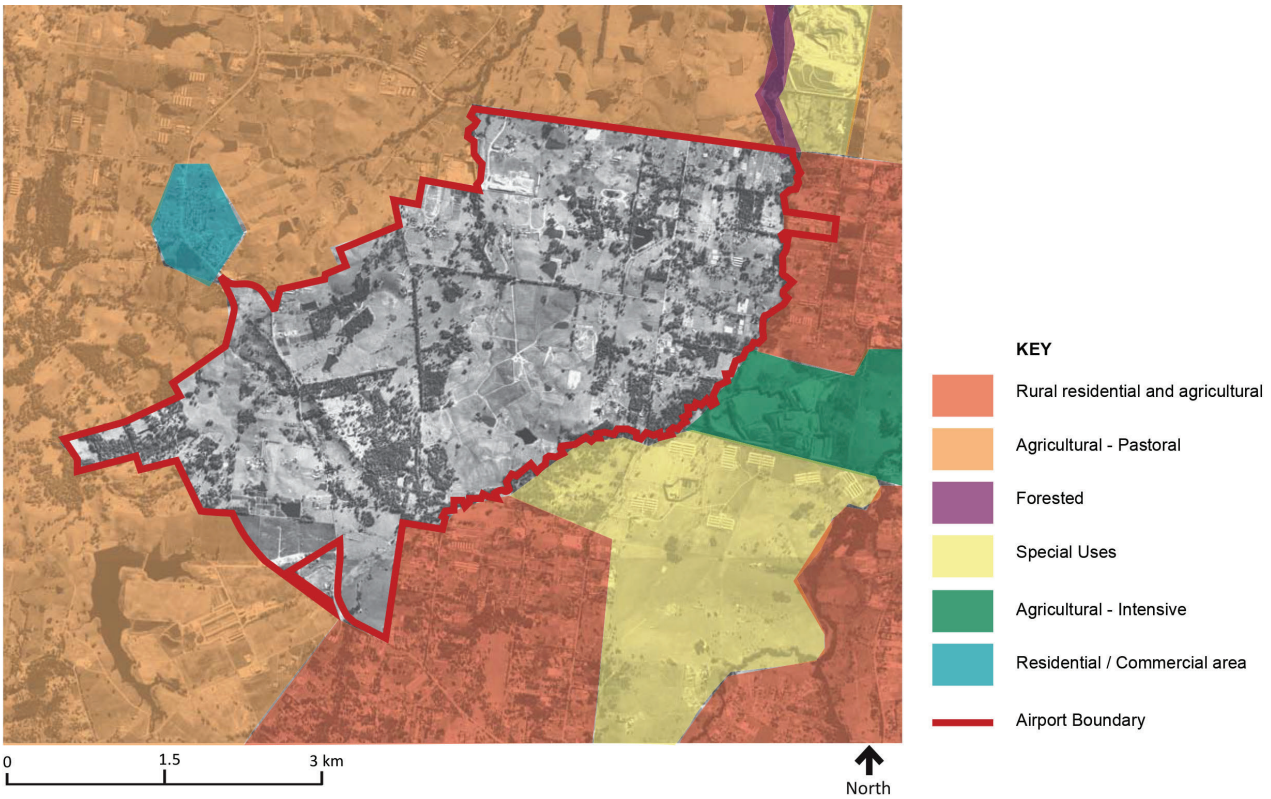


Figure 3 – Surrounding Land Uses

3.5 Heritage items

An understanding of the area's historic landscape is considered important in a landscape character assessment as it looks at the material remains of the past in order to help understand the present-day landscape and inform the overall landscape character.

Based on a review of the findings of the European and other heritage technical report (RPS 2015), there is one item of State heritage significance located near the airport site. Other items of European heritage which are locally listed on either the Liverpool or Penrith LEPs in the suburbs of Luddenham and Badgerys Creek are shown in the following table;

ITEM No.	Name and Location	Heritage Significance	Type of Impact
SA1	Former Overseas Telecommunications Commission site group Badgerys Creek Road, Bringelly	Local	Indirect: Visual impact.
SA2	Kelvin 30 The Retreat, Bringelly	State	Indirect: Visual impact, impact to ambience of site.
SA3	Two RAAF water tanks Badgerys Creek Road, Bringelly	Local	Indirect: Visual impact.
SA4	Mount Pleasant homestead 3 Shannon Road, Bringelly	Local	Indirect: Visual impact, impact to ambience of site.
SA5	Bringelly Public School group 1205 The Northern Road, Bringelly	Local	None
SA6	Wilmington Reserve 17 Jamison Street, Luddenham	Local	Indirect: Visual impact, impact to ambience of site
SA7	Luddenham Public School The Northern Road, Luddenham	Local	Indirect: Visual impact, impact to ambience of site.
SA8	Lawson's Inn Lot 2 DP 623457, Luddenham	Local	Indirect: Visual impact, impact to ambience of site.
SA9	McGarvie Smith University Farm 124 Elizabeth Drive, Badgerys Creek	Local	Indirect: Visual impact, impact to ambience of site.
SA10	Brick cottage 21-55 Campbell Street, Luddenham	Local	Indirect: Visual impact, impact to ambience of site.
SA11	Luddenham Road alignment	Local	Indirect, direct: Visual impact, impact to southern alignment of Luddenham Road following Elizabeth Drive realignment
SA12	Weatherboard cottage 3065-3067 The Northern Road, Luddenham	Local	Indirect: Visual impact, impact to ambience of site.

ITEM No.	Name and Location	Heritage Significance	Type of Impact
SA13	Weatherboard cottage 3075 The Northern Road, Luddenham	Local	Indirect: Visual impact, impact to ambience of site.
SA14	Luddenham Progress Hall 3091-3095 The Northern Road, Luddenham	Local	Indirect: Visual impact, impact to ambience of site.
SA15	Luddenham Uniting Church and cemetery 3097-3099 The Northern Road, Luddenham	Local	Indirect: Visual impact, impact to ambience of site.
SA16	St James Anglican Church and cemetery 3101-3125 The Northern Road, Luddenham	Local	Indirect: Visual impact, impact to ambience of site.
SA17	Showground 428-452 Park Road, Luddenham	Local	Indirect: Visual impact, impact to ambience of site
SA18	Shadforth Monument Greendale Road, Greendale	Local	None
SA19	Private dwelling (former St Marks) Greendale Road, Greendale	Local	None
SA20	Greendale Roman Catholic Cemetery Greendale Road, Greendale	Local	None
SA21	Vertical slab dairy Lot 10, Adams Road, Badgerys Creek	Local	Indirect: Visual impact, impact to ambience of site.
SA22	Evergreen homestead Off Derwent Road, Bringelly	Local	Indirect: Visual impact, impact to ambience of site.

Table 2 Heritage Items near the airport

Aboriginal cultural heritage values also contribute to the visual context of the airport site and more broadly to the local area. Badgerys Creek was a focus for past Aboriginal occupation and contains a relatively high predicted subsurface occurrence of stone artefacts and archaeological deposits. Two identified items on the site comprise a modified tree (site ID B40) and a sandstone outcrop with grinding grooves (site ID B120) which are both located in close proximity to Badgerys Creek. (Navin Officer Heritage Consultants, 2015). Other sites existing within the airport site and more broadly in the Western Sydney region are likely to continue to be displaced as a result of urbanisation

Management of the Aboriginal heritage items and values currently present at the airport site may assist in reducing the visual impacts of the airport development. Both can be effected through the maintenance and improvement of the natural vegetation structure in the riparian zone along Badgerys Creek and where possible, along other property boundaries and creek lines.

4.0 Visual Impact Assessment

The visual impact assessment of the proposed airport involves the identification of the visual catchment and key representative viewpoints, the sensitivity of the selected viewpoints and assessment of their visual impact.

Potential visual impacts were identified following review and consideration of the Airport Plan and the Draft Construction Planning Report (GHD, May 2015) for both the airport construction and operation. Indicative layouts for the Stage 1 and longer term development found in the Airport Plan provided information on the general arrangement and location of airport facilities.

Indicative information on maximum building heights for items such as the terminals and car parks was back calculated from the maximum permissible heights identified from the obstacle limitations surfaces for the airport which governs the protection of the airspace from protrusions. In lieu of specific information on building heights, the parameters used in this assessment are expected to be very conservative.

4.1 Visual Catchment

The visual catchment of a site is the extent of the landscape that can be viewed from the site and, by extension, the extent of locations from which the site can be seen. Landscape vegetation, land use and landform all play large roles in determining the visual catchment.

An initial desktop survey was undertaken to identify and consider possible representative viewing points from which the proposed airport may be visible. Field surveys were then conducted to ‘ground truth’ the desktop survey. Ground truth means to check and confirm decisions made in the desktop survey by visiting locations and confirming that the conclusions are generally as anticipated.

A Visibility Envelope is a map, usually digitally produced, showing areas of land within which a development is theoretically visible. For this study, two maps were generated for areas within a 10 kilometre radius of the airport based on the maximum allowable structure heights within the airport site as defined by the obstacle limitations surface (OLS) for both the Stage 1 area and the longer term development. The purpose was to get a better understanding of the potential visibility of the airport development from the surrounding areas and to inform selection of representative viewpoints for analysis. The OLS defines limits to which structures or objects may project into the airspace to ensure the safety of aircraft and includes both onsite and offsite elements.

Figures 4 and 5 provide indicative visibility envelope maps for the Stage 1 and longer term airport developments. They show the potential visual catchment based on existing topography and the maximum allowed building heights of key buildings and structures on the site such as the airport control tower, terminal buildings and other major structures based on the Stage 1 and the longer term master plans for airport development. Each visibility envelope map gives an indication of potential views in the short and longer term helping to inform the selection of representative viewpoints for assessment.

The visibility envelope is a guide of potential views only and does not take into consideration other factors such as existing structures in the surrounding areas, trees or vegetation such as in forested areas of the Blue Mountains that may block or prevent views of the airport.

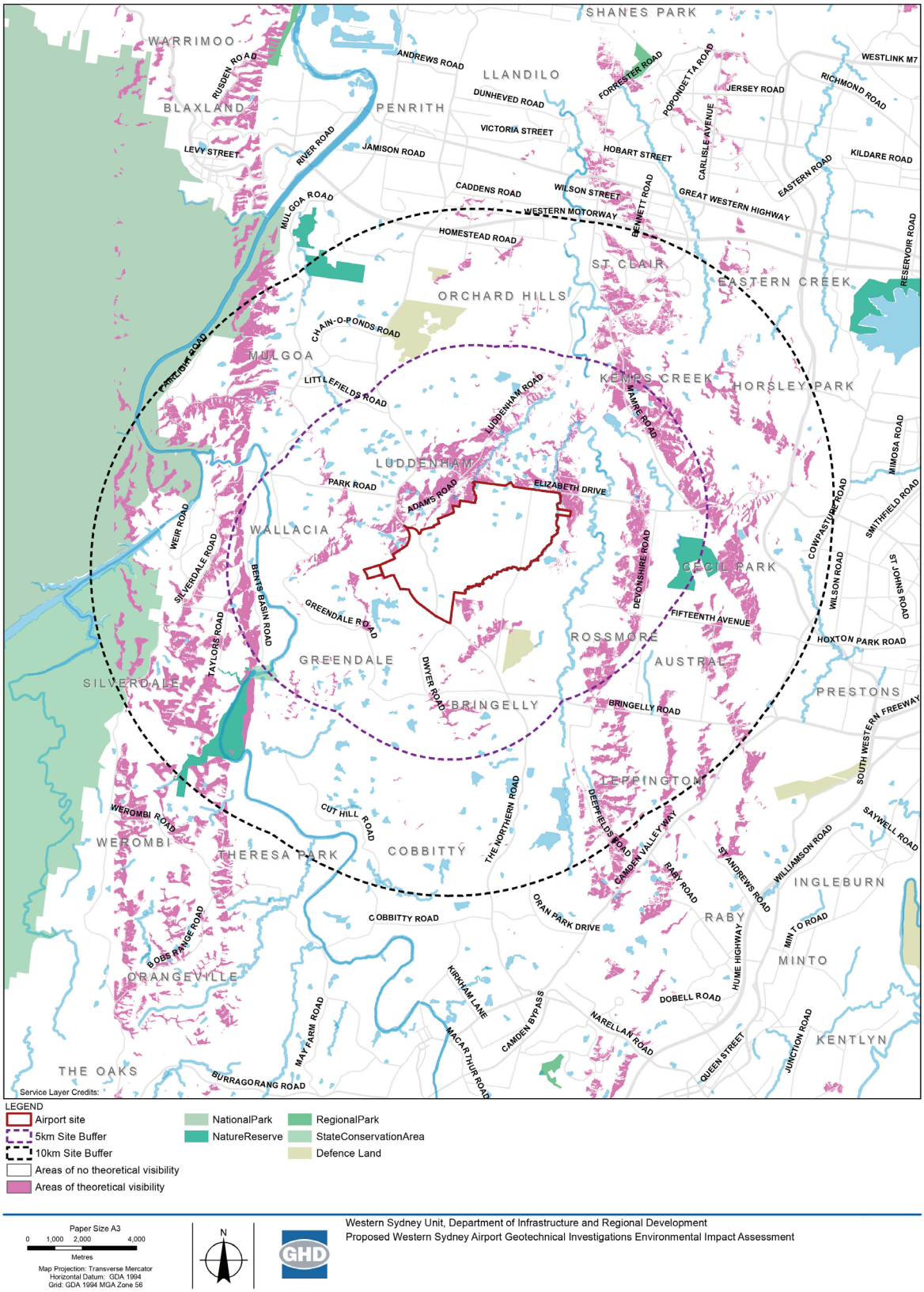


Figure 4 Visibility Envelope - Stage 1 Airport Development

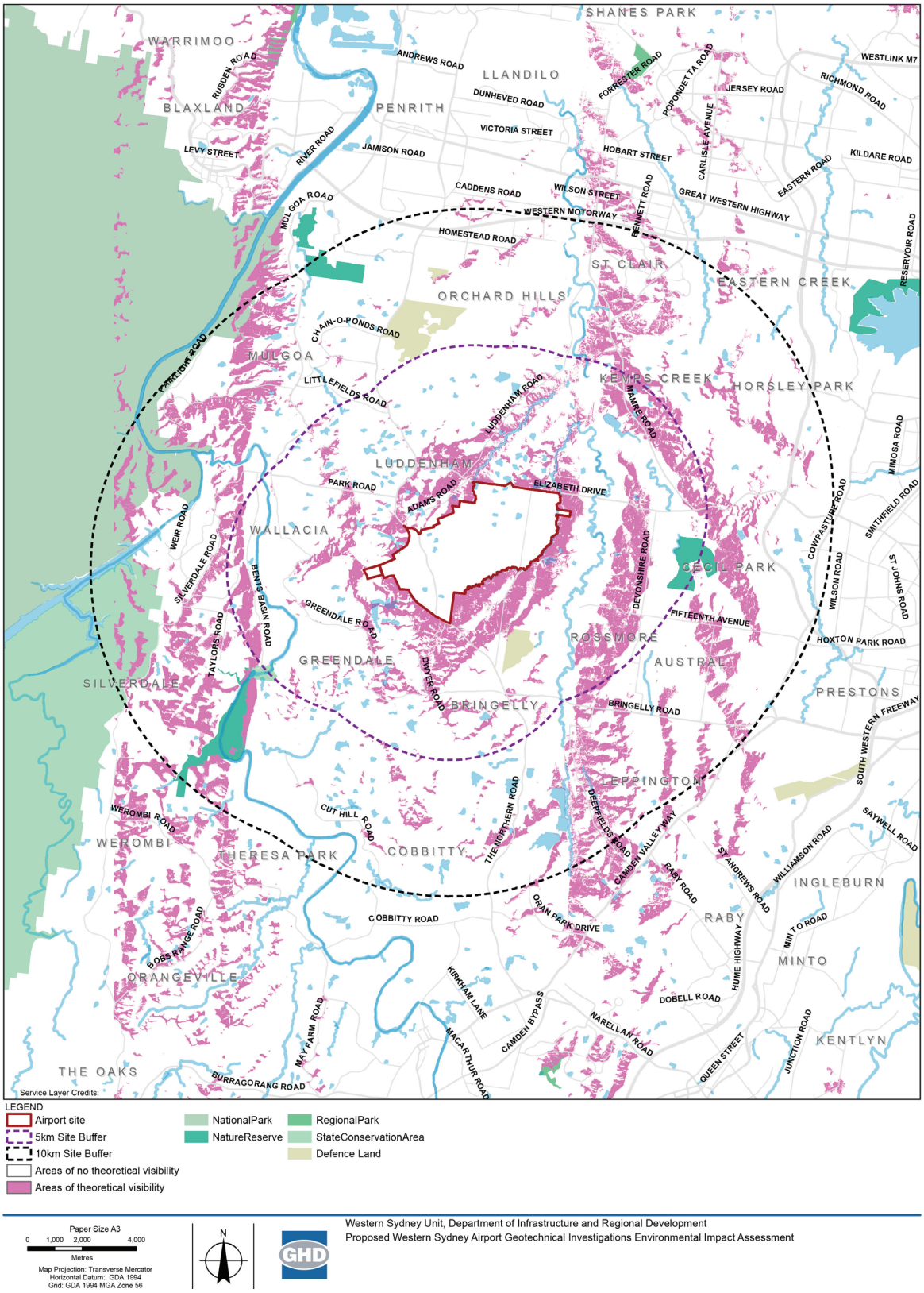
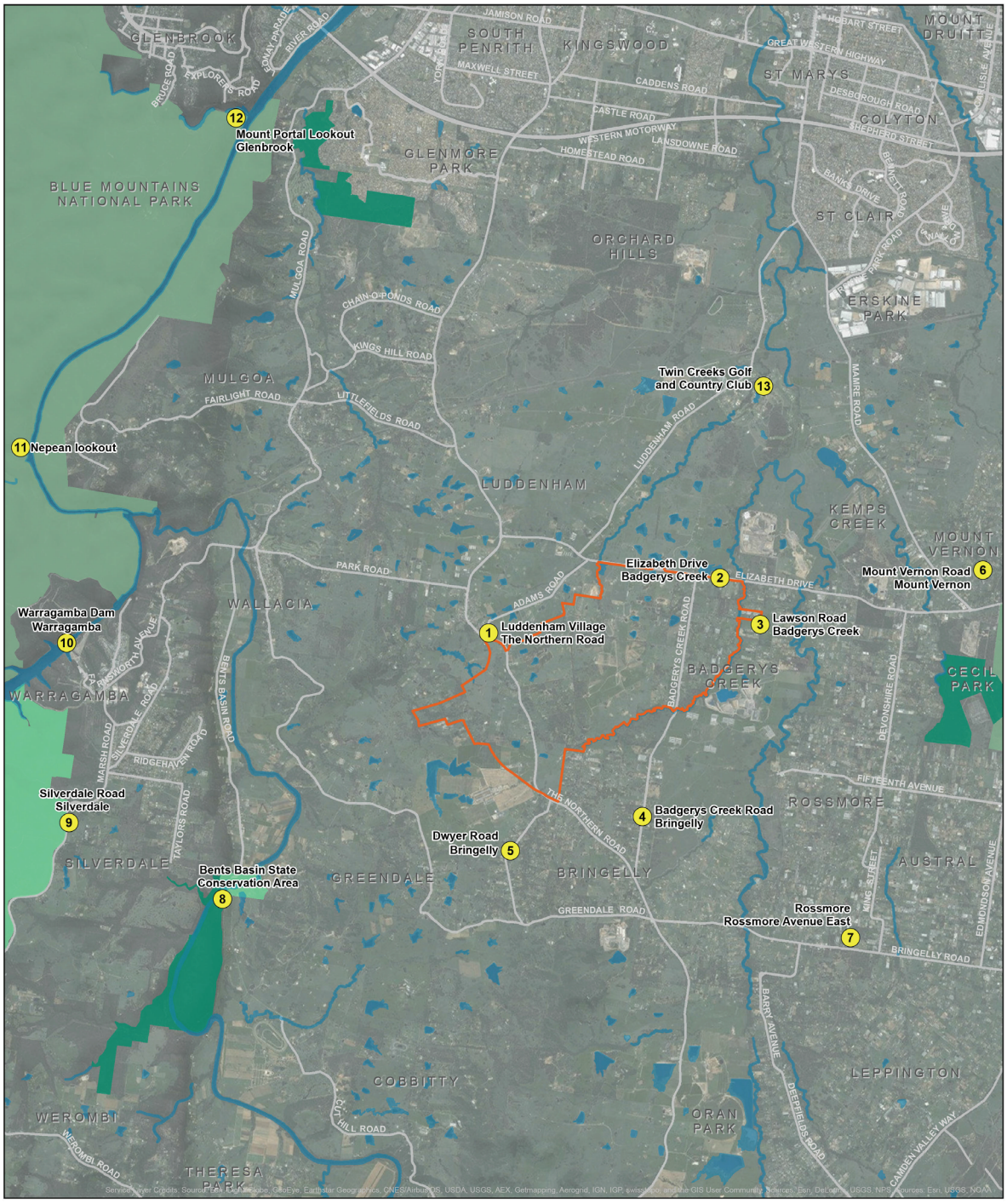


Figure 5 Visibility Envelope - Longer Term Development

4.2 Selection of representative viewpoints

The viewpoints selected in this assessment are intended to represent a range of typical views found within the area. Figure 6 shows the location of the selected view points from which assessments of visual impacts are made in Section 4.3.

The selected viewpoints are considered to represent locations where a reduction in visual amenity would have some visual impact either because of: the duration of the view (such as views from residential areas), the importance of visual amenity to the experience of the location (such as recreational areas) or where there are large numbers of potential viewers (such as busy roads).



LEGEND

Viewpoints
Badgerys Creek site boundary
Waterways
NationalPark
NatureReserve
RegionalPark
StateConservationArea
Roads

Paper Size A3
0 0.75 1.5 3
Kilometres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Western Sydney Unit, Department of Infrastructure and Regional Development
Proposed Western Sydney Airport Geotechnical Investigations
Environmental Impact Assessment

Job Number 21-24265
Revision A
Date 20 Jul 2015

Viewpoint location plan

FIGURE 6 Selected Representative Viewpoints

Table 3 summarises the location of selected representative viewpoints shown in Figure 6 and indicates the relative heights of the viewpoints and their distance to the airport control tower which is the tallest structure located near the centre of the airport.

View point No.	Location	Height (approx) (metres above sea level)	Approx distance to the airport control tower	Area Type
1	Luddenham Village, east of The Northern Road	100-105	3 kilometres	Commercial & residential area
2	Elizabeth Drive, Badgerys Creek	65-90	2 kilometres	Road
3	Lawson Road, Badgerys Creek	60-65	3 kilometres	Rural residential & agricultural area
4	Badgerys Creek Road, Bringelly	60-75	2 kilometres	Rural residential & agricultural area
5	Dwyer Road, Bringelly	105	5 kilometres	Rural residential
6	Mount Vernon Road, Mount Vernon	80	7 kilometres	Rural residential
7	Rossmore, Rossmore Avenue East	90	7 kilometres	Rural residential
8	Bents Basin State Conservation Area	45	10 kilometres	Recreational area
9	Silverdale Road, Silverdale	210	13 kilometres	Rural residential
10	Warragamba Dam, Warragamba	155	12 kilometres	Recreational area
11	Nepean lookout, Glenbrook	115	13 kilometres	Recreational area
12	Mount Portal Lookout, Glenbrook	150	14 kilometres	Recreational area
13	Twin Creeks Golf and Country Club	45-50	6 kilometres	Recreational and residential area

Table 3 Relative Heights and Offsets of Representative Viewpoints from the Airport

4.3 Assessment of Selected Viewpoints

The extent of visual impact of the airport is largely determined by the visual prominence of the elements proposed, the extent the proposal reduces pre-existing views, and number of visual receivers likely to be impacted by any change in the visual landscape character of the site post development.

In making a judgement about what is a significant or high impact, the following points were taken into consideration:

- The sensitivity to changes in views and visual amenity;
- The effects on visual receivers at recognised and important public viewpoints; and
- Large-scale changes which introduce new, non-characteristic, discordant or intrusive elements into a view.

There will be three general types of visual impacts created by the airport.

1. Temporary views of construction activity.
2. Permanent views of the airport site and associated infrastructure.
3. Ongoing views of aircraft taking off and/or landing.

The assessment also considers the visual impact coinciding with different stages of the proposed development including:

- Construction phase – Temporary construction activities associated with the Stage 1 development and indicative activities associated with construction of the longer term airport development;
- Stage 1 - Operational airport at opening with one runway, airport control tower, terminal and facilities; and
- Longer term development – Operational airport including two runways, airport control tower, and expanded terminal and facilities.

The assessment of permanent visual impacts associated with the Stage 1 development as well indicative impacts associated with the longer-term development on the representative viewpoints are summarised in Table 4 below. Due to the long term nature of the airport development, it was decided not to assign visual impact ratings for the longer term.

A separate assessment of the impacts of construction activities, aircraft operation and operational lighting can be found in section 4.5.

Table 4: Assessment of Selected Viewpoints

	Viewpoint 1 - Luddenham Village
Stage 1	**SENSITIVITY = High-Moderate** The viewpoint is representative of views from the Luddenham commercial and residential area. Views to the south and west will be dominated by the airport development and boundary fence in the foreground. There is assumed cultural value placed on the existing rural landscape by local residents where visual amenity is important and where residents and workers will be subject to long duration views. **MAGNITUDE = High-Moderate** The existing ridge line south of the Luddenham residential area will assist in restricting views directly south from residents however airport development along the western boundary will likely be partially or directly visible by residents and workers. Viewing distance is approximately one kilometre from the western end of the runway and there will be views of aircraft taking off or landing. Furthermore, there is little visual capacity of the surrounding rural landscape to absorb the airport development. **VISUAL IMPACT** The likely visual impact from this location is *Moderate-High* due to there being a noticeable reduction in the amenity of existing views from airport development and aircraft.
Longer term (indicative)	**SENSITIVITY** It is expected that the character of the broader area is expected to change from rural to more urbanised with the development of the Western Sydney Employment Areas particularly to the north and east of Luddenham, the upgrade of The Northern Road and Elizabeth Drive and future implementation of the M12 motorway. In this context, the sensitivity of viewers will decrease over time. **MAGNITUDE** There will be an increased visual prominence through the expansion of the airport terminal complex, the additional second runway, maintenance, cargo, commercial and car parking facilities. There will likely also be an increased amount of aircraft taking off and landing from the second runway and overall increase in air traffic in general.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 2 - Elizabeth Drive, Badgerys Creek
Stage 1	**SENSITIVITY = Moderate** The viewpoint is representative of views from drivers and passengers of vehicles using Elizabeth Drive. Views are brief however are at relatively close distance to the northern areas of the airport and runway. **MAGNITUDE = High** The existing landscape character within the airport site will be highly modified with landform changes and removal of the existing vegetation. The scale and nature of the airport site development during operation will be noticeable to visual receivers with views of airport features and boundary fence in the foreground. Aircraft will be similarly prominent as flights are directed over Elizabeth Drive from the eastern end of the airport runway based on current flight path information. **VISUAL IMPACT** The likely visual impact from this section of Elizabeth Drive is regarded as *Moderate-High* due to there being a noticeable reduction in the amenity of the surrounding views from the airport development and aircraft.
Longer term (indicative)	**SENSITIVITY** Minimal increases to sensitivity could be expected to occur with higher road traffic levels over time. **MAGNITUDE** The context of the view will change over time with areas north of Elizabeth Drive expected to be developed as part of the WSEA development and future implementation of the M12 motorway, however it is likely the aircraft will become more prominent due to expected increases in aircraft movements over Elizabeth Drive.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 3 - Lawson Road, Badgerys Creek
Stage 1	**SENSITIVITY = High** The viewpoint is representative of views from rural residences and farms approximately five hundred meters east of the airport boundary. Views to the west of the airport features may be possible from some properties and be dominated by the airport boundary fence in the foreground. There is assumed cultural value placed on the existing rural landscape and the landscape along Badgerys Creek by local residents where visual amenity is important and where residents and workers will be subject to long duration views. **MAGNITUDE = Moderate** The clearance of vegetation and overall extent of change in topography for the operation of the airport is likely to be visible from some properties in this area however it will not be prominent due to the intervening vegetation along Badgerys Creek obscuring much of the airport site. Aircraft movements will be directed to the north over Elizabeth Drive and to the south based on current flight path information. **VISUAL IMPACT** The likely visual impact from this location is *Moderate-High* due to the proximity of viewers to airport development leading to a reduction in the amenity of existing views.
Longer term (indicative)	**SENSITIVITY** It is expected that the character of the broader area will change from rural to more urbanised with the development of the industrial precincts and employment areas as part of the planned South West Growth Centre and the upgrade of key roads such as Lawson Road and Elizabeth Drive. In this context, it could be expected that the Sensitivity of viewers will decrease over time. **MAGNITUDE** There will be a significant increase in the visual prominence of the airport through the expansion of the terminal complex, maintenance, cargo, commercial and long term employee car park and the second airport runway one and a half to two kilometres to the west. Aircraft will be prominent with aircraft movements over Lawson Road and an increased amount of aircraft taking off from the second runway.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 4 - Badgerys Creek Road, Bringelly
Stage 1	**SENSITIVITY = High-Moderate** The viewpoint is representative of views from rural residences and farms one to two kilometres south of the airport boundary. Views to the north of the airport features may be possible from some properties. There is assumed cultural value placed on the existing rural landscape by local residents where visual amenity is important and where residents and farm workers will be subject to long duration views. **MAGNITUDE = Moderate-Low** The clearance of vegetation and overall extent of change in topography for the operation of the airport is likely to be visible from some properties in this area however it will not be prominent due to the intervening vegetation obscuring much of the airport site. Aircraft will be visible as flights are directed in a north-south direction approximately one kilometre to the east of Badgerys Creek Road based on current flight path information. **VISUAL IMPACT** The likely visual impact from this location is *Moderate* due to there being a reduction in the visual amenity of the view.
Longer term (indicative)	**SENSITIVITY** It is expected that the character of the broader area will change from rural to more urbanised with the development of the industrial precincts and employment areas as part of the planned South West Growth Centre and the upgrade of key roads such as Bringelly and The Northern Road identified in the Western Sydney Infrastructure Plan. In this context, the sensitivity of viewers would be expected to decrease over time. **MAGNITUDE** There will be a significant increase in the visual prominence of the airport through the expansion of the terminal complex, maintenance, cargo, commercial and other airport facilities as well as a second airport runway. There will likely also be an increased amount of aircraft taking off and landing from the opening of the second runway and overall increase in visible aircraft with the aircraft movements over Badgerys Creek Road on an east-west flight path orientation.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 5 - Dwyer Road, Bringelly
Stage 1	**SENSITIVITY = High-Moderate** The viewpoint is representative of views from rural residences approximately two kilometres south of the airport boundary. There is assumed cultural value placed on the existing rural landscape by local residents where visual amenity is important and where residents will be subject to long duration views. **MAGNITUDE = Moderate-Low** Views to the north of airport features during its operation are unlikely due to existing vegetation and topography. Aircraft will be visible both day and night as aircraft movements are directed in a north-south direction approximately two kilometres to the east of Dwyer Road based on current flight path information. **VISUAL IMPACT** The likely visual impact is *Moderate* due to there being a general reduction in the visual amenity from aircraft.
Longer term (indicative)	**SENSITIVITY** The sensitivity of this view would be expected to increase as a result of increases in the overall number of visual receivers over time. **MAGNITUDE** Increased development south of the airport as part of the planned South West Growth Centre and the upgrade of key roads such as Bringelly Road and The Northern Road as identified in the Western Sydney Infrastructure Plan will further reduce the relative prominence of the airport.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 6 - Mount Vernon Road, Mount Vernon
Stage 1	**SENSITIVITY= High-Moderate** The viewpoint is representative of views from rural properties at elevations higher than Badgerys Creek approximately five kilometres from the airport boundary. Some properties have broad views of areas to the west and possibly of the Blue Mountains beyond. Sensitivity is derived from the assumed cultural value placed on the existing rural landscape by local residents where visual amenity is important and where residents will be subject to long duration views. **MAGNITUDE = Moderate** Airport features such as the control tower as well as aircraft taking and landing will likely be visible. Views of some areas within the airport site however may be partially screened by vegetation and topography depending on the elevation and aspect of individual residences. The overall landscape has some capacity to absorb views of the development given the views consist of an existing modified landscape character. Aircraft may be seen but at a distance of over four kilometres based on current flight path information. **VISUAL IMPACT** The likely visual impact is *Moderate-High* due to there being a noticeable reduction in the amenity of the view from the airport development and aircraft.
Longer term (indicative)	**SENSITIVITY** It is expected that the character of the broader area is expected to change from rural to more urbanised with the development of the Western Sydney Employment Areas particularly to the north of the airport and the upgrade of Elizabeth Drive and future implementation of the M12 motorway. In this context, the sensitivity of viewers will decrease over time. **MAGNITUDE** There will be an increased visual prominence of the airport through the expansion of the terminal complex, the additional second runway, maintenance, cargo, commercial development and car parking facilities. There will likely also be an increased amount of aircraft taking off and landing from the second runway and overall increase in air traffic with the flight paths from the second runway orientated in a northwest direction over the Mount Vernon Area.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 7 - Rossmore, Rossmore Avenue East
Stage 1	**SENSITIVITY = Moderate** The viewpoint is representative of views from rural residential and agricultural properties approximately seven kilometres to the airport boundary. Properties in this area of Rossmore are at elevations higher than Badgerys Creek with some having broad views toward the west and northwest. The visual sensitivity of this location is derived from it being a residential and agricultural area, where visual amenity is important and where residents and workers are subject to long duration views. **MAGNITUDE = Low** Changes to the landscape including vegetation clearance, earthworks and new structures such as the control tower and terminal will result in a noticeable change in the view and a reduction in visual amenity. The view however is filtered by local vegetation. Aircraft movement will be visible in the sky at a distance of over five kilometres based on current flight path information. VISUAL IMPACT The likely visual impact on this view is regarded as *Moderate-Low* due to there being a minor reduction in the amenity of the view from the airport development.
Longer term (indicative)	**SENSITIVITY** It is expected that the character of the broader area will change from rural to more urbanised with the development of the industrial precincts and employment areas as part of the planned South West Growth Centre and the upgrade of key roads such as Bringelly Road identified in the Western Sydney Infrastructure Plan. In this context, the sensitivity of viewers would be expected to decrease over time. **MAGNITUDE** There will be an increased visual prominence of the airport through the expansion of the terminal complex, the additional second runway, maintenance, and cargo, facilities in the southern half of the airport site. There will likely also be an increased amount of aircraft taking off and landing from the second runway and overall increase in air traffic with the flight paths from the second runway orientated in a northwest direction over Bringelly Road, Rossmore based on current flight path information.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 8 - Bents Basin State Conservation Area
Stage 1	**SENSITIVITY = Moderate** Some visual sensitivity is derived at this location from the importance of visual amenity due to its use as a State Recreation Area by visitors and staff. Visitor numbers will fluctuate seasonally and are only temporary. At night the location will have a higher degree of sensitivity due to the nature of use as an overnight recreation use. **MAGNITUDE = Low** There are no direct views of the airport features however visual receivers are able to see aircraft in the sky from a distance of approximately two kilometres based on current flight path information. **VISUAL IMPACT** The likely visual impact is *Moderate-Low* due to there being only a minimal perceivable reduction in visual amenity from aircraft.
Longer term (indicative)	**SENSITIVITY** The location is expected to remain a State Recreation Area and it is assumed that there is significant value placed on the natural landscape by visitors. Additional recreation activity could be expected in the future. In this context, an increase of sensitivity is expected. **MAGNITUDE** There would be no direct views of the airport features however aircraft will be more prominent with the location of a flightpath over the recreation area and an expected increase in air traffic having a greater degree of visual impact.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 9 - Silverdale Road, Silverdale
Stage 1	**SENSITIVITY = Moderate** The visual sensitivity of this location is derived from it being an elevated, rural residential area with broad expansive views over surrounding areas, where visual amenity is important and where residents are subject to long duration views. Residences are located approximately 10 kilometres from the airport boundary. **MAGNITUDE = Low** Vegetation clearance for the airport will result in a change in the view and a reduction in visual amenity in the vicinity of this view, particularly from houses that have may have an unobstructed view of the Badgerys Creek landscape. The new runway and airport features will be visible from some residences however limited in others depending on the aspect, topography and vegetation. Visual impacts from aircraft are possible due to the southwest-northeast alignment of the flight path approximately two to three kilometres to the south based on current flight path information. **VISUAL IMPACT** The likely visual impact is *Moderate-Low* due to there being a noticeable reduction in the amenity of views to residences.
Longer term (indicative)	**SENSITIVITY** The sensitivity of this view would be expected to be similar as the number of viewers and the duration of the views is unlikely to change. **MAGNITUDE** Further development of the areas both north and south of the airport will alter the existing visual landscape as currently seen from this area from rural/semi-rural to increasingly urbanised. This change to a more urban environment will likely result in a decrease in the sensitivity of visual receivers in this area. The overall landscape will have greater capacity to absorb views with the expected urbanisation of areas north and south of the airport. After the opening of the second runway, views of aircraft will be more prevalent and closer to viewers based on current flight path alignment thus having a greater degree of visual impact.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 10 - Warragamba Dam and Recreation Area
Stage 1	**SENSITIVITY = High** Visual sensitivity is derived at this location from the importance of visual amenity due to its use as a recreation, educational and historic area. It is assumed that there is significant value placed on both the natural and cultural landscape by visitors and staff. As an operational facility, workers will be subject to long duration views, visitors however are only temporary. **MAGNITUDE = Negligible** There are no direct views of the airport features and aircraft will not be prominent at a distance of approximately five kilometres from the recreation areas and visitors centre. **VISUAL IMPACT** The likely visual impact is *Negligible* due to there being little or no perceivable reduction in visual amenity.
Longer term (indicative)	**SENSITIVITY** Increased recreational visitors over time will increase the visual sensitivity. It is unlikely that its use or function will change or that development will occur in the immediate surrounding area. **MAGNITUDE** There are no direct views of the airport features and aircraft however there will be increased aircraft at a distance of approximately three kilometres to the north and five kilometres to the south from the recreation areas and visitors centre based on current flight path information.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 11 - Glenbrook Nepean Lookout
Stage 1	**SENSITIVITY = High-Moderate** Visual sensitivity is derived from this location being one of the closest elevated positions to the west of the airport site at approximately eleven kilometres and within the Blue Mountains area. It is assumed that there is significant recreational and cultural value placed on the natural landscape and bush setting by park users. Viewer times may be of a long or short duration and tend to fluctuate seasonally. **MAGNITUDE = Low** Direct views of airport features are prevented by topography and vegetation and views of aircraft may be possible at a distance of over three kilometres based on current flight path information. **VISUAL IMPACT** The likely visual impact is *Moderate* due to there being perceived reduction in visual amenity from the visibility of aircraft in a natural landscape.
Longer term (indicative)	**SENSITIVITY** The value placed on the visual qualities of the natural landscape at this location would be expected to remain or possibly increase over time. Visitors to the lookout would also be expected to increase thereby slightly increasing the level of sensitivity. **MAGNITUDE** There are no direct views of the airport features however due to the realignment of the flight paths, aircraft will be seen directly overhead based on current flight path information therefore in this context thereby increasing the magnitude rating.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 12 - Mount Portal Lookout
Stage 1	**SENSITIVITY – High-Moderate** This is an elevated lookout 12 kilometres northwest of the airport site within the Blue Mountains offering broad regionally significant views over western Sydney on a clear day to the south and west. Visitors may stay for short or long durations and fluctuate seasonally. It is assumed that there is significant recreational and cultural value placed on the landscape by visual receivers. **MAGNITUDE = Negligible** Landform and vegetation in the foreground will largely prevent views of the airport features to the south. There is capacity of the landscape to absorb views of the airport development due to broad landscape views of the existing developed areas to the south and east. Views of aircraft are possible at a distance of more than ten kilometres. **VISUAL IMPACT** The likely visual impact is *Negligible* due to there being little or no perceived reduction in visual amenity.
Longer term (indicative)	**SENSITIVITY** Increased population and visitation of the lookout would be expected to increase use and therefore visual sensitivity, however it is also expected that the character of the areas within the broader views will change from rural to more urbanised with the development of the Western Sydney Employment Areas particularly to the north between the airport and lookout. **MAGNITUDE** The visibility of airport features is unlikely to change however, based on current flight path information, the alignment of flight paths will bring aircraft at a closer distance to the lookout and an increase in aircraft that will create a greater visual impact and reduce visual amenity.

Table 4: Assessment of Selected Viewpoints (continued)

	Viewpoint 13 - Twin Creeks Golf and Country Club
Stage 1	**SENSITIVITY = High-Moderate** Twin Creeks is located approximately six kilometres to the northeast of the airport boundary. The sensitivity of this view relates to its use as a country club and recreational and social hub with a presumed high level of use as well as a residential estate. Many views therefore would be of a long duration. **MAGNITUDE = Moderate-Low** Existing vegetation and landform prevent direct views of airport features however aircraft movements are prominent both day and night with the flight path positioned over the golf club and oriented on a north-south alignment. **VISUAL IMPACT** The likely visual impact is *Moderate* due to there being a general reduction in the visual amenity from aircraft.
Longer term (indicative)	**SENSITIVITY** The Twin Creeks Golf and Country Club is likely to perform a similar role however development of the residential estate is expected to continue thereby increasing visual sensitivity. **MAGNITUDE** There are no direct views likely of the airport features however visual receivers will be affected by an increased number of aircraft with more visual effect due to increased air traffic with flight paths positioned over the golf club and oriented on a north-south alignment based on current flight path information.

4.4 Flight Paths

Preliminary flight paths indicate that aircraft may be directed over a range of sensitive areas including residential and rural-residential areas, recreational areas and national parks creating visual impacts beyond the airport site. Aircraft will be visible as they fly overhead as well as when they pass through views towards the site. Both views of aircraft however are temporary and will be at varying distances and heights and will therefore have different effects on the receiver.

It can generally be assumed that arriving and departing aircraft, the further an aircraft is from the airport, the higher it will be and therefore less visually prominent. Furthermore, airport operational patterns, although generally consistent, will vary depending on wind conditions and other operational factors.

Many aircraft approaching and departing Sydney (Kingsford Smith) Airport currently fly over the Blue Mountains. Aircraft arriving and departing from the proposed airport would add to the existing density of flights over the Blue Mountains and be at lower altitudes, compared to aircraft using Sydney (Kingsford Smith) Airport. Consequently, aircraft approaching and departing the proposed airport would be more visible and audible to residents and visitors.

The impact of aircraft overflights on the World Heritage and other values of the Greater Blue Mountains is considered separately in the draft EIS.

4.5 Construction

Construction of the Western Sydney Airport will result in substantial changes to the landscape primarily through major earthworks and removal of existing vegetation. The presence of construction plant, equipment, stockpiling areas and storage areas will also have a temporary visual effect.

Construction activities are generally divided between site preparation and aviation infrastructure. Major construction activities consist of the early development work such as security fencing, topsoil stripping and stockpiling, construction of access roads and services and establishing temporary site facilities.

An summary of the likely visual impacts during construction of the Stage 1 development follows in Table 5.

Table 5: Summary of Construction Impacts from Selected Viewpoints

Viewpoint	Analysis
1. Luddenham Village	Views of the construction of the airport in the northern areas of Stage 1 are likely from some areas in Luddenham and could include fencing, earthworks, plant and equipment therefore a perceived loss of visual amenity is expected. In the longer term, construction activities will be concentrated in the southern portion of the site and further away from viewers therefore visual impacts would be expected to be less.
2. Elizabeth Drive, Badgerys Creek	Views of the Stage 1 construction of the airport in the northern areas of Stage 1 are possible at close distance as well as views of construction vehicles accessing the site from Elizabeth Drive therefore a perceived loss of visual amenity is expected. In the longer term, construction areas in the southern portion of the site are further away from the viewer however there may be commercial development near Elizabeth Drive therefore similar or potentially slightly lower visual impacts could be expected.

Viewpoint	Analysis
3. Lawson Road, Badgerys Creek	In Stage 1, views of the construction of the airport in the northern areas including fencing, earthworks, plant and equipment may be possible however could be filtered by existing vegetation. Views of construction areas in the longer term around the eastern and southern edges of the site will likely be possible from some properties meaning the anticipated visual impacts would likely remain at a similar level as Stage 1.
4. Badgerys Creek Road, Bringelly	Views of the construction of the airport such as fencing and earthworks in Stage 1 may be possible but are likely filtered or blocked by vegetation and/or topography. When longer term development occurs, construction areas will be in the southern portion of the airport site and closer to the viewer therefore a greater impact is possible.
5. Dwyer Road, Bringelly	Views of the construction of the airport In Stage 1, may be possible but are likely filtered or blocked by vegetation and/or topography. When longer term development occurs in the southern airport areas, construction activity will be closer to visual receivers and therefore expected to have a greater visual impact.
6. Mount Vernon Road, Mount Vernon	Broad views of the construction of the airport in the northern areas of Stage 1 are likely from some areas in Mount Vernon and could include earthworks, plant and equipment therefore some loss of visual amenity is expected. Views of the construction of the airport in the southern areas in the longer term are at a greater distance but would likely be of a similar extent as Stage 1 due to the extent of views of the overall airport area.
7. Rossmore Avenue East, Rossmore	Broad views of the construction of the airport in the northern areas of Stage 1 are possible and could include earthworks, plant and equipment therefore some loss of visual amenity is expected. Longer term views of the construction of the airport in the southern areas would likely be of a similar extent as Stage 1 due to the extent of views of the overall airport area.
8. Bents Basin State Conservation Area	Views of the construction of the airport in either the Stage 1 or longer term are prevented by existing topography and vegetation.
9. Silverdale Road, Silverdale	Broad views of the construction of the airport in the northern areas of Stage 1 are possible but from a distance of approximately 10 kilometres therefore some loss of visual amenity is expected. Longer term views of the construction of the airport in the southern areas would likely be of a similar extent as Stage 1 due to the extent of views of the overall airport area.
10. Warragamba Dam and Recreation Area GBMWHA	Views of the construction of the airport in either the Stage 1 or longer term are prevented by existing topography and vegetation.
11. Glenbrook Nepean Lookout	Views of the construction of the airport in either the Stage 1 or longer term are prevented by existing topography and vegetation.
12. Mount Portal Lookout	Views of the construction of the airport in either the Stage 1 or longer term are prevented by existing topography and vegetation.

Viewpoint	Analysis
13. Twin Creeks Golf and Country Club	Views of the construction of the airport in either the Stage 1 or longer term are unlikely as they may be inhibited by existing topography and/or vegetation.

4.6 Lighting and skyglow effects

Lighting impacts

A review of lighting impacts from the proposed airport was conducted by a specialist consultant (Lighting, Art and Science 2015). The Airport Plan provides an indicative concept design of how an airport may be developed. The actual details of the design will only become known once an airport lessee company is in place and they submit building control approvals under the *Airports Act 1996.* As such, a preliminary assessment of lighting impacts has been based on information from the Civil Aviation Safety Authority (CASA) Manual of Standards (MOS) and the Australian Standard AS4280: *Control of the obtrusive effects from outdoor lighting* provides a likely performance specification for any lighting which is likely to be implemented. These have been used alongside the Airport Plan and the previous Operational Lighting Impacts Assessment (O'Hanlon Design Pty Ltd, 1998) to inform this preliminary assessment. It is noted that there are some limitations in applying AS4280 to this application and for the purpose of the visual impact assessment.

The CASA MOS Part 139 provides guidance regarding the design of airfield lighting including cyclic or flashing lighting and also the approach and runway lighting at the airfield. The CASA MOS regulates the light above the horizontal plane for lights within proximity of the runways to limit confusing lighting and glare for the pilots. The MOS does not however address the obtrusive effects of the lighting, however as the majority of the lighting is aimed into the sky, the obtrusive effects are likely to be minimal but the contribution to skyglow thus needs to be considered. Skyglow is the brightening of the night sky above our towns, cities and countryside.

There are two main lighting categories that need to be considered: airfield lighting and infrastructure lighting. Regarding airfield lighting, consideration in this assessment has included the effect of runway and approach lighting, the aerodrome beacon light and taxiway lighting. Taxiway lighting will have low intensity and will therefore have a negligible effect beyond the airport boundary.

The runway and approach lighting are assumed to comprise high intensity flashing lights which have a controlled beam width in both the horizontal and vertical planes and direct their peak intensity towards the sky. To be affected by these lights, a sensitive receiver would need to be in a location within a horizontal angle of 15 degrees of the axis of the runway, at the end of the runway and in an elevated position. To protect the airspace around the airport, and particularly in line with the approach and departure routes, building close to the end of the runway and along its axis will not be allowed. Based on the site inspection and the topography of the area, it is not considered that there are any locations where the beam of the approach lighting would be visible.

Similarly for runway lights, as the fittings are ground mounted, the lower angles will also be shielded by the topography of the ground and therefore it is not expected to be visible from surrounding residences with the exception of residences along the southern section of Badgerys Creek Road. There will be virtually no awareness of the lights unless there is fog.

The aerodrome beacon light is designed to produce the peak intensity between 2 and 8 degrees above the horizontal plane. In addition, there is no requirement for light below 1 degree above the vertical plane. There will therefore be a fall-off in intensity below 1 degree. As the position of the beacon is elevated, it will not have significant impact in the area immediately surrounding the airport. Due to the relatively flat terrain, there will be a low level of impact at ground level.

There is an Australian Standard for Obtrusive Light, AS4280: *Control of the obtrusive effects of outdoor lighting* which is not mandatory but is assumed to address the external infrastructure lighting of other airport infrastructure including roads, carparks and apron lighting. As the lighting impact from the airport is assessed at the receiver property boundary and the windows of habitable rooms, the distance from the airport lighting to the boundary should mean that any installations easily comply. Also, the majority of the airport infrastructure will be located between the two runways such that distances to the airport boundary will be substantial.

The impact of skyglow

There are three ways that sky glow will be generated from the airport development:

- Direct light into the sky from the airport lights.
  The main source of direct lighting would be the approach lighting and runway lighting that deliberately direct light into the sky as it is part of their function. Infrastructure lighting would be controlled through lighting design so that no light leaves the fitting above the horizontal plane.
- Light reflected off the ground.
  This is dependent on the illumination level and the reflectivity of the ground. The light levels would be an order of magnitude lower than those used in a sports stadium. A sports stadium generally directs some light above the horizontal to illuminate the ball in the air. The airport skyglow would therefore be much lower than skyglow emitted from a sports stadium.
- Light emitted from the windows of buildings.
  This is a common issue with all buildings. The design of the buildings is not yet known at this stage and this issue can be further considered once more information is made available.

An overall reduction in the potential for lighting impacts, including skyglow, would be achieved if LED apron lighting and external lighting is incorporated into the design. These lights offer high efficacy, low energy consumption and extended life. Their smaller size means that they can be optically controlled to achieve more accurately defined distributions. LEDs are already available in obstruction lights and taxiway lights and emit no light in the horizontal plane so that there would be no spill of light off the site.

4.7 Cumulative Impacts

The proposed airport would likely be a catalyst for the development of future residential, commercial and industrial uses throughout Western Sydney and in particular services that support the proposed airport. Surrounding areas to the north and west of the airport site are designated as future employment areas as part of the BWSEA while areas to the east and south are currently earmarked for future industrial use as part of the SWGC. The proposed airport will accelerate industrial and urban development in these areas..

The BWSEA also indicates potential future primary and secondary roads, an orbital Multi Modal Corridor connection to the north and south and town centres to the south east. Future development of these areas will likely be led by or in response to the growth of Western Sydney generally and subsequent growth of the airport in response to changing demographics and economic opportunities.

Depending on the final design outcomes, these projects may increase the urban character of the area and will have a visual effect. These projects will also change the local rural character of the roads in the district. In particular, realignment of The Northern Road by the New South Wales Government as part of the WSIP may have a more significant visual impact depending on its final alignment and design. It is noted that this work is a New South Wales action outside the scope of this EIS.

Future development of surrounding area as supported by the BWSEA and the SWGC will lead to increased urbanisation over time. This will generally reduce the impact of the airport development, including night time lighting effects, as it becomes a part of the changing urban visual character of the area.

5.0 Mitigation and Management Measures

The following broad management measures are proposed to assist in managing the visual effects of the airport development. These measures take into account the urbanisation that is already underway in many surrounding areas.

5.1 Operation

Retention of Existing Vegetation

A key recommendation of this visual impact assessment is that existing vegetation along the perimeter and wherever possible elsewhere within the airport site should be retained for as long as possible. This would reduce visual impacts and screen views of key airport features. In the longer term it is expected that the entire site will need to be cleared for the airport development with the exception of the riparian zone along Badgerys Creek.

Furthermore, the surviving native vegetation on the airport site has acknowledged Aboriginal cultural value as a remnant of a past cultural landscape and the plant and animal resources it provided to local tribal groups (Navin Officer Heritage Consultants 2015). For this reason, any retention, rehabilitation or reinstatement of native vegetation (and associated habitat values) as part of visual impact management would also complement the maintenance of local cultural landscape values

Revegetation and Planting

Opportunities for revegetation and planting programs along the Badgerys Creek riparian corridor would help to reduce the overall visual impact of the airport and its key infrastructure in both the short and longer term. Local planting strategies should also be considered that assist adjacent landholders to help buffer the impact of the airport development. However any proposed planting and vegetation strategies need to be cognisant of the hazards posed by potential regional bushfires and should therefore not materially add to existing risk levels of the airport development.

Revegetation within the Badgerys Creek riparian zone, and elsewhere where possible, should aim to re-establish vegetation communities that currently exist on the site or in the Cumberland Plain region. Landscape species could utilise native plant species identified as components of Cumberland Plain Woodland and River-Flat Forest, both of which are endangered ecological communities, and potentially other regionally significant species.

Aircraft Overflights

As concluded in the 1997-1999 EIS visual impact assessment, there are very limited opportunities to mitigate the visual impacts of aircraft overflights on surrounding areas. The most effective solution would be to modify flight paths to avoid visually sensitive areas within close proximity to the airport. However it is acknowledged that such changes may have important operational, cost and safety implications.

Further, it is expected that the indicative flight paths which form the basis of this EIS would be progressively refined during a detailed design process, prior to the commencement of any airport operations. Any formal change to flight paths may be the subject of a future referral under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act) once detailed design has occurred.

Landform

Where possible, future site levels should integrate with the surrounding terrain as much as possible to assist with the visual assimilation of the airport into the surrounding landscape. Significant and abrupt level changes along the airport perimeter should be avoided wherever possible.

Landscape Features

The airport design should seek to integrate existing landscape features such as Badgerys Creek wherever possible. Badgerys Creek in particular is an important existing asset of both the site and surrounding catchment and there is an opportunity to rehabilitate the creek and thereby benefit an existing natural visual asset.

Perimeter Fencing

Given the extent of construction and security fencing required around the airport site, mitigation measures should seek to diminish its visual impact from surrounding areas, subject to safety and security requirements. The layout of the fencing should also avoid long, straight continuous runs. The finish and colour of the fence should not be reflective or brightly coloured. Planting design can assist by providing a visual buffer such as providing setbacks (2 metres minimum) from the boundary to allow planting. Fencing locations should also aim to avoid sensitive areas such as along Badgerys Creek wherever possible.

Lighting

The indicative concept design in the Airport Plan locates the key airside infrastructure such as the main terminals, carparks and hangers in the middle of the site, south of the Stage 1 runway. It is expected that in the longer term a second runway would be developed on the southern portion of the site, resulting in buildings and facilities being located between the two runways. This enables the rest of the airport to act as a buffer to offsite areas from the impact of infrastructure lighting. There will still be some lighting that is emitted from within those buildings, however this could be limited as the buildings may be relatively low rise depending on their final design.

LED lighting is becoming widely used in external lighting and is gradually being introduced into all lighting applications. The small source size means that they can be optically controlled to achieve accurately defined distributions. Other international airports have recently begun relighting some of their aprons using LED lights. They effectively light the space with good colour rendering. Importantly, LED lights emit no light in the horizontal plane so that there would be no spill off the site,significantly reduce stray light particularly in areas with major infrastructure.

Low angle cut-off fittings should also be considered for use to mitigate the impact of the high intensity approach lighting and runway lighting. These, and any future improvements, should also be considered in the longer term airport development.

5.2 Construction

The following management measures should be considered for implementation during construction of the airport to reduce offsite visual impacts:

- establish sterile cover crops over topsoil stockpiles, bund and surcharge areas;
- maintain the integrity of the surrounding landscape by integrating the levels of the airport earthworks with the surrounding perimeter levels and topography wherever possible to avoid large grade transitions through cutting and filling activities;

- provide adequate measures to maintain existing vegetation wherever possible, particularly along the site perimeter, to ensure vegetation remains healthy or promotes new growth;
- locate construction plant, machinery and vehicle parking areas away from public or sensitive viewing areas;
- locate any night lighting needed for construction away from public or sensitive viewing areas; and
- revegetate site areas no longer in use as soon as possible.

5.3 Residual Effects

There is potential through the implementation of the mitigation and management measures to lessen the visual effects created by the proposed airport development, particularly those during the construction phase. Implementation of vegetation planting around the airport site in combination with the preservation of remnant vegetation will potentially reduce high impact ratings to moderate-high or possibly moderate depending on the extent and success of the planting implementation and the location of the receiver.

As outlined earlier, residual impacts could also be reduced by ensuring that key airside infrastructure such as the main terminals, carparks and hangers are located in the middle of the site where they could be surrounded by the two runways in the longer term, enabling the rest of the airport to act as a buffer from the impact of lighting.

6.0 Summary and Conclusions

The visual impact assessment process has considered the existing landscape character coupled with an overlay of local community sensitivities and cultural associations at selected representative viewpoints. The proposed airport size, scale and character, along with other major infrastructure developments in the region over the next decade, will involve substantial modification of the landscape and the existing rural visual quality to a more urbanised and commercial landscape character.

The existing environment is rural with agricultural and rural-residential properties the most common land use in the vicinity of the airport site. Given these types of land uses, visual impacts for airport operations have been assessed as being moderate-high to high for some of the most proximate areas such as Luddenham and Bringelly.

Further from the airport, areas such as Mount Vernon, Bents Basin State Conservation Area, and the Twin Creeks Golf Club, although having limited or no views of the airport development, will be visually affected by aircraft overflights. They have been assessed as having moderate to moderate-high ratings as these areas are highly sensitive to urban development influences based on their cultural and recreational values.

Areas such as Warragamba Dam and the Glenbrook Nepean Lookout, although at a distance of over 10 kilometres from the proposed airport, are assessed as being a moderate to moderate-high visual impact due to their sensitivity ratings and visual impacts from overflights.

A review of potential lighting impacts concluded that due to the orientation of the runways, location of the key airside infrastructure between the two runways and the overall distance to the boundary, there is unlikely to be any significant lighting impacts on surrounding areas. Those areas which could potentially be exposed are relatively flat and will not have sufficient elevation to be impacted as these lights are generally directed upward towards the approaching aircraft. The 05/23 (north-east/south-west) runway alignment inherently limits the populated areas that could potentially be affected by the approach lighting and runway lighting. The Airport Plan locates key airside infrastructure such as the main terminals, carparks and hangers in the middle of the site.. This means that in the longer term these buildings would likely be in between the parallel runways, enabling the rest of the airport to act as a buffer to offsite areas from the impact of infrastructure lighting. There will still be some lighting that is emitted from within those buildings, however this will be limited as the buildings will be relatively low rise. Both the potential lighting impacts and skyglow could be substantially reduced if LED lighting technology can be incorporated into the airfield design.

A number of mitigation and management measures have been recommended for consideration to reduce the visual impacts of the airport development during its construction, Stage 1 and the longer term development.

These mitigation measures generally consist of utilising locally endemic planting to screen and provide some visual continuity with the surrounding landscape both during construction and operation. Retention of as much of the existing remnant vegetation as possible will help to reduce visual impacts, particularly outside of the Stage 1 construction area, providing some screening of the airport primarily to the south and east. Any additional planting proposed would need to be cognisant of the potential hazards of regional bushfires and aim to not materially increase existing levels of risk at the site.

7.0 References

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VOLUME 4

Appendix P1
Social impact





Department of Infrastructure and Regional Development

Western Sydney Airport EIS

Socio-Economic Impact Assessment

October 2015

Limitations

GHD has prepared this report pursuant to the conditions in the Department of Infrastructure and Regional Development Deed of Standing Quotation (SON2030181), the Commonwealth RFQTS Number 2014/7540/001, the subsequent response accepted and referenced in the relevant Official Order (collectively the “Contract”):

In particular, this report has been prepared by GHD for the Commonwealth (and to the extent expressly stated in the Contract (and for the purposes stated therein) the parties referred to in the Contract (“Other Parties”) and may only be used and relied on by the Commonwealth and the Other Parties in accordance with the Contract for the purpose agreed between GHD and the Commonwealth as set out in the Contract.

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The services and the purpose undertaken by GHD under the Contract in connection with preparing this report were limited to those specifically detailed in the Contract and this report and are subject to the scope limitations set out in the Contract and this report.

Other than as expressly stated in this report to the contrary, the opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

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Executive summary

Purpose

This report presents a Social Impact Assessment (SIA) as part of the Environmental Impact Assessment (EIS) for the proposed Western Sydney Airport (proposed airport).

This SIA seeks to:

- Identify and define the social area of influence (hereafter referred to as the 'study area') including communities and regions likely to be affected by the proposed airport, including the airport site, surrounding communities (local study area), surrounding local government areas that are likely to engage in socio-economic interaction with the airport (referred to as the Western Sydney region) and the wider area of influence (Greater Sydney);
- Develop an appreciation of the existing social, economic and cultural characteristics and dynamics of the communities within the study area to establish a social baseline on which potential social impacts could be predicted;
- Identify potential benefits and impacts of the airport on the study area communities and assess these impacts in terms of the likelihood and consequence of their occurrence; and
- Develop mitigation and management strategies to avoid or minimise potential adverse impacts and maximise benefits to the stakeholders and communities.

Scope of SIA

The SIA investigations are based on the following principal stages of airport development:

- Stage 1 construction - construction activities associated with the Stage Development taking place between 2016 and 2024.
- Stage 1 operation – operation of the proposed airport includes a single runway, air traffic control tower and terminal and facilities capable of handling approximately 10 million passengers annually. For assessment purposes, the draft EIS assumes the proposed airport commences operations in mid-2020s and would reach 10 million passengers in 2030.
- Longer term development – an indicative future stage in the development of the proposed airport, where the airport site is assumed to comprise parallel runways and handling approximately 82 million passengers annually. For assessment purposes, the draft EIS assumes this occurs in 2063.

To understand the existing social environment, a social baseline for both the local study area and Western Sydney region were prepared, with appropriate comparative reference to Greater Sydney. The baseline was prepared through consultation with all 14 local councils included in the Western Sydney region, NSW Government service providers and other relevant organisations. It also included social research including demographic analysis and review of relevant strategic documents. Based on this research, as well as review of other relevant draft EIS technical studies, an assessment of the potential social benefits and impacts arising from the proposed airport was undertaken.

Summary of key socio-economic benefits

The majority of benefits for Western Sydney and Greater Sydney communities as a result of the proposed airport are expected to be related to economic development and employment opportunities. The project would create jobs for many types of workers of various ages, skills and qualifications, contributing to increased incomes across the Western Sydney region. This report's recommendation to develop a local participation plan as part of an Australian Industry Participation Plan would aim to ensure a high level of local and regional community involvement in the construction of the proposed airport. As a catalyst for growth and change in Western Sydney, the proposed airport would stimulate further development in regional and local centres, providing better quality social infrastructure, such as shops, health services, recreation and leisure services. Additionally, the development of training opportunities in the region undertaken by the state government and local governments will encourage innovation to create new small and large businesses supporting the proposed airport development.

When considered with other employment initiatives taking place in the region, the opportunities for positive change and improved socio-economic outcomes for Western Sydney are significant. This transformation is validated by the size of the economic benefits outlined in the economic assessment (EY 2015). The following table presents a summary of the expected key social and economic benefits of the project.

Social and economic benefits	Stage 1 construction	Stage 1 operations	Longer term development
Increased opportunities for local, regional and broader businesses through direct, indirect and induced spending from the proposed airport development.	✓	✓	✓
Increased benefits for other industry sectors such as construction, utilities, trade, transport and services, accommodation, retail, professional services, public administration and tourism.	✓	✓	✓
The value-add from construction of the proposed airport would peak in 2022 with benefits to Western Sydney reaching $450 million, and a further $90 million to Greater Sydney in that year. This represents a cumulative value-add for Western Sydney from Stage 1 construction estimated to be $1.9 billion, with a further $400 million for the rest of Sydney, over the construction period.	✓	-	-
During operations of the proposed airport, the value-add is expected to increase commensurate with passenger movements. In 2031 (roughly aligning with the end of the Stage 1 development), the proposed airport is estimated to generate an additional $205 million in value-add per year across Australia. Of this, $77 million of value –add will be generated in the Western Sydney region. In 2063, the proposed airport would increase value-add in the Australian economy by $5.8 billion. Of this, approximately $1.5 billion would be generated in the Western Sydney region.	-	✓	✓
An increase in average incomes in Western Sydney. By the time the proposed airport is fully operational, average incomes in Western Sydney are expected to increase to just over 95 per cent of the average for Greater Sydney, compared to 90 per cent in 2014.	-	✓	✓

Social and economic benefits	Stage 1 construction	Stage 1 operations	Longer term development
The proposed airport will generate a number of direct, indirect and induced jobs in Western Sydney and Greater Sydney including – • Peaking of construction employment at 758 direct FTE jobs in 2022 in Western Sydney, which corresponds to approximately 3,200 cumulative person-years in Western Sydney over the construction period (from 2016-2024) (EY, 2015) • There would be indirect and induced employment generated for 8,000 person years in Western Sydney over the construction period between 2016-2024 (EY, 2015) • An additional 2,200 person years in the rest of Greater Sydney over the construction period between 2016-2024 (EY, 2015) • A total of approximately 7,500 direct FTE jobs would be required by the end of Stage 1 in 2030 for airport operations. In addition, a further 4,440 FTE jobs are forecast to be generated from commercial activities on business parks on the airport site (EY, 2015) • A total of approximately 61,500 direct FTE jobs would be required in the longer term in 2063 for airport operations. A further 27,150 FTE jobs would be generated from commercial activities from business on the airport site (EY, 2015).	✓	✓	✓
Employment opportunities from the proposed airport will provide work prospects closer to home for the residents of Western Sydney, who otherwise often have long commutes, this will reduce travel times and improve quality of life (e.g. increased time spent with families, recreation and leisure as well as increases in household incomes).	✓	✓	✓
Employment opportunities due to the proposed airport development would contribute to strong population growth of approximately 17,800 persons by 2031 in Western Sydney. The new residents are likely to be younger people attracted to employment opportunities and housing that is affordable compared to other parts of Sydney.	-	✓	✓
Potential increase in tourism to the Blue Mountains recreation areas and related attractions and services due to the close proximity of the airport site.	-	✓	✓

Summary of key social and economic impacts

The construction and operation of the proposed airport would be likely to result in changes to the social amenity and lifestyle of communities both in the vicinity of the airport site, and in Western Sydney more broadly. Expected key social amenity and economic impacts as a result of the proposed airport development are summarised in the table below.

Social and economic impacts	Stage 1 construction	Stage 1 operations	Longer term development
Amenity and lifestyle impacts resulting from construction impacts such as dust, noise, changes to visual amenity, traffic and related health impacts, particularly on communities surrounding the site.	✓	-	-
Noise impacts due to airport ground-based operational noise. These impacts would occur during the daytime and night time and affect dwellings and community infrastructure, particularly in Luddenham, Mulgoa, Wallacia, Badgerys Creek, Bringelly and Greendale.	-	✓	✓
Depending on the operating strategy adopted for the proposed airport, communities that may experience aircraft noise at varying levels during the daytime and night time include areas of Badgerys Creek, St Marys, Erskine Park, Greendale, Silverdale, Horsley Park and parts of Blacktown. Many of these areas (particularly Greendale, Silverdale and Horsley Park) are semi-rural areas where a high value is placed on the amenity provided by a semi-rural lifestyle.	-	✓	✓
Overflight noise and visual impacts may lead to a minor reduction in amenity and enjoyment of recreational areas located in Western Sydney e.g. Bents Basin Conservation Area, Burragorang State Conservation Area as well as the Blue Mountains (Blaxland).	-	✓	✓
Visual amenity impacts for communities close to the site, including Luddenham, Badgerys Creek, Mount Vernon, Silverdale and Rossmore. Views would be permanently changed due to the proposed change in use of the site.	-	✓	✓
Increased emissions from existing conditions but below permissible levels during airport operation for communities close to the airport site including in Luddenham, Wallacia, Mulgoa, Greendale, Badgerys Creek, Rossmore, Mount Vernon, Kemps Creek and Badgerys Creek.	-	✓	✓
Increased traffic on local and regional roads as a result of the airport operations.	-	✓	✓
Changes to air quality due to aircraft emissions could increase the risk of health impacts on communities near the site, particularly in Bringelly, Luddenham, Rossmore and Kemps Creek.	-	✓	✓

Social and economic impacts	Stage 1 construction	Stage 1 operations	Longer term development
The risk of health effects resulting from daytime and night time (sleep disturbance) noise will increase, particularly in areas surrounding the site as a result of airport activities. The risks are highest in Luddenham, Greendale, Bringelly, Rossmore, Badgerys Creek and Horsley Park. The specific impacts from aircraft overflights will be determined by the preferred airport operating strategy following the finalised EIS.	-	✓	✓
There is a potential that there is an increase in aircrafts that may fly over the catchment of the Warragamba Dam and Prospect Reservoir. There is no evidence of impacts from current aircraft emissions on Sydney's drinking water catchment or data available which can be used to assess whether emissions from aircraft operations would result in increased loading of contaminants to surface waters.	-	✓	✓
Overall, there is no discernible negative impact expected on property values, as the anticipated value uplift from land use changes is expected to outweigh any consequence or concern about noise impacts.	-	✓	✓
Changes to land use in Western Sydney due to the proposed airport development and other planned development may result in competition for land and labour and a consequential decline in industry sectors such as agriculture and manufacturing. SIA stakeholder consultations and ABS data show a trend that these industries have been on a decline in Western Sydney.	✓	✓	✓
There may be a minor impact on some businesses who need to hire new staff to replace workers taking up employment at the proposed airport.	✓	✓	✓
The proposed airport employees may choose to relocate to live closer to the future airport, which may increase demand for housing locally in Western Sydney. This may particularly affect socio-economically disadvantaged groups due to issues of housing availability and affordability.	-	✓	✓

Key impact management strategies

The management strategies recommended in this report are based on existing industry practices and stakeholder feedback received during SIA consultation. They are recommended in addition to other specific impact mitigation and management measures contained in other draft EIS technical studies.

The Department of Infrastructure and Regional Development will be responsible for development, implementation and monitoring of the social impact management strategies which are within its control until an airport lease is granted for the proposed airport. Some responsibilities would be devolved to relevant construction contractors, by way of their terms and conditions of engagement. After an airport lease is granted, the airport lessee company will generally be responsible for those strategies that relate to operation of the airport site.

Due to the proposed timeframes of the proposed airport development, it is expected that the associated socio-economic impacts may vary over time, subject to changes outside the control

of the Australian Government. Socio-economic impacts will be monitored over time through ongoing stakeholder engagement with relevant stakeholders, including the NSW Government and local governments. As a result, the management strategies proposed are intended to adapt to these changing conditions and would be reviewed and updated routinely as required.

The socio-economic impact management strategies detailed in the SIA will be finalised subject to a review by the relevant stakeholders during the draft EIS public consultation process.

Key strategies recommended to enhance social benefits and manage adverse impacts would include:

- Developing an overarching local procurement policy to encourage all contractors to give preference to recruitment of a locally based workforce and local suppliers for goods and services. Contractors will be asked to develop a local industry participation plan in accordance with the Australian Industry Participation Plan. Local recruitment services with appropriate training programs will be engaged as required.
- Preparing and following an equal opportunities policy during construction of the proposed airport. Indigenous participation and participation of people with disadvantages will be considered equally in the training and recruitment programs.
- Aligning the Australian Government, NSW Government, and Western Sydney local governments economic and employment policies, strategies and plans to realise the full benefit from the proposed airport and other projects in the Western Sydney region.
- Continue to liaise with relevant agencies that may include local and state government agencies, tourism agencies, agencies responsible for affordable housing, Western Sydney Business Chamber and educational facilities including universities and TAFE, to inform agency planning activities and allocation of funding to programs that may benefit or otherwise be affected by the proposed airport.
- Continuing engagement with key stakeholders through the ongoing WSA Communication and Engagement Strategy and the EIS Community and Stakeholder Engagement Plan. The Australian Government would continue to engage on the proposed airport's development, timeframes and requirements to align development plans and services provision.
- Managing and mitigating community concerns about amenity and health impacts though the detailed WSA Communication and Engagement Strategy and EIS Community and Stakeholder Engagement Plan. Providing timely information to communities whose lifestyle and amenity may be affected will allow them to understand how they may be impacted, prepare for the impacts, and make informed decisions.
- Implementing mitigation and management measures that would also address social amenity impacts as detailed in the relevant draft EIS technical studies including:
  - Aircraft and ground based operational noise assessments;
  - Surface transport and access assessment;
  - Local air quality and greenhouse gases assessment;
  - Landscape character and visual impact assessment;
  - Community health risk assessment; and
  - Regional air quality assessment.

- Finalising, communicating and implementing a proposed noise mitigation policy to address landowner anxiety regarding noise impacts.
- Implementing other mitigation measures that may address community concerns, including measures such as air quality and water quality monitoring within or in the vicinity of the proposed airport.

Terms and abbreviations

Abbreviation	Name
ABS	Australian Bureau of Statistics
AFP	Australian Federal Police
ANEC/ANEF	Australian Noise Exposure Concept/Forecast
ARFFS	Aviation Rescue Fire Fighting Services
APU	Auxiliary Power Units
BWSEA	Broader Wester Sydney Employment Area
CBD	Central Business District
dBA	A-Weighted Noise Level (dBA) – A value representing the loudness of a sound at a specific time, allowing for the differential response of the human ear to sound frequencies
DEC	NSW Department of Education and Communities
DIRD	Australian Government Department of Infrastructure and Regional Development
DPandE	NSW Department of Planning and Environment
EIS	Environmental Impact Statement
EPBC	Environment Protection and Biodiversity Conservation Act 1999
FTE	Full Time Equivalent
GBMWHA	Greater Blue Mountains World Heritage Area
GDP	Gross Domestic Product
GSM	Greater Sydney Metropolitan region – as defined by the ABS Census 2011
GSE	Ground support equipment
GSP	Gross State Product
GVA	Gross Value Added - a measure of income earned from the production of goods and services in the area
IAIA	International Association for Impact Assessment
IO	Input Output Model
KSA	Sydney (Kingsford Smith) Airport
LGA	Local Government Area
MACROC	Macarthur Regional Organisation of Councils
MAP	Million Annual Passengers
NSW	New South Wales
NWGC	North West Growth Centre
PPK	PPK Environment and Infrastructure Pty Ltd

Abbreviation	Name
RAAF	Royal Australian Air Force
RFS	Rural Fire Service
SIA	Social Impact Assessment
SEIFA	Socio-Economic Indexes for Areas
SGS	SGS Economics and Planning Pty Ltd
SLA	Statistical Local Area
SMEC	Snowy Mountains Engineering Corporation Pty Ltd
SWGC	South West Growth Centre
TAFE	Technical and Further Education Institution
UWS	University of Western Sydney
WSA	The proposed Western Sydney Airport
WSEA	Western Sydney Employment Area
WSROC	Western Sydney Regional Organisation of Councils
WSU	Western Sydney Unit, Australian Government Department of Infrastructure and Regional Development

Table of contents

1. Introduction 1
   - 1.1 Background 1
   - 1.2 Purpose of the report 2
   - 1.3 Structure of the report 3
2. Methodology 5
   - 2.1 Overall approach 5
   - 2.2 Detailed methodology 5
3. Review of relevant literature 15
   - 3.1 Strategic planning documents 15
   - 3.2 Review of previous studies undertaken 16
   - 3.3 Review of other relevant airport projects 20
4. Airport site social baseline 23
   - 4.1 Overview 23
   - 4.2 Area and ownership of land 23
   - 4.3 Existing land use 23
   - 4.4 Indicative social characteristics of the community on site and Badgerys Creek 24
   - 4.5 Current relocation process 25
5. Local area and Western Sydney region social baseline 27
   - 5.1 Overview 27
   - 5.2 Summary of economic and employment issues for the Western Sydney region 27
   - 5.3 Summary of lifestyle and amenity issues for the Western Sydney region 29
   - 5.4 Summary of housing and accommodation issues for the Western Sydney region 30
   - 5.5 Regional open space and recreational areas 30
   - 5.6 Summary of Western Sydney future growth 31
   - 5.7 Summary of socio-economic profile of the Western Sydney region 44
   - 5.8 Summary of demographic profile of communities in local study area 44
6. Identification and assessment of socio-economic impacts 47
   - 6.1 Economic benefits 47
   - 6.2 Employment opportunities 47
   - 6.3 Impacts on other industries 49
   - 6.4 Property impacts 49
   - 6.5 Lifestyle and amenity 51
   - 6.6 Demographics 66
   - 6.7 Housing and accommodation 67
   - 6.8 Impacts on social infrastructure 68
   - 6.9 Impacts on emergency services 69
   - 6.10 Summary of socio-economic impacts and assessment 70
7. Mitigation and management measures 79

7.1 Introduction 79
7.2 Regional employment and business development 79
7.3 Stakeholder engagement and complaints management 80
7.4 Planning interventions 80
7.5 Lifestyle and amenity impacts 80
7.6 Summary of social impacts and corresponding management measures 81
8. Conclusions 91
8.1 Summary of key social and economic benefits 91
8.2 Summary of key social and economic impacts 92
8.3 Key impact management strategies 93
8.4 Contribution to economic and employment issues for Western Sydney 94
8.5 Contribution to lifestyle and amenity issues for Western Sydney 95
8.6 Contribution to housing and accommodation issues for Western Sydney 97
9. References 99

Table index

Table 2-1 Proposed Western Sydney Airport development milestones 10
Table 2-2 Likelihood criteria 13
Table 2-3 Consequence criteria 13
Table 2-4 Impact significance matrix 14
Table 3-1 Summary of SIA's for recent airport expansions 21
Table 5-1 Selected demographic indicators for suburbs within the local study area 45
Table 6-1 Assessment of property values by land use 50
Table 6-2 Summary of social impacts and their significance rating 71
Table 7-1 Summary of social impacts and mitigation measures 82

Figure index

Figure 2-1 Airport site and social local study area 7
Figure 2-2 Social study area - Western Sydney region and Greater Sydney region 8
Figure 4-1 Former Badgerys Creek Primary School 24
Figure 4-2 Badgerys Creek Park 24
Figure 5-1 Priority growth areas for Sydney from A Plan for Growing Sydney (West Central Subregion) 32
Figure 5-2 Priority growth areas for Sydney from *A Plan for Growing Sydney (West Subregion)* 33

Figure 5-3 Priority growth areas for Sydney from *A Plan for Growing Sydney (South West Subregion)* 34
Figure 5-4 Location of the Western Sydney Employment Area 36
Figure 5-5 Greater Macarthur Investigation Area....38
Figure 5-6 Greater Parramatta to Olympic Peninsula Priority Urban Renewal Area 39
Figure 5-7 Sydney Metro network 40
Figure 5-8 Locations of new roads and upgrades as part of the Western Sydney Infrastructure Plan....42
Figure 5-9 Investigation corridor for the proposed Outer Sydney Orbital 43
Figure 6-1 Social infrastructure and residences potentially affected by worst case operational noise envelope in 2030(combined 05 and 23 operational strategy) 56
Figure 9-1 Greater Blue Mountains World Heritage Area 204
Figure 9-2 Western Sydney Parklands 208

Appendices

Appendix A – Preliminary scoping of social impacts and benefits
Appendix B – Western Sydney population and demographic analysis report
Appendix C – Review of Strategic Planning Documents
Appendix D – Badgerys Creek community profile
Appendix E – Western Sydney region - community profiles
Appendix F – Summary of regional open space and recreation areas
Appendix G – Social profiles of representative local communities/villages
Appendix H – Social infrastructure impacted by one or more operational noise sources

1. Introduction

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a curfew free basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the site.

On 23 December 2014, a delegate of the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth)(EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the airport will be controlled by the *Airports Act 1996* (Cth). The *Airports Act 1996* provides for the preparation of an Airport Plan which will serve as the authorisation for the development for which it provides.

The Australian Government Department of Infrastructure and Regional Development (DIRD) is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond the initial stage would be managed in accordance with the existing process in the *Airports Act 1996*. This includes a requirement that for major developments (defined in the Airports Act), a major development plan be approved by the Infrastructure Minister following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Purpose of the report

The social impact assessment (SIA) report has been prepared as part of the proposed Western Sydney Airport (referred to as the proposed airport) draft EIS, in accordance with Section 10 of the EIS Guidelines issued in January 2015 by the Department of the Environment. Section 10 of the Guidelines sets out the following requirements:

- The economic and social impacts of the action, both positive and negative, must be analysed. Matters of interest may include:
  - Details of any public consultation activities undertaken, and their outcomes
  - Details of any consultation with Indigenous stakeholders [1]
  - Projected economic costs and benefits of the project, including the basis for their estimation through cost/benefit analysis or similar studies
  - Employment opportunities expected to be generated by the project (including construction and operational phases).
- The economic and social impacts must include impacts at the local, regional and national level.
- Details of the relevant cost and benefits of alternative options to the proposed action, as identified in section 3, should also be included.

To fulfil these requirements, the SIA undertook to:

- Identify and define the social area of influence (hereafter referred to as the 'study area') including communities and regions likely to be affected by the proposed airport
- Develop an appreciation of the existing social, economic and cultural characteristics and dynamics of the communities within the study area to establish a social baseline on which potential social impacts could be predicted
- Identify potential benefits and impacts of the airport on the study area communities and assess these impacts in terms of the likelihood and consequence of their occurrence
- Develop mitigation and management strategies to avoid or minimise potential adverse impacts and maximise benefits to the stakeholders and communities.

The proposed airport would be developed in a number of stages as described in the draft Airport Plan. In line with the scope of the draft EIS, the social impacts associated with the following stages of the development have been considered and addressed in this document:

- Stage 1 construction - initial construction activities associated with the Stage 1 development taking place between 2016 and 2024.
- Stage 1 development – the airport includes a single runway, air traffic control tower and terminal and facilities with 10 million annual passengers (notionally from 2025 to 2030) – this is the action being assessed.

[1] This scope of work was undertaken by Navin Officer (2015) as a component of the EIS Aboriginal Cultural Heritage

- Longer term development – a future stage in the development of the proposed airport, where the airport is assumed to comprise parallel runways and handling approximately 82 million passengers annually. For assessment purposes, the draft EIS assumes this occurs in 2063.

1.3 Structure of the report

The remainder of this report is structured as follows:

- **Chapter 1 – Introduction:** This chapter introduces the project and outlines the purpose and structure of the SIA
- **Chapter 2 – Methodology:** This chapter outlines the approach to the SIA and details the steps undertaken to complete the assessment.
- **Chapter 3 – Review of relevant literature:** This chapter nominates the relevant regional and local plans that are applicable to the study area and presents key findings from the previous EIS studies undertaken for the proposed airport, namely Second Sydney Airport Site Selection Programme Environmental Impact Statement (1985) and Draft Environmental Impact Statement (1997)
- **Chapter 4 and 5 – Social baseline:** These chapters provide a high level overview of the existing environmental values of the study area relevant to the social aspects. This includes results of any desktop assessments and stakeholder consultations where applicable (as detailed in the relevant Appendices).
- **Chapter 6 – Impact assessment:** This chapter examines the potential socio-economic impacts associated with construction, Stage 1 operations and the longer term development of the proposed airport.
- **Chapter 7 – Mitigation and management measures:** This chapter outlines the proposed mitigation strategies to be implemented to manage the potential socio-economic impacts.
- **Chapter 8 – Conclusions:** This chapter presents a conclusion to the report and presents recommended next steps.

2. Methodology

2.1 Overall approach

The overall approach to this SIA has been guided by practices developed by the International Association for Impact Assessment (IAIA); specifically the *International Principles for Social Impact Assessment 2003* (Vanclay, 2003) and *Social Impact Assessment: Guidance for Assessing and Managing the Social Impacts of Projects* (Vanclay F, et al, 2015). According to these principles, social impacts are changes to:

- People's way of life – that is, how they live, work, play and interact with one another on a day-to-day basis
- Their culture – that is, their shared beliefs, customs, values and language
- Their community – its cohesion, stability, character, services and facilities
- Their environment – the quality of their physical environment including air, noise, water, soil and hazard or risk
- Their physical safety - their access to and control over resources
- Their health and wellbeing – including physical, mental and social wellbeing and not merely the absence of disease or infirmity
- Their personal and property rights – particularly whether people are economically affected, or experience personal disadvantage which may include a violation of their civil liberties
- Their fears and aspirations – their perceptions about their safety, their fears about the future of their community, and their aspirations for their future and the future of their children
- Their economic environment – including employment and business development opportunities or loss of certain employment opportunities.

The SIA includes impact assessment for potential future impacts that may be caused by the construction and operation of the Stage 1 development as described in Part 3 of the draft Airport Plan as well as the potential impacts associated with the indicative longer term development. Many of these impacts have been assessed in the draft EIS in technical studies on: biodiversity, air quality, noise, water, community health, property values, land use and planning, transport and access, Aboriginal heritage and European and other heritage. The SIA has considered the outcomes of these studies to understand and interpret the social implications.

2.2 Detailed methodology

In accordance with this framework, the following key activities were undertaken to complete the SIA:

- Literature review, including reviewing relevant project information and other project documentation
- Study area definition , determining an area of influence for potential impacts through a preliminary understanding of study area characteristics, identifying relevant stakeholders, and scoping of the project related social benefits and issues
- Developing the social baseline for the project area (airport site) and the regional baseline with reference to a wider area of influence

- Identifying and assessing social benefits and impacts
- Developing the management and mitigation strategies for potential social impacts.

Specific tasks performed under each of the above are detailed in section 2.2.

2.2.1 Literature review

A detailed review of a number of key project documents, strategic policy documents and case study examples was undertaken. This included review of the EIS guidelines and legislative framework, the proposed Western Sydney Airport EIS project documents, previous studies undertaken for the proposed airport and examples of socio-economic studies undertaken for other similar airport projects, strategic plans and community plans for the study area. The literature reviewed is outlined in section 3.

2.2.2 Study area definition

This stage included a number of activities that determined the scope, spatial boundaries and limitations of the SIA. These activities are detailed below.

The construction and operations activities related to the proposed airport will generate social, economic and cultural interactions with surrounding regions and communities. To enable effective identification and assessment of socio-economic impacts the area of social influence has been categorised into four levels:

- Airport site – this is defined as the area within the airport site boundary (refer to Figure 2-1).
- Local study area – the local study area includes communities in close proximity to the Airport site that may potentially experience most impacts from the proposed Western Sydney Airport development (Figure 2-1). These communities are - Arndell Park, Austral, Badgerys Creek, Bringelly, Chatsworth, Cobbitty, Eastern Creek, Erskine Park, Glenfield, Greendale, Horsley Park, Kemps Creek, Leppington, Luddenham, Mount Vernon, Mulgoa, North St Marys, Orchard Hills, Penrith, Prospect, Rossmore, Silverdale, South Penrith, St Clair, St Marys, Theresa Park, Wallacia, Werombi and Werrington.

Western Sydney region – this is defined as the area and communities which may potentially experience a high level of social interaction with the proposed airport development. The Western Sydney region was identified as a study area in line with the planning regions surrounding the proposed airport as determined by New South Wales (NSW) Government in *A Plan for Growing Sydney 2014*. For the purpose of this SIA the Western Sydney region includes three planning regions and all the local government areas (LGA) within these planning regions, as listed below and shown in Figure 2-2.

  - Sydney South West region – includes Liverpool, Fairfield, Camden, Campbelltown and Wollondilly LGAs
  - Sydney West region – includes Penrith, Hawkesbury and Blue Mountains LGAs
  - Sydney West Central – includes Auburn, Bankstown, Blacktown, Holroyd, Parramatta and The Hills LGAs.



LEGEND

- Airport site
- Local government areas
- Social local study area

Paper Size A3

0 1,300 2,600 5,200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

Job Number	21-24265
Revision	A
Date	01 Sep 2015

Airport site and social local study area

Figure 2-1

Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

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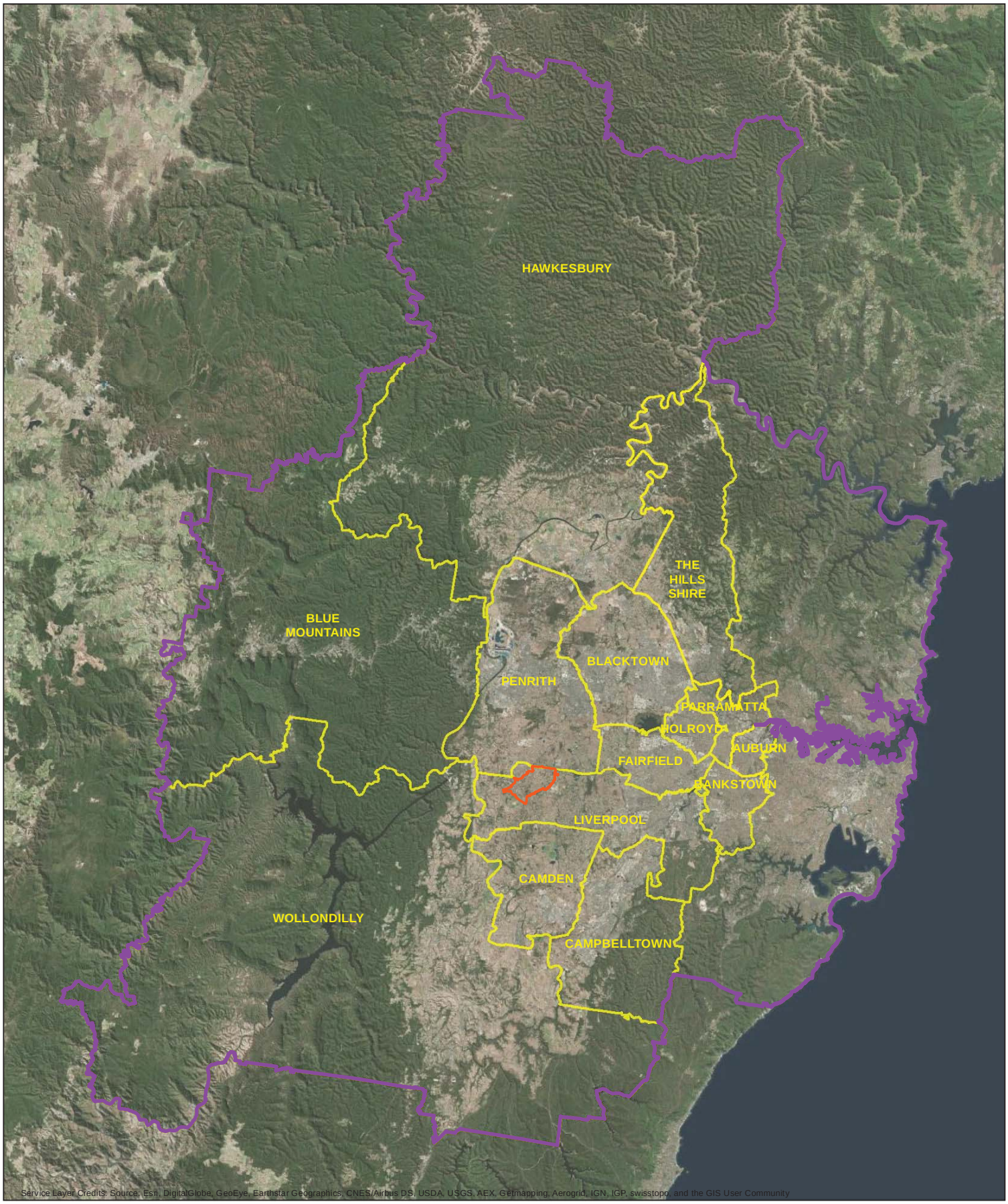
Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:jrichardson



LEGEND

- Airport site
- Greater Sydney region
- Western Sydney region

Paper Size A3

0 4,000 8,000 16,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Western Sydney region
and Greater Sydney region

Job Number	21-24265
Revision	A
Date	31 Aug 2015

Figure 2-2

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Level 15, 133 Castlereagh Street Sydney NSW 2000 **T** 61 2 9239 7100 **F** 61 2 9239 7199 **E** sydmail@ghd.com.au **W** www.ghd.com.au

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Data source: Data source: General Topo - NSW LPI DTDB 2012, Imagery - ESRI 2015 Created by: jrichardson

Greater Sydney – this wider area of influence is anticipated to interact with the propose airport through the provision of some goods, services and workforce. Greater Sydney is based on the Greater Sydney Metropolitan (GSM) region as defined by the ABS Census 2011, and which is detailed in Figure 2-2.

Preliminary community profiles were developed to gain an initial appreciation of the diversity and dynamics within the study area. These profiles were based on desktop research and local knowledge of the GHD SIA team.

2.2.3 Initial identification of potential social benefits and issues

Based on an understanding of the proposed airport development activities, previous EIS studies, and other case studies, a list of potential benefits and impacts relevant to the project was developed to inform the research and consultation. These were identified for each study area (i.e. the project site, the local study area, Western Sydney region, and the wider area of influence) and for the pre-construction, construction and operational phases. The scoping exercise is included at Appendix A. This initial identification of impacts did not preclude the addition of other impacts that were identified during the later stages of the SIA.

2.2.4 Developing the social baseline

A description of the existing social characteristics and community dynamics was compiled to form a basis on which social impacts could be predicted. The existing social environment (also referred to as the social baseline) was developed for the local study area and Western Sydney region with references to the wider area of influence where required.

Data and information for the social baseline were gathered from various sources as listed below:

Existing characteristics

Information has been sourced from:

- Australian Bureau of Statistics (ABS) Census 2011 data;
- websites and publications of local governments in the Western Sydney region;
- NSW Government agencies; and
- where possible the baseline was also supplemented with information from stakeholder consultations (see section 2.2.4), site visits and information from other technical studies.

Population forecasts

The development of the proposed airport occurs over a considerably long period of time. The population of Greater Sydney and Western Sydney is expected to change over this period. To support the impact assessment discussion, this SIA has referred to the demographic projections prepared by SGS Economics and Planning referred to as SGS, 2015 (Appendix B). Demographic projections by SGS, 2015 have been determined for Statistical Local Areas (SLA) within Greater Sydney. In most cases LGA boundaries align reasonably well with SLA boundaries, hence for the purpose of this SIA, projections for SLAs within each of the study area LGAs have been aggregated.

The years for which the population projections have been considered in the SIA broadly align with the key Western Sydney Airport development milestones as specified in section 1.2 and as shown in Table 2-1.

Table 2-1 Proposed Western Sydney Airport development milestones

Project milestone	Year
Construction commences	2016
Construction complete	2024
Operations commence	2025
Stage 1 development – the airport includes a single runway, air traffic control tower and terminal and facilities capable of handling approximately 10 million passengers annually. Further airport infrastructure and facilities expected to be provided after this point to accommodate further airport growth.	2030
Longer term development – the airport is assumed to comprise parallel runways, an air traffic control tower and expanded terminal and facilities capable of handling approximately 82 million passengers annually.	2063

The population projections provided by SGS, 2015 do not align with project milestones for the years 2024 and 2063. Therefore a year close to these milestone years was selected, including:

- 2025 data representative for the project milestone year 2024
- 2030 data representative for the project milestone yea 2030
- 2065 data representative for the project milestone year 2063

Structure of social baseline

The social baseline describes the following community characteristics and issues.

- Community lifestyle, values and aspirations
- Demographic characteristics, including
  - Total population; population trends, growth and forecasts
  - Age and gender profile
  - Family composition
  - Cultural and ethnic composition
  - Employment and unemployment profile
  - Employment by industry and occupation profile
- Housing availability, affordability and costs
- Social and community infrastructure, including:
  - Health services and facilities
  - Community support services
  - Education and training facilities
- Challenges and opportunities within each community.

2.2.5 SIA stakeholder consultations

To satisfy the requirements of the EIS guidelines, stakeholder consultation was integrated as part of the SIA methodology. Face to face and telephone meetings were undertaken from January to August 2015 to consult with a range of stakeholders to:

- Inform and validate the social baseline

- Understand existing opportunities and challenges to support the airport development in communities within the study area
- Identify and discuss perceived and real potential social benefits and impacts arising from the airport development
- Discuss successful examples and lessons learnt with respect to impact management strategies adopted by the stakeholders/communities on past development projects in the area.

The stakeholders consulted during the SIA are outlined below.

Internal stakeholders

- Department of Infrastructure and Regional Development (DIRD)
- EIS stakeholder engagement team
- EIS technical specialists for noise, air quality, community health, hazard and risk, traffic and transport, visual amenity, economic and world heritage studies
- Airport site place manager and property manager.

NSW Government agencies

Consultation took place with staff responsible for service planning at the following agencies:

- NSW emergency services including NSW Police, NSW Fire and Rescue and NSW Ambulance
- NSW Land and Housing Corporation – South Western Sydney and Nepean Blue Mountains District
- NSW Department of Education and Communities
- South West Sydney Local Health District and Nepean Blue Mountains Local Health District (as part of the consultations undertaken for the community health study).

Local government authorities

Consultations took place with staff responsible for social and economic planning/development, development/maintenance of open spaces and recreational areas, and urban planning, at the following councils.

- Auburn City Council
- Bankstown City Council
- Blacktown City Council
- Blue Mountains City Council
- Camden Council
- Campbelltown City Council
- Fairfield City Council
- Hawkesbury City Council
- Holroyd City Council
- Liverpool City Council
- Parramatta City Council
- Penrith City Council

- The Hills Shire Council
- Wollondilly Shire Council.

Other organisations

- Western Sydney Business Chamber
- Catholic Education Office Archdiocese of Sydney.

2.2.6 Identification and assessment of social benefits and impacts

For the purpose of this SIA, social impacts were defined based on the description by Vanclay. F, et al. (2015). This defines social impacts as issues associated with a planned intervention that affect or concern people due to actual or perceived social changes invoked by the intervention. It included any aspect of human life and its environs as long as it is valued or considered important by people who will directly or indirectly experience the change. It should be noted that perceived impacts are as important as actual (measurable) impacts as people may modify their behaviours or experience discomfort simply because of a perceived impact.

To predict social benefits and impacts resulting from the airport development, this SIA adopted the precautionary and uncertainty principles (IAIA, 2003). With regards to the precautionary principle, this means that even though some impacts were not fully confirmed, they were still considered as part of the assessment. By adopting the uncertainty principle, there is recognition that the predicted impacts may change from place to place and people to people over time due to ever changing social processes and as knowledge of these social processes increases.

The predicted impacts were identified based on the social conditions (including trends and forecasts) in the study area at the time when the SIA was undertaken (February – August 2015). It is recognised that the predicted social impacts and their assessment may change with any alterations to the socio-economic and political context or as stakeholder perceptions change over time as more information about the project is available. The social impacts may also change once the airport is in the construction phase, and when it becomes operational.

In light of the variables mentioned above, the process of impact prediction was made robust through data triangulation, where the SIA team used multiple sources of information to identify the social impacts. Impact identification was informed by:

- Targeted stakeholder consultations undertaken during the SIA process
- Airport development information available at the time, social baseline of the study area and the scoping of social issues carried out by the SIA team
- A literature review of social impact assessments of similar projects, community and regional plans for the study area and relevant information/documents shared by stakeholders
- Other technical studies prepared for the proposed Western Sydney Airport draft EIS namely the planning and land use assessment, landscape and visual impact assessment, noise and vibration impact assessment, air quality impact assessment, economic impact report, traffic and transport impact assessment, property values study, Aboriginal heritage assessment, European and other heritage assessment and hazard and risk assessment.

Once the impacts were identified, they were categorised based on the nature of each impact:

- Positive impact/benefits – where the impacted stakeholders would be ‘better off’ or would benefit due to the proposed development
- Negative impacts – where the impacted stakeholders would be ‘worse off’ due to the proposed development.

The positive and negative impacts for the Western Sydney region were further assessed to determine their impact significance, using the 'impact likelihood and consequence' framework explained in Table 2-2, Table 2-3 and Table 2-4.

Table 2-2 Likelihood criteria

Likelihood level	Description
Almost certain Common	Will occur, or is of a continuous nature. It often occurs in similar environments. The event is expected to occur in most circumstances.
Likely Has occurred in recent history	There is likely to be an event on average every one to five years. Likely to have been a similar incident occurring in similar situations. The event will probably occur in most circumstances.
Possible Could happen, has occurred in the past, but not common	The event could occur, but there is no certainty of the occurrence
Unlikely Not likely or uncommon	The event could occur but is not expected. A rare occurrence (once per one hundred years).
Remote Rare or practically impossible	The event may occur only in exceptional circumstances. Very rare occurrence (once per one thousand years). Unlikely that it has occurred elsewhere; if it has occurred, it is regarded as unique.

Table 2-3 Consequence criteria

Consequence category	Social/community/reputation description
Critical Severe, widespread long-term effect	Irreversible changes to social characteristics and values of the communities of interest or the community has no capacity to adapt and cope with change.
Major Wider spread, moderate to long-term effect	A long-term recoverable change to social characteristics and values of the communities of interest or the community has limited capacity to adapt and cope with change. Long-term opportunities emanating from the project.
Moderate Localised, short-term to moderate effect	Medium-term recoverable changes to social characteristics and values of the communities of interest or the community has some capacity to adapt and cope with change. Medium term opportunities emanating from the project.
Minor Localised short-term effect	A short-term recoverable change to social characteristics and values of the communities of interest or the community has substantial capacity to adapt and cope with change. Short-term opportunities emanating from the project.
Negligible Minimal impact or no lasting effect	Local, small-scale, easily reversible change on social characteristics or values of the communities of interest or the community can easily adapt or cope with change. Local small-scale opportunities emanating from the project that the community can readily pursue and capitalise on.

Table 2-4 Impact significance matrix

Consequence	Likelihood				
	Almost certain	**Likely**	**Possible**	**Unlikely**	**Remote**
Critical	Very High	Very High	High	High	Medium
Major	Very High	High	High	Medium	Medium
Moderate	High	Medium	Medium	Medium	Low
Minor	Medium	Medium	Low	Low	Very Low
Negligible	Medium	Low	Low	Very Low	Very Low

The socio-economic impacts on the local study area have been identified and discussed in section 6.2 However because these impacts have already occurred and mitigation measures have already been implemented (e.g. tenancy transition process detailed in section 4.5) prior to the SIA, these impacts have not been further assessed according to the impact significance criteria detailed above.

Because many of the impacts for the wider area of influence will be similar to those for the Western Sydney region, these impacts have not been assessed according to the impact significance criteria detailed above. Instead the impacts have been discussed within the impact assessment for the Western Sydney region.

2.2.7 Social impact management strategies

The social impact management strategies outlined in this report seek to both enhance the benefits for the stakeholders and communities as well as mitigate negative impacts from the airport development. The SIA also draws upon the various draft EIS technical studies for mitigation/management of specific impacts such as noise, air quality, visual amenity, traffic and transport and others as specified in section 7.

Management strategies included in this report were developed using adaptive management principles as there is recognition that impacts may change over time (see section 2.2.6) and that ongoing monitoring of impacts would provide the flexibility to accommodate such changes.

3. Review of relevant literature

3.1 Strategic planning documents

As the proposed airport is located in NSW, the socio-economic context of the study considers NSW Government and local government policies and strategies relevant to the Western Sydney region.

The following plans and strategies were carefully considered.

Regional area plans/strategies

- Western Sydney Infrastructure Plan, DIRD
- A Plan for Growing Sydney, NSW Department of Planning and Environment
- 2014 State Infrastructure Strategy Update, Infrastructure NSW
- Broader Western Sydney Employment Area (WSEA)– Draft Structure Plan, NSW Department of Planning and Environment
- Regional Plan for Sydney, Regional Development Australia
- Future Directions Western Sydney 2030, Western Sydney Regional Organisation of Councils (WSROC)
- Progressing the NSW Economic Development Framework, WSROC
- South West Rail Link Extension Submission, Macarthur Regional Organisation of Councils (MACROC).

Local government plans/strategies

- Auburn City Community Strategic Plan 2013 – 2023
- Bankstown Community Plan 2030
- Blacktown City 2030
- Sustainable Blue Mountains 2025
- Camden 2040
- Creating our Future Together – Campbelltown's Community Strategic Plan
- Fairfield City Plan 2012-2022
- Hawkesbury Community Strategy Plan 2013 - 2023
- Living Holroyd – Community Strategic Plan
- Growing Liverpool 2023
- Parramatta 2038
- Penrith Community Plan
- The Hills Future Community Strategic Plan
- Wollondilly Community Strategic Plan 2033.

Appendix C provides a summary of these key planning documents and details their relevance and implications for this SIA.

3.2 Review of previous studies undertaken

This section summarises the socio-economic issues identified in the previous environmental assessments. It also summarises issues identified in the other reports relevant to the proposed airport development at Badgerys Creek.

3.2.1 Second Sydney Airport Site Selection Programme Environmental Impact Statement - 1985

The 1985 EIS was undertaken by Kinhill Stearns, and considered 10 potential locations for a second airport. The EIS short-listed Badgerys Creek as the 'best' close site and Wilton as the 'best' mid-distance site. These two locations were then evaluated more closely in the EIS.

Socio-economic impacts were discussed in Chapter 9 of the report. The Chapter included a description of the existing socio-economic environment, the likely effects of acquisition of land, and construction and operation of the airport, and environmental safeguards and monitoring programs.

Identified social impacts and benefits

The principal social impacts and benefits identified in the EIS were:

- Noise impacts – including direct noise impacts and effects on property values.
- Impacts on sites with archaeological potential
- Decrease in available agricultural land and associated agricultural activities and production
- Economic effects - including employment opportunities and contribution to the economy
- Regional planning and development including changes to land use at the site and in the surrounding region due to the airport and activities associated with the airport.

Recommended impact mitigation measures

A range of mitigation measures were also identified to address the various socio-economic impacts identified in the study.

In mitigating the impacts relating to land acquisition, the report stated that the Department of Aviation was limited in the ways it could ameliorate the adverse social effects of uncertainty and loss associated with the process of land acquisition. The report made a number of suggestions to minimise the impacts:

- Ensure the Department of Aviation maintained a tight schedule to prepare and exhibit the EIS.
- Ensure public consultation procedures included an information hot line to ensure residents had access to relevant information throughout the processes.
- Provide a lease-back arrangement to residents following the acquisition of their properties by the Government.

The report also identified three key measures to ameliorate noise impacts:

- Source operation controls: improvement in aircraft technology to reduce noise and management of runways and flight paths to minimise the area affected by noise
- Land use controls: creating a Section 117(2) direction under the NSW Environmental Planning and Assessment Act 1979, to restrict powers of councils to rezone land in areas where the ANEF level exceeds 20.

- Building controls: in conjunction with the land use controls, implement building standards and construction techniques to ensure desired indoor sound levels can be achieved.

Following completion of the EIS, the Australian Government proceeded to acquire land at Badgerys Creek for a future airport. The land acquisition process was undertaken in accordance with the mitigation measures recommended in the EIS, including leasing back properties to residents following acquisition to allow property owners to remain in their homes in the interim, if they chose to. Penrith City Council and Liverpool City Council also implemented planning controls to limit development in areas that were identified to be impacted by aircraft noise.

3.2.2 Draft Environmental Impact Statement - 1997

The 1997 EIS was undertaken by PPK and considered three options for an airport located at Badgerys Creek capable of handling up to around 360,000 aircraft movements and 30 million passengers per year. Key issues considered in this study included:

- Aboriginal Cultural Heritage;
- non-Aboriginal Cultural Heritage;
- transport;
- aviation;
- visual and landscape impacts;
- economic and financial costs; and
- social and economic impacts.

The Social and Economic Chapter summarises the detailed findings of *Technical Paper 2 Planning, Land Use and Social Impacts* and *Technical Paper 15 Economics*.

The methodology adopted for the SIA was based on analysis of 1991 Australian Bureau of Statistics Census data and 1995 NSW Department of Urban Affairs and Planning data for 13 LGAs in Western Sydney, with updated information from each Council provided. The SIA considered the character and social cohesion of the communities affected by each option, including community lifestyles, character, activities and interrelationships in terms of use and dependence on facilities and services.

The economic impact assessment was based on an assessment of impacts on employment, businesses, agricultural displacement, property devaluation from noise impacts and displacement of businesses.

Information from other chapters of the EIS was also incorporated including noise, property values, air quality, water, risks and hazards, and results of community consultation undertaken prior to the EIS being publicly exhibited.

Identified social impacts and benefits

Major social impacts and benefits that were considered as part of the SIA included:

- Construction impacts including construction traffic, air quality, vibration, noise, water quality and lighting. Traffic would particularly impact on the ‘peace and quiet of the area’ including disturbance to local schools, and on the character and amenity of land uses adjoining major roads.
- Potential relocation of existing residents living in properties at the airport site, and reordering of future urban release areas.
- Subsequent change in demand for, and potential closure of, community services and facilities.

- Reduction in the ability to use community facilities, particularly open space and recreation facilities located in high noise areas.
- Loss of residential amenity and impact on quality of life, including increased urbanisation of communities in the vicinity of the airport as a result of increases in population and traffic.
- Potential severance impacts including loss of Badgerys Creek community services (e.g. Badgerys Creek Public School, the Post Office and convenience store).
- Provision of road upgrades and new rail lines.

Major economic benefits and impacts that were considered as part of the impact assessment included:

- Demand on-site and off-site for construction employment, as well as indirect positive employment effects on other industries during construction.
- Substantial increases in the level of direct and indirect employment in the Badgerys Creek region over the period to 2016.
- Considerable changes in the structure of local industry towards a greater number of value added services.

Recommended impact mitigation measures

The report did not recommend specific measures to manage social and economic impacts, instead referring to the environmental management measures recommended for the other chapters of the Draft EIS.

Ongoing consultation was also mentioned as an important part of managing social impacts, particularly with the local councils, and the involvement of the community in the development of environmental management plans.

Assessment of Draft Environmental Impact Statement

The 1997 Draft EIS was evaluated by SMEC Australia in an Auditor's Report, released in January 1998. The audit found Technical Paper 2 (Planning, Land Use and Social Impact) was "an inadequate assessment of the issues it was to address". Most of the identified deficiencies related to the assumptions made and conclusions drawn about potential land use and planning impacts, which were not considered to realistically reflect the impact that the airport proposal could have on land use, and therefore related social impacts. The inadequacy of the SIA was considered to be primarily due to the inability to "draw a picture of the urban form once the airport is completed".

The SIA also failed to address issues raised in the EIS Guidelines including impacts on potential Native Title Claimants and impacts on radio and television reception. Other deficiencies included lack of evidence from other similar projects, and of the lack of viable scenarios to assist in quantifying impacts or benefits.

3.2.3 Environmental Impact Statement, Supplement to Draft - 1999

Based on the outcomes of the public exhibition of the Draft EIS and the Audit Report by SMEC, additional work was undertaken by PPK to address the issues raised. Together, the Draft EIS and Supplement Report form the Final EIS.

The supplementary report was structured in the same way as the draft report, including *Part G - Social and Economic Impacts.* The Supplement provides a more detailed assessment of cumulative impacts and specific issues raised during the public consultation process.

Assessment of Supplement to the Draft Environmental Impact Statement

SMEC audited the Supplement Reports in June 1999. The Audit Report found that although in some areas the analysis was brief, in the context of the project the coverage was adequate to identify the principal impacts.

3.2.4 Environmental Assessment Report – 1999

Environment Australia provided an assessment report on the environmental assessment to the Minister for the Environment and Heritage in accordance with the Administrative Procedures of the *Environmental Protection (Impact of Proposals) Act 1974*. The report took into account public comments received.

The report stated that no single environmental issue identified in the EIS or its assessment should lead to a decision that the construction of an airport at Badgerys Creek should not proceed, although the direct cumulative impacts of the construction and operation of an airport would be very substantial for the Western Sydney region. The presence of an airport would act as a catalyst for urban development, and substantial and permanent changes to the character of the area within a 10 to 15 kilometre radius around the airport site would result.

The impacts of aircraft noise was identified as a major environmental issue, and further work was seen to be required to identify the specific impacts of each airport concept design or option. Other impacts of note included increased pollution, health impacts resulting from exposure to noise, traffic volumes and congestion, and impacts on existing communities. Further requirements for strategic planning for road and rail connectivity, community services and health services for Western Sydney were also identified.

Potential benefits included increases in economic activities and jobs, potential increases in land values in many areas, and the provision of better and more comprehensive services and infrastructure.

The report found that the preparation and public review of the EIS was conducted in a manner consistent with the procedures of the Act. Nevertheless, the report stated that there should be limits to the scope of decisions taken following the EIS, particularly regarding which option would be chosen for the new airport.

The environmental assessment report made a number of recommendations to the Minister for action by the proponent and other relevant parties if the Government decided to proceed with construction of an airport at Badgerys Creek. Where relevant, these recommendations were reviewed for consideration in this SIA.

3.2.5 Joint Study on Aviation Capacity in the Sydney Region - 2012

The Joint Study was completed for the Australian and NSW Governments in 2012 to examine:

- Future demand for aviation in the Sydney region.
- How the demand relates to the growth of the population and economic activity in the region.
- How an integrated aviation, surface transport and land development strategy can be developed and implemented over time.

The study provides a brief profile of the existing population, and the proposed growth for Sydney, which indicates that Sydney's South West and North West will experience the greatest rate of population growth. According to the projections used, by 2036 nearly half the population of Sydney will live in Western Sydney. The study also provides an overview of Sydney's economy, which in 2009-10 accounted for almost a quarter of Australia's gross domestic product (GDP) and 70% of the NSW gross state product (GSP).

The report also discusses the role of the aviation industry in driving economic growth, both through creation of jobs in the sector, and flow-on effects for other industries (e.g. retail, tourism), as well as through the facilitation of finance and trade.

Based on the outcomes of the study, a number of recommendations were made to increase the aviation capacity of Sydney, including the need to select a site for a new supplementary airport that could accommodate a full service airport in the long term.

3.3 Review of other relevant airport projects

The proposed airport would be the first new major greenfield airport to be developed in Australia in the last 40 years, and is therefore, relatively unique. It will lead to changes in the socio economic environment of the local area and the Western Sydney region.

Selected comparable case studies have focused on expansions of existing airports. These case studies are relevant as there may be similar impacts with proven mitigation strategies. The case studies reviewed include:

- A Second Runway for Gatwick Airport
- Sunshine Coast Airport Expansion
- Brisbane Airport New Parallel Runway

A summary of the SIA's including the key impacts and mitigation measures are outlined in Table 3-1 below.

Table 3-1 Summary of SIA's for recent airport expansions

Case study name	Date	Location and project description	Key socio-economic issues considered	Suggested management strategies
Second Runway for Gatwick Airport	May 2014	London Gatwick is 45km south of London and the project was to develop a second runway at the existing airport.	• Noise impacts – Annoyance, sleep disturbance, cardiovascular responses, cognitive responses in children • Air quality impacts • Impacts on surface access and local transport networks • Land take • Changes to community facilities • Social capital (i.e. the quality and quantity of social connections in a given population, such as a sense of belonging to the local community) • Employment and income • Access to leisure and economic opportunities overseas.	• Noise insulation and management • Expand the Home Owners Support Scheme to owners of properties whose homes would be newly exposed to medium-to-high levels of noise (66dB), as a direct result of the development. Eligible property owners can require Gatwick to purchase their property for its unblighted value (i.e. if no runway development had been proposed) if Gatwick announces its intention to proceed with construction (having received the necessary consents) • Engagement and communication • Minimise land-take • Supporting sustainable communities • Financial compensation for loss of resources including loss of property, care home, pre-schools, place of worship and other community resources • Relocation of facilities.
Sunshine Coast airport expansion	Exhibited September 2014	The Sunshine Coast Airport is located in Marcoola and the project is to develop a new runway and expand the terminal.	• Potential for change in the demographic structure of communities as a result of economic development attracting people to the region • Impacts on the characteristics of the area due to amenity impacts from construction activities • Indirect impacts on land uses and ownership as a result of growth in aviation and aviation-related commercial uses • Changed use and access to local recreational areas (during operation) and coastal pathways (during construction)	• Environmental management plan and traffic management plan to address impacts during construction • Dredge management plan to address dredge-related activities • Alternative pathways provided for pedestrian access along coast

Case study name	Date	Location and project description	Key socio-economic issues considered	Suggested management strategies
Brisbane Airport parallel runway	Exhibited in September 2007	The airport is located on the north side of Brisbane and will be expanded with a new runway.	• Amenity and lifestyle impacts during construction including air quality, noise, visual pollution, traffic impacts. • Changes to access and movement patterns • Noise and visual impacts from sand transfer operations during construction • Impacts on ecological or community values due to removal of vegetation • Impacts on Indigenous cultural heritage • Impacts on adjacent communities including social infrastructure as a result of overflight noise • Decreased amenity for recreational areas which may impact on users • Community safety or access to the airport by emergency services • Economic benefits for South East Queensland/ Brisbane/Queensland business community including increased investment opportunity, contribution to tourism etc.	• Limit plant operating and best practice noise management during construction, manage construction noise within regulation standards, prepare dust and odour management plan for the duration of the construction phase, implement effective community engagement program to address complaints • Terrestrial flora and flora management plans for construction e.g. Fauna Movement and Animal Welfare Plan • Develop Cultural Heritage Management Plan to minimise harm to Aboriginal cultural heritage • Develop emergency management plan

4. Airport site social baseline

4.1 Overview

The Badgerys Creek social baseline describes the existing environment of the proposed Western Sydney Airport site, located in Badgerys Creek in the Liverpool LGA. The northern boundary of the airport site adjoins the Penrith LGA boundary. The study area is situated about 50 kilometres west-southwest of the Sydney CBD. Badgerys Creek can be accessed from the north via Elizabeth Drive or from the south via The Northern Road, both of which are main roads in this area. Kemps Creek and Luddenham are the closest town centres for Badgerys Creek residents.

4.2 Area and ownership of land

The airport site is around 1,700 hectares in size. The Australian Government acquired the land in the 1980s and 1990s. Since the land was acquired, the Australian Government has been leasing properties to private tenants, and a property management agency has been contracted to manage the properties.

4.3 Existing land use

The main existing land uses, prior to the tenant transition process, as described in the Planning and Land Use Report include:

- 139 residential tenancies ranging in area from approximately one to 40 hectares
- 16 minor agricultural tenancies including market gardens growing cucumber, strawberry, Asian herb and tomato, and livestock farming including a poultry farming, and cattle grazing
- Eight major commercial tenancies including the operator of a shale quarry, a vineyard and a Christmas tree farm
- The former Badgerys Creek Primary School which was closed by the NSW Department of Education and Communities in December 2014 (Figure 4-1)
- Badgerys Creek Park, which is located on Badgerys Creek Road (Figure 4-2)
- Two cemeteries (St Johns Anglican Church and Badgerys Creek Uniting Church)
- A Scout hall located on Elizabeth Drive.

The biodiversity characteristics and transport network on the site has been described in detail in the Planning and Land Use Report.



Figure 4-1 Former Badgerys Creek Primary School



Figure 4-2 Badgerys Creek Park

4.4 Indicative social characteristics of the community on site and Badgerys Creek

Information about tenants has been sourced from information provided to GHD by DIRD and consultations with the property manager and place manager (see section 4.5 below), indicative demographic data was sourced from ABS Census 2011 data for the suburb of Badgerys Creek (refer to Appendix D and Appendix G for detailed social profile of Badgerys Creek community).

Consistent with the semi-rural location of the site and the ABS data for Badgerys Creek, dwellings on the 139 residential tenancies were separate houses. The tenancies included a range of household types, including families with children (both large and small), couples without children, and single households. Tenants were primarily from English speaking backgrounds, with some people from Italian and Maltese backgrounds.

Some tenants were over 65 years of age, a few of which were on pensions or disability pensions. This is supported by the lower rate of labour force participation for Badgerys Creek (49 per cent) compared to the whole of the Liverpool LGA (58 per cent).

Of the 139 residential tenancies, 38 were long term tenants who had been living in the same property for 20 years or more, while five per cent (six tenancies) were original land owners who had been leasing properties on the site since they were acquired by the Australian Government.

The occupations of tenants varied, from those who were self-employed and worked from home, or worked on the land (i.e. agriculture), to professionals, contractors and truck drivers. This is reflected by the employment profile for Badgerys Creek, with the top industries of employment being construction (13.3 per cent), agriculture (9.8 per cent), transport and warehousing (9.2 per cent). The top occupations were managers (18.5 per cent), labourers (16.8 per cent) and technicians and trades (16.8 per cent).

ABS Census 2011 data indicate that Badgerys Creek households had lower incomes compared to the LGA average, with Badgerys Creek having a SEIFA score of 913, indicating a higher level of disadvantage[2].

4.5 Current relocation process

Information about the tenant relocation process was provided to GHD by DIRD in July and August 2015 and supplemented by consultations with the property manager and Place Manager in 2015.

Since taking over ownership of the site, DIRD has acted as a typical landlord, leasing properties to tenants through private lease arrangements, with a property management company dealing with day to day matters such as collection of rent, property inspections and general site maintenance.

The Australian Government is currently in the process of arranging vacant possession of the site in preparation of the development of the proposed airport. Most residential tenants vacated the site by the required date in June 2015, and DIRD is working closely with the property manager and the tenants who require extended vacation dates.

Some agricultural and minor commercial tenants were granted a three month extension until late September 2015 for continued access (but not residential occupancy) based on requests for special consideration. Separate termination strategies have also been developed for the four major commercial tenants on site that take into consideration their individual circumstances.

[2] Based on the SEIFA Score for Advantage and Disadvantage, where a score below 1,000 indicates a higher level of disadvantage.

5. Local area and Western Sydney region social baseline

5.1 Overview

The social baselines for the local study area and Western Sydney region in this section summarises the demographic characteristics, economic characteristics, opportunities and challenges within these areas. This section also includes a summary of key recreational areas in the region and a summary of proposed growth and major transport infrastructure projects in the region.

Detailed socio-economic profiles of each of the LGAs included in the Western Sydney region have been organised in alphabetical order and are presented in Appendix E, as follows:

- Auburn
- Bankstown
- Blacktown
- Blue Mountains
- Camden
- Campbelltown
- Fairfield
- Hawkesbury
- Holroyd
- Liverpool
- Parramatta
- Penrith
- The Hills
- Wollondilly.

5.2 Summary of economic and employment issues for the Western Sydney region

Using the social baseline developed for each of the LGAs (Appendix E), the following broad opportunities and challenges have been identified and considered in this SIA for economic and employment issues in the Western Sydney region.

Opportunities

- Development of employment lands and development of residential precincts bringing new infrastructure to enable population growth
- Investment in education, health sector and aged care opportunities
- Promotion of the agricultural and farming sectors
- Development of local employment initiatives which target service gaps and employment barriers for migrants and refugees.
- Harnessing the increasingly educated population, including university, vocational and trade qualifications
- Encouraging a wider variety of businesses to locate in the area to improve access to services.

Challenges

- Reducing the relatively high rates of unemployment and limited job opportunities, particularly the high rates of youth unemployment
- Finding work for unskilled or semi-skilled occupations, particularly for new migrants and refugees who have low English levels, low skill levels, or skills not recognised in Australia.
- Replacing jobs lost in the decline of manufacturing and trade industries
- Managing the loss of agricultural land and associated industries as a result of development
- Ensuring sufficient jobs, services and facilities and infrastructure are provided in time to meet the needs of a growing population, and to reduce the incidence of long distance commuting (particularly by car).

5.3 Summary of lifestyle and amenity issues for the Western Sydney region

Using the social baseline developed for each of the LGAs (Appendix E), the following broad opportunities and challenges have been identified and considered in this SIA for lifestyle and amenity issues in the Western Sydney region.

Opportunities

- Celebrating the cultural and linguistic diversity to create a unique community identity, with strong connections and networks (e.g. through coordinated activities, public artworks and festivals).
- Engaging young people and providing accessible, youth-specific spaces.
- Implementing health and wellbeing programs which encourage physical activity.
- Providing safe and accessible public transport networks which are functional, accessible and acceptable to the community with designated pedestrian and bike paths
- Highlighting the close proximity to the Greater Blue Mountains World Heritage Area, with its environmental, cultural and recreational significance as a major tourism destination.
- Preserving the rich cultural and built heritage.
- Enjoying the variety of cuisines, cafes, and local businesses that reflect the diverse population.
- Provision and promotion of high quality community facilities including libraries and child care centres which meet the needs of families.

Challenges

- Managing population growth effectively and ensuring new development is supported by transport infrastructure and services to meet community, health, education, economic and recreational needs (social infrastructure).
- Improving community identified issues with transport infrastructure (need to improve frequency and accessibility of public transport services and links between centres and key destinations, roads, parking, accessibility, access afterhours including lighting, pedestrian and cycle facilities and footpaths) to reduce car dependency, traffic and congestion.
- Catering to the ageing population and large proportion of young children requiring high quality health services.
- Addressing concerns around safety in public areas and reducing vandalism.
- Providing services and support to the increasingly culturally diverse community e.g. translation services, support networks.
- Conserving natural, built and cultural heritage in the context of limited resources and responding to increased pressures for change and growth.
- Providing more accessible recreation and entertainment options to encourage a healthier lifestyle.

5.4 Summary of housing and accommodation issues for the Western Sydney region

Using the social baseline developed for each of the LGAs (Appendix E), the following opportunities and challenges have been identified and considered in this SIA for housing and accommodation issues in the Western Sydney region.

Opportunities

- Significant urban revitalisation projects driven from new transport infrastructure construction.
- Housing and land more affordable than other areas of Sydney, leading to new population growth and high numbers of young families.
- Preserving areas of 'rural living' and lifestyle.

Challenges

- Addressing the fall in housing affordability in areas previously known as affordable, and reducing the incidence of housing stress.
- Housing the significant population of newly arrived migrants and refugees, many of whom experience multiple disadvantages e.g. poverty, housing stress, and unemployment.
- Providing affordable housing and a mix of housing types so residents can still live in the area when circumstances change.
- Avoiding and improving pockets of significant socio-economic disadvantage e.g. large social housing areas.

5.5 Regional open space and recreational areas

As the airport site is located on the edge of the Sydney metropolitan area, a number of significant natural areas surround the site and may be impacted by the proposed airport. These areas provide for a range of recreational pursuits and are significant for their natural, cultural and heritage values. They include:

- Blue Mountains National Park and World Heritage Area, including the WaterNSW 'Special Areas' which prevent public access to protect Sydney's drinking water supply.
- Bents Basin State Conservation Area
- Burragorang State Conservation Area
- Gulguer Nature Reserve
- Mulgoa Nature Reserve
- Warragamba Dam
- Western Sydney Parklands (including Nurragingy Reserve, Prospect Reservoir and Nature Reserve, Kemps Creek Nature Reserve).

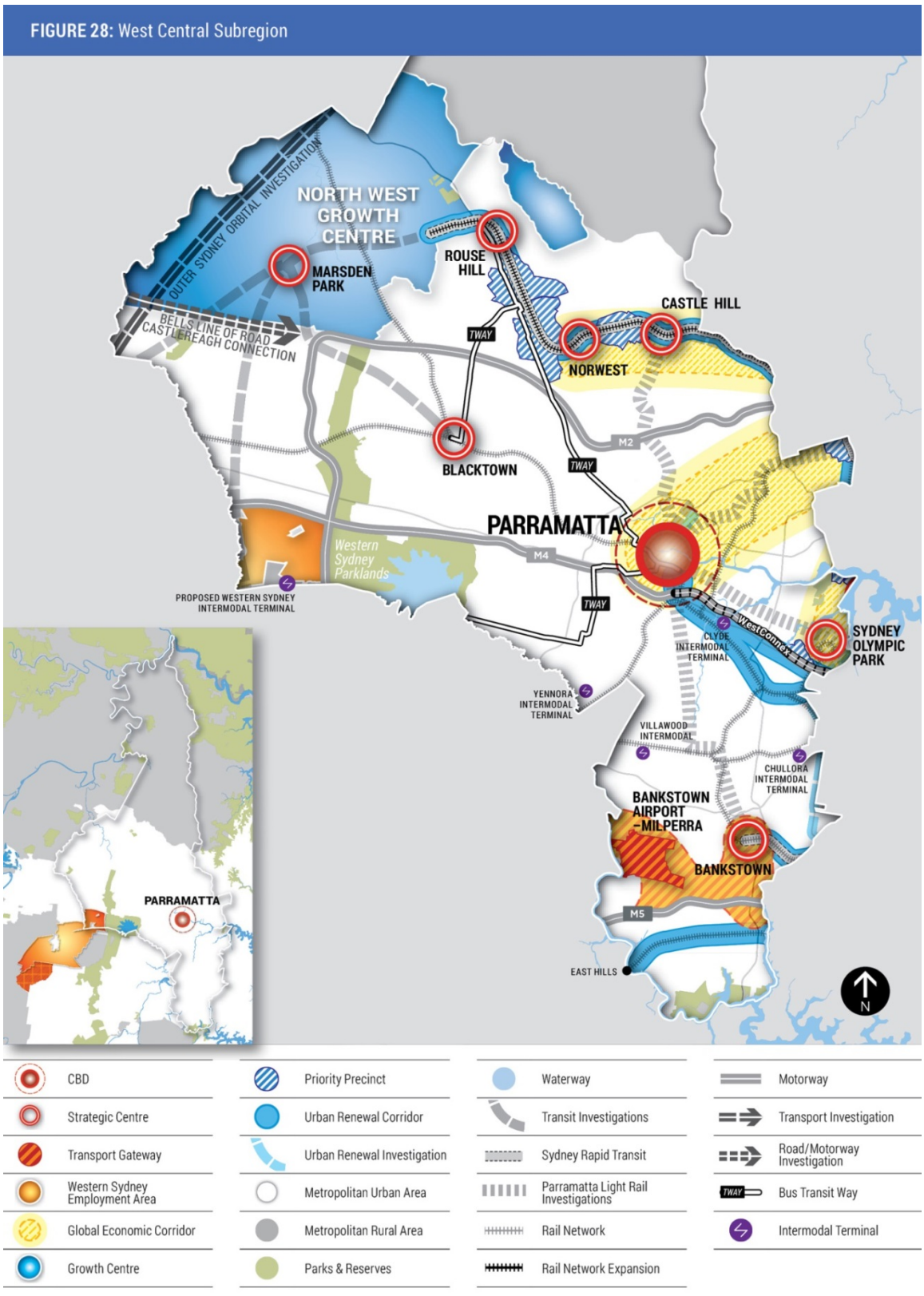
Further information on each of these regional open space and recreation areas is presented in Appendix F.

5.6 Summary of Western Sydney future growth

As highlighted in the strategic documents in section 3.1 and Appendix C, and outlined in section 4, Greater Sydney and Western Sydney region have experienced significant population growth and change, and will continue to do so over the next several decades.

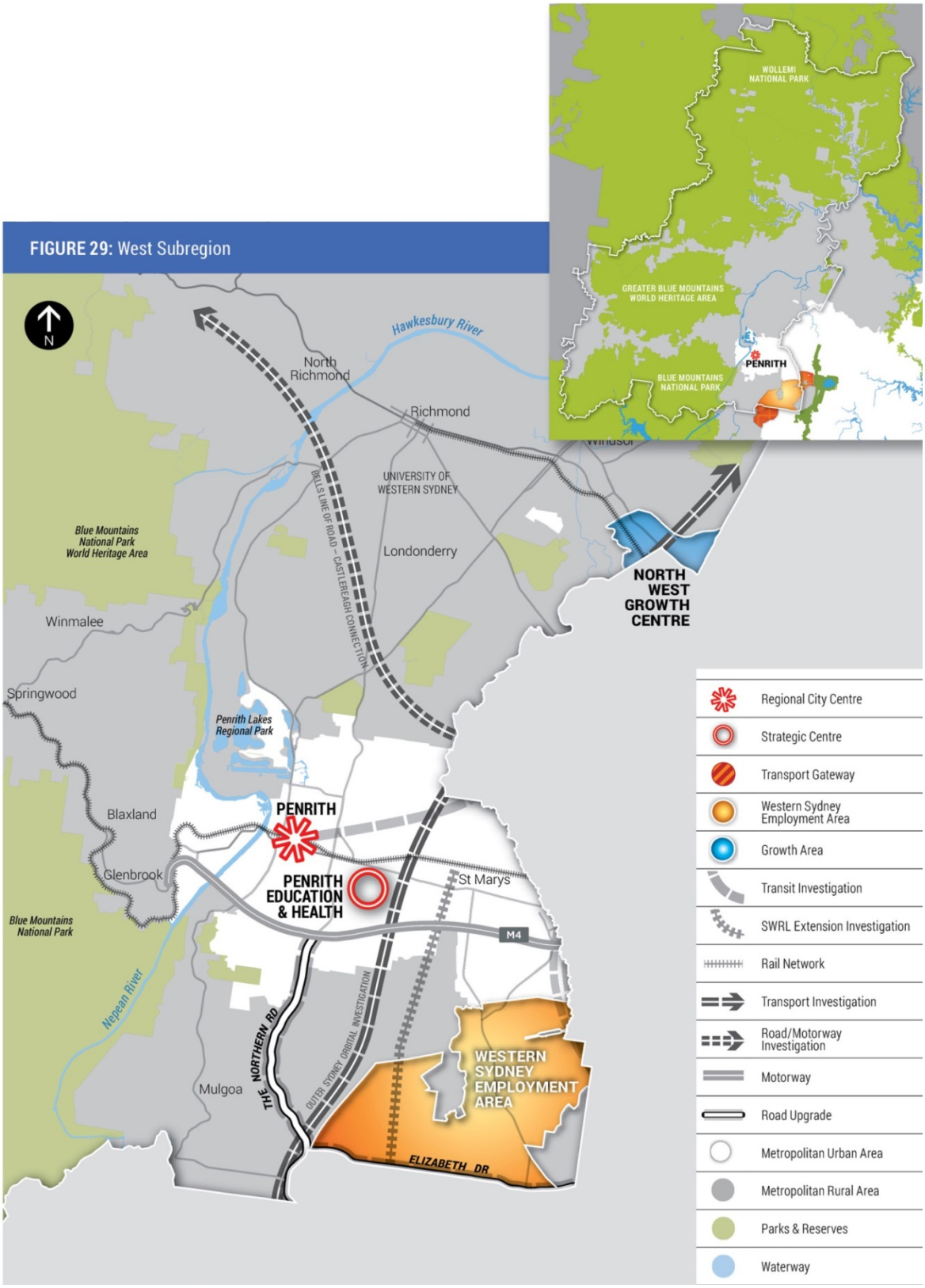
Figure 5-1, Figure 5-2 and Figure 5-3 display the planning approach for Sydney as outlined in *A Plan for Growing Sydney* (NSW Department of Planning and Environment 2014). Parramatta is recognised as Sydney's second CBD and will be supported by regional cities at Liverpool, Campbelltown-Macarthur and Penrith. These centres will provide a major focus for jobs, transport and services in outer Western Sydney communities.

This section provides an overview of the major employment, residential and transport infrastructure projects planned for Western Sydney that would support the region's growth.



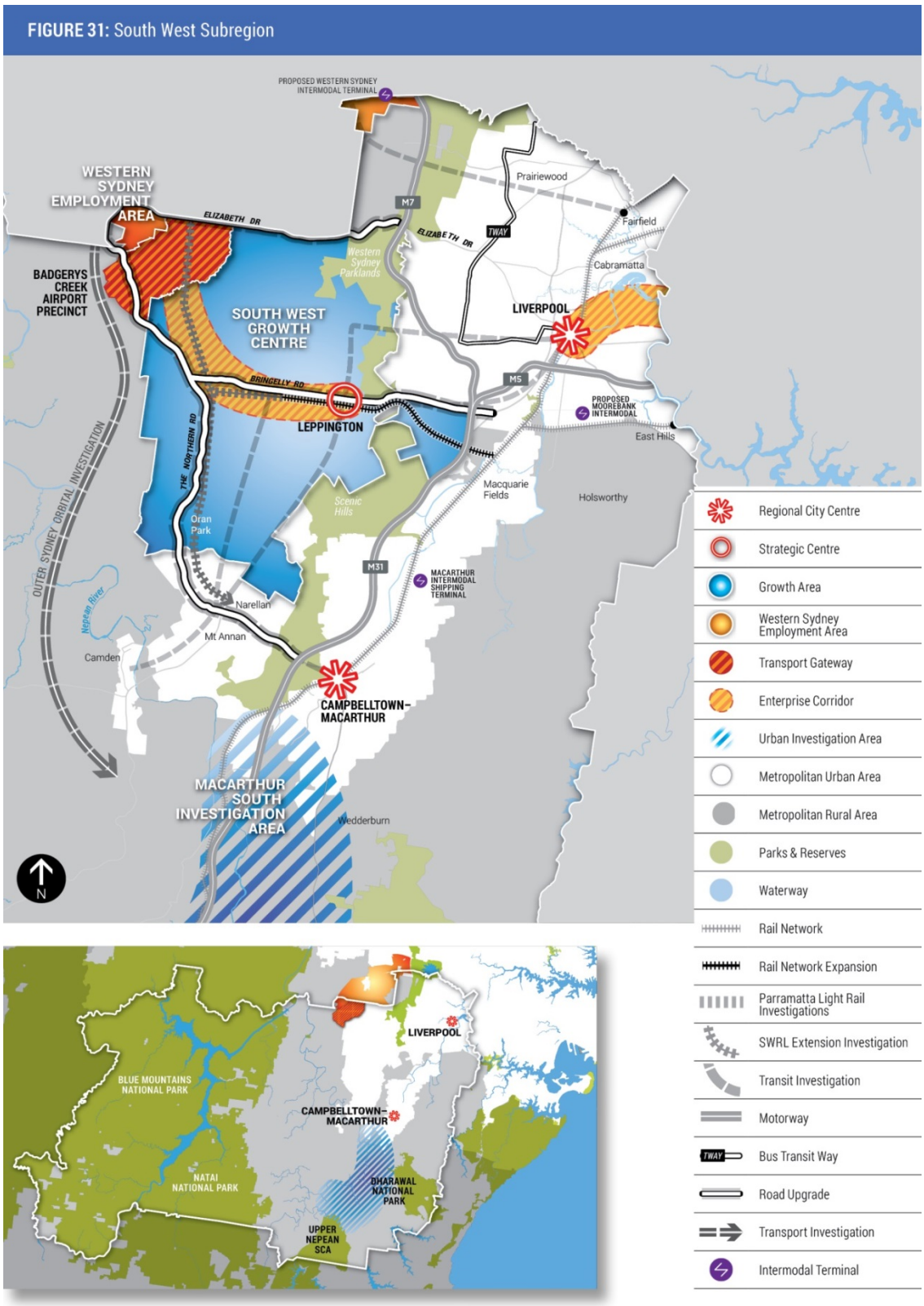
(Source: NSW Department of Planning and Environment, 2014)

Figure 5-1 Priority growth areas for Sydney from A Plan for Growing Sydney (West Central Subregion)



(Source: NSW Department of Planning and Environment, 2014)

Figure 5-2 Priority growth areas for Sydney from *A Plan for Growing Sydney (West Subregion)*



(Source: NSW Department of Planning and Environment, 2014)

Figure 5-3 Priority growth areas for Sydney from *A Plan for Growing Sydney (South West Subregion)*

5.6.1 Economic and employment growth

A Plan for Growing Sydney focuses heavily on the role of Western Sydney in driving the future productivity of Sydney and NSW. Parramatta's emergence as Sydney's second CBD will increase Western Sydney's national and metropolitan influence. As well as an employment hub, Parramatta will become an education hub, with the University of Western Sydney currently developing a new campus in the CBD, and plans to increase the capacity of the campus at Rydalmere. Adjacent to Parramatta, the Westmead Health precinct is one of the largest integrated health, research, education and training precincts in the world.

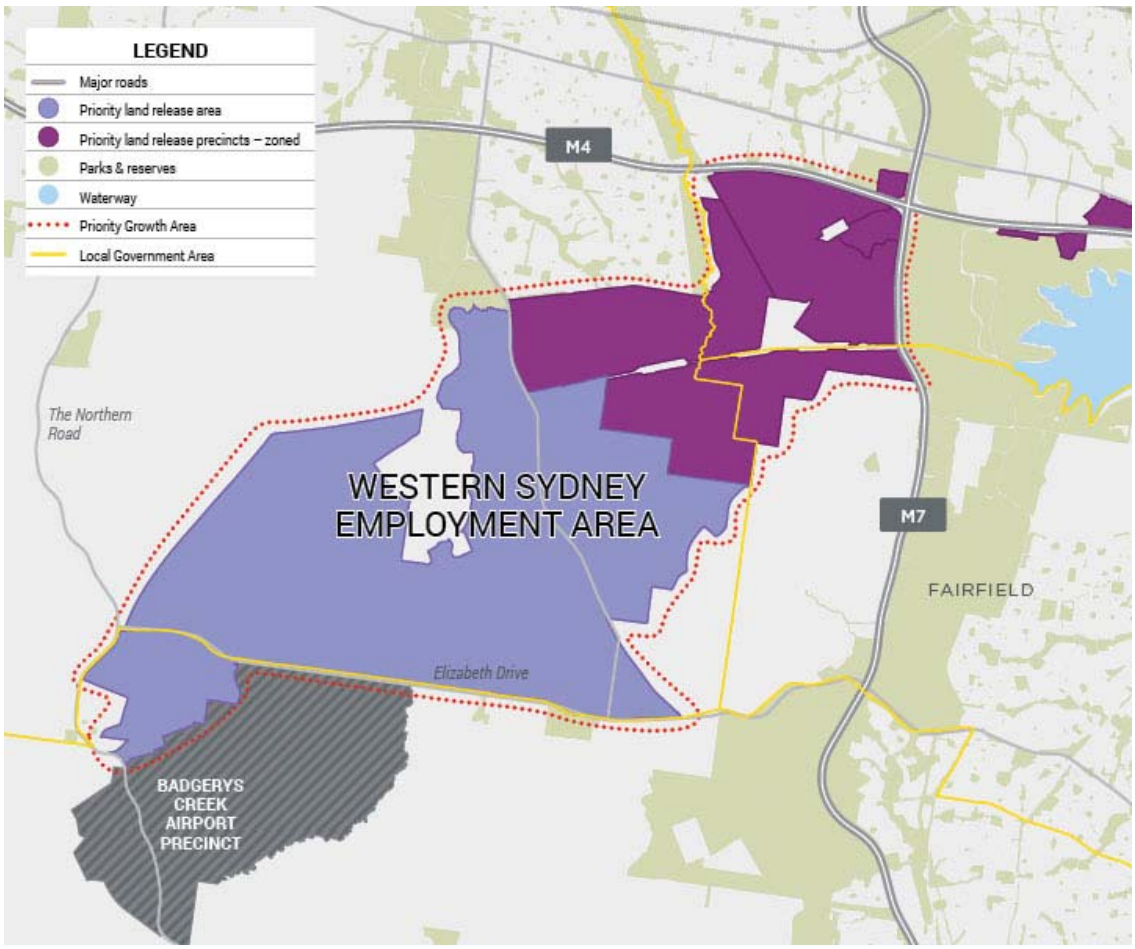
Parramatta CBD will link with the Global Economic Corridor (see Figure 5-1) which will link Port Botany and Sydney (Kingsford Smith) Airport to the future employment hubs at Norwest and Sydney Olympic Park.

Providing more jobs in Western Sydney is a key requirement to providing liveable and healthy communities. Although half of Sydney's population lives in Western Sydney, only a third of Sydney's jobs are located in Western Sydney, leading to long commutes for many workers.

This will be particularly important given that, due to expected population growth, demand for employment in Western Sydney is expected to increase faster than overall demand for employment in Greater Sydney. By 2025, the total labour force (persons aged 15 to 64 years) of Western Sydney is expected to be 1,609,401 persons, increasing to 1,744,955 persons by 2030 and 2,664,991 persons by 2065. This is equivalent to an increase of approximately 66 per cent between 2025 and 2065. The total labour force for Greater Sydney is expected to be 3,297,664 by 2025, 3,522,912 persons by 2030 and 5,016,069 by 2065, which is equivalent to an increase of approximately 52 per cent over the same period (SGS, 2015).

Employment areas will be key contributors to providing new jobs to meet this projected demand. The WSEA is planned to be a major contributor to the economic development of Western Sydney. WSEA has been established to provide businesses with land for industry and employment, particularly transport and logistics, warehousing and office space. The WSEA is located close to major roads and utility services, and is adjacent to the proposed airport.

The WSEA is expected to have capacity for more than 57,000 jobs over the next 30 years, and 212,000 jobs in the long term. The WSEA area has also been extended to the south to Elizabeth Drive, and to include land to the west of the airport site, allowing the NSW Government to dedicate 4,537 hectares to economic growth in Western Sydney (NSW Department of Planning and Environment 2015a). Figure 5-4 shows the WSEA area and location.



(Source: NSW Department of Planning and Environment, 2015a).

Figure 5-4 Location of the Western Sydney Employment Area

5.6.2 Population growth and residential development

Many areas in Western Sydney have experienced a significant amount of development and growth over recent years. This is expected to continue, as new areas in Western Sydney are developed, and population density intensifies around regional and town centres.

The population of Western Sydney is expected to grow significantly, so that by 2030, the population is expected to increase by 29 per cent to 2,734,565 persons (SGS, 2015). Significant new development is required to house this expected population growth. A recent report by the Property Council of Australia shows that Sydney will be facing a housing deficit of 190,000 homes by 2024 (Property Council of Australia 2015). The report notes that failing to keep up with demand for housing drives up property prices and makes housing less affordable. Housing affordability was noted by most stakeholders during consultation for this SIA as a key growing issue for communities in the Western Sydney region.

To provide for this growth, the NSW Government has earmarked areas for residential development in Western Sydney, as described below.

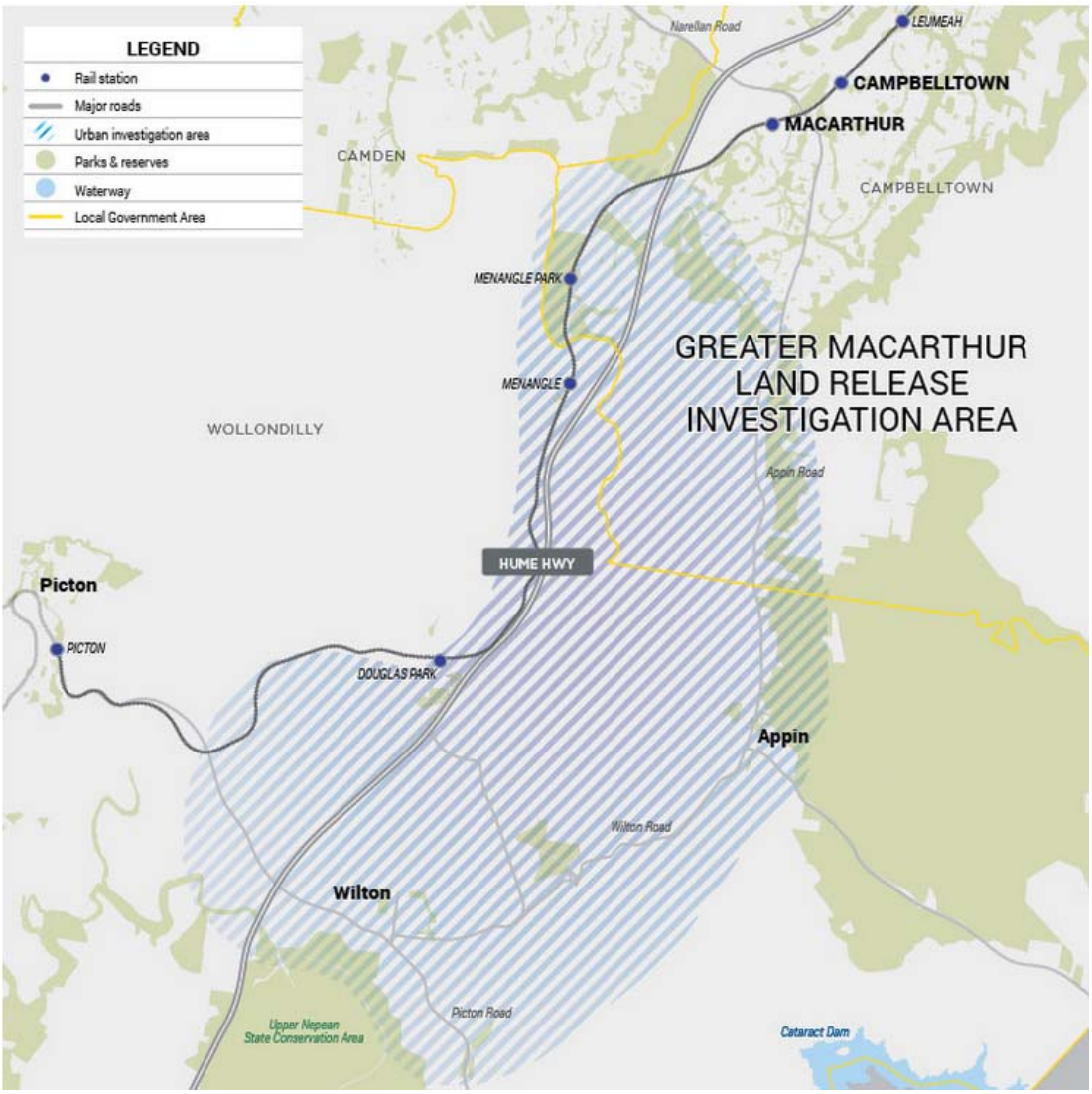
New release areas

Two key growth areas in Western Sydney are the North West and South West Priority Growth Areas, which were established by the NSW Government in 2005 to sustainably plan Sydney's growth on its urban edge. Together, the growth areas will become home to half a million people over the next 25 to 30 years. The locations of the Priority Growth Areas are shown above in Figure 5-1.

The North West Priority Growth Area (NWPGA) is located around 20 kilometres north east of the airport site and covers around 10,000 hectares across The Hills, Blacktown and Hawkesbury LGAs with capacity for 70,000 new dwellings and up to 200,000 people (NSW Department of Planning and Environment 2011). The NWPGA will support the Rouse Hill Town Centre which has been identified in *A Plan for Growing Sydney* as a strategic centre, and has been developed in recent years with a large shopping centre and key services (e.g. public library and community centre). In the future, Marsden Park will be developed as a new strategic centre within the NWPGA.

The South West Priority Growth Area (SWPGA) is located south east of the airport site across the Liverpool, Camden and Campbelltown LGAs. Covering approximately 17,000 hectares, the SWPGA has capacity for up to 110,000 new dwellings and 300,000 people (NSW Planning and Environment, 2011). The SWPGA will support a new strategic centre at Leppington. Recent developments within the SWPGA include Oran Park, which supports a town centre including shopping centre, and will soon include a new library, community centre, and administration building for Camden Council. Edmondson Park is another recent area which will provide a new town centre around a bus and rail interchange (see section 5.6.3 below).

The NSW Government is also investigating releasing land for new residential development in the Greater Macarthur region, which is located in the Campbelltown and Wollondilly LGAs (see Figure 5-5). The investigation will consider the impacts of new urban areas on the environment, agricultural and mining activities, as well as how new communities would access jobs, services and amenities. The investigation will also consider existing planning proposals for land release in areas within the Greater Macarthur region (NSW Department of Planning and Environment 2015b). This includes Wilton Junction, which is proposed to include a new town centre, with a population of over 30,000 people (Wilton Junction Consortium 2015).



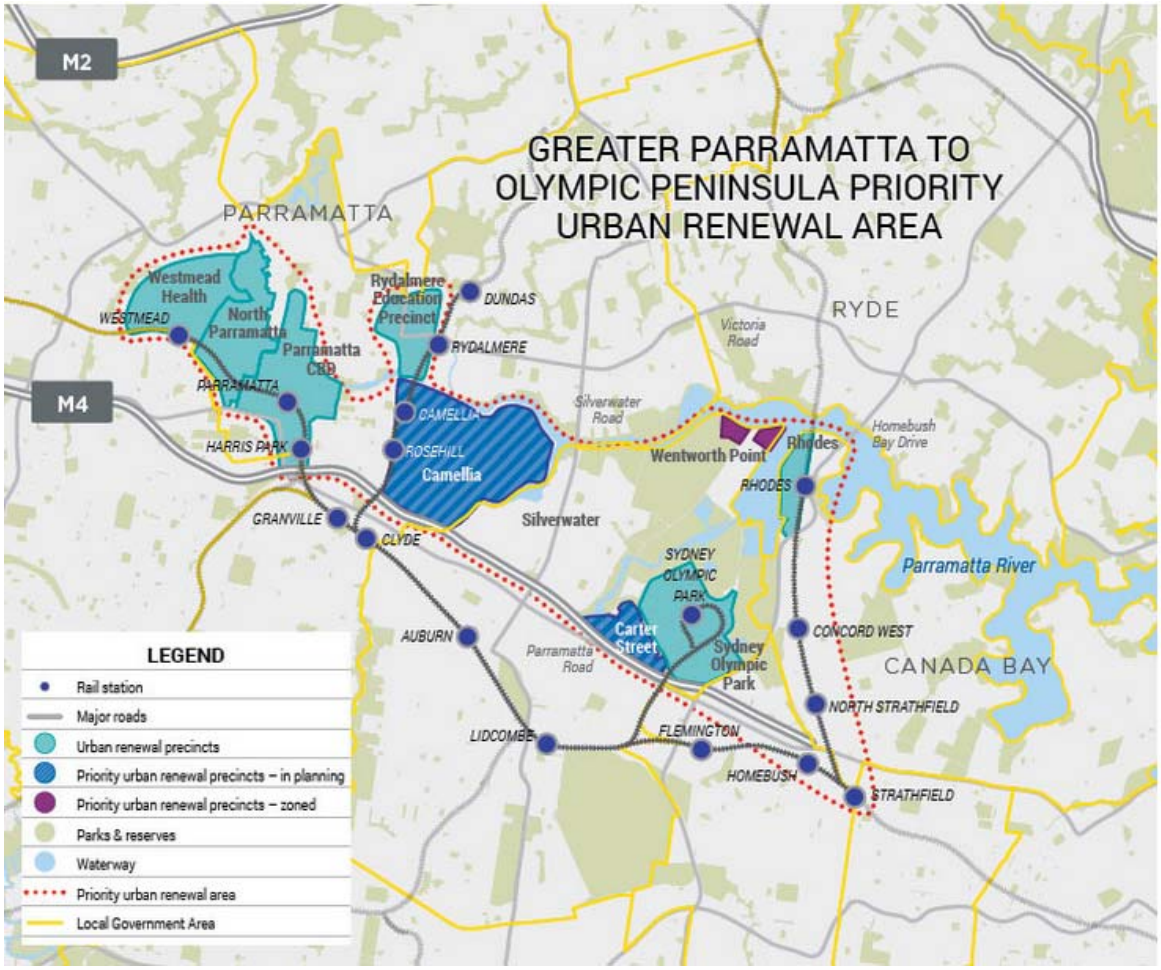
(Source: NSW Department of Planning and Environment, 2015b)

Figure 5-5 Greater Macarthur Investigation Area

Urban renewal areas

The renewal of established areas is also a key strategy for the NSW Government to provide increased housing and jobs in Sydney, with the focus on transport corridors and around strategic centres. A number of areas in Western Sydney have been identified as priority urban renewal areas including:

- Glenfield to Macarthur priority urban renewal corridor - located in Campbelltown LGA, with the area around seven train stations being investigated for redevelopment and provision of new homes.
- Greater Parramatta to Olympic Peninsula priority urban renewal area – located across the Parramatta and Auburn LGAs, work has already begun on revitalising Wentworth Point and Carter Street, and plans are being developed for Camellia (see Figure 5-6 below).



(Source: NSW Department of Planning and Environment, 2015c)

Figure 5-6 Greater Parramatta to Olympic Peninsula Priority Urban Renewal Area

5.6.3 Major transport projects

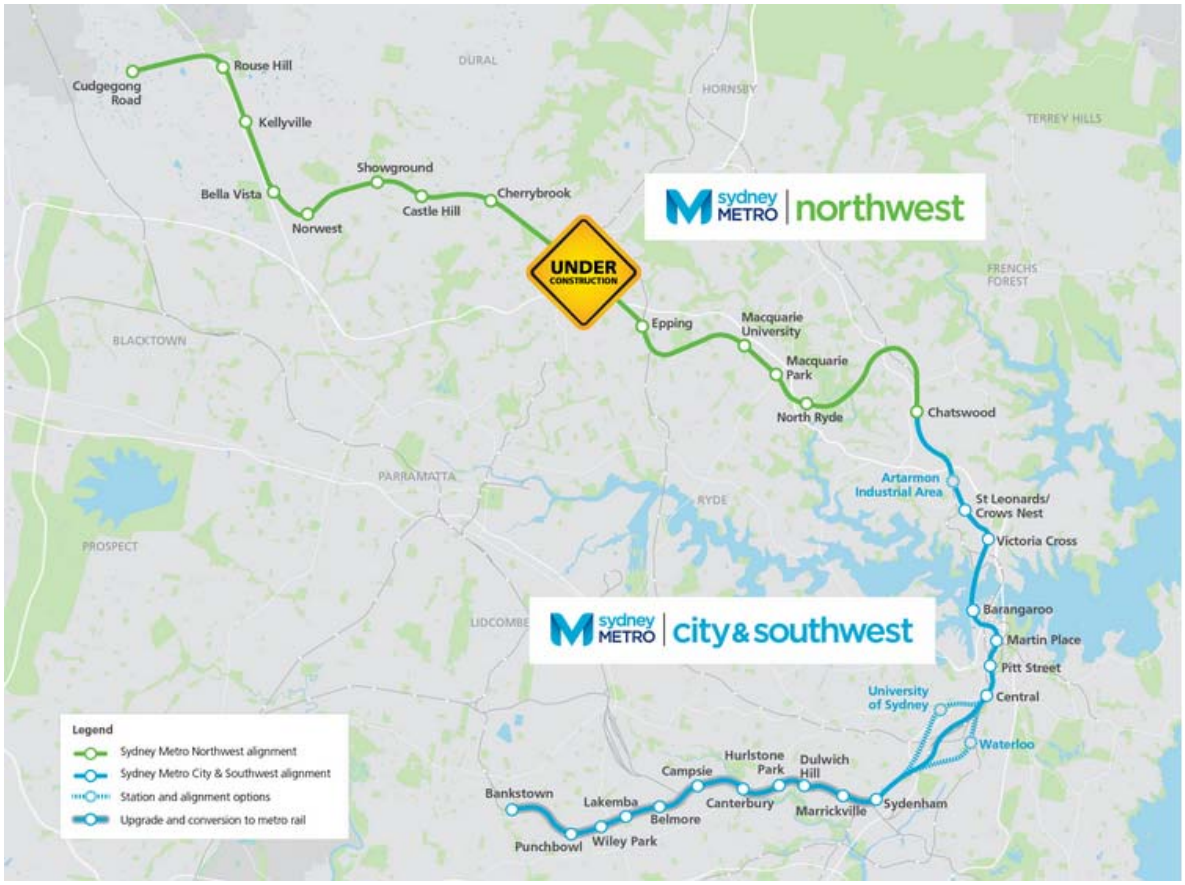
A number of major transport projects are in various stages of planning and construction throughout Greater Sydney, which will connect Western Sydney to various centres and the CBDs at Parramatta and the City.

Sydney Metro

Sydney Metro is a new standalone railway network that will deliver higher frequency train services across Sydney. There are two core components to the Sydney Metro network including:

- Sydney Metro Northwest – construction has begun on this 36km line which will connect from Chatswood through to the NWGC. This project is currently under construction, and is expected to be open to customers in 2019.
- Sydney Metro City and Southwest – a new 30km metro line will link with Metro Northwest at Chatswood, then travel under Sydney Harbour, through the CBD and southwest to Bankstown.

Figure 5-7 shows the location of the Sydney Metro network including existing and proposed stations.



(Source: Transport for NSW, 2015a)

Figure 5-7 Sydney Metro network

South West Rail Link

The South West Rail Link was delivered in response to population growth and reliability issues on the metropolitan rail network in south-west Sydney. The South West Rail Link opened to the public in early 2015 and included a major upgrade of the existing station at Glenfield, and a new twin track passenger rail line between Glenfield and Leppington.

The NSW Government is also currently investigating an extension of the South West Rail Link with a view to preserving a corridor. The extension is proposed to connect Leppington Station to Bringelly, and then head into two different directions: north via the airport site to the Western Line near St Marys in the Penrith LGA; and south to Narellan in the Camden LGA. The NSW Government is also considering extending the corridor further south to Campbelltown.

The extension will provide a north-south connection through the SWPGA and WSEA including the proposed airport. New stations are proposed for Rossmore, Bringelly, North Bringelly, Oran Park, Narellan, and at the proposed airport (Transport for NSW 2015b).

Light Rail

Sydney's light rail network is being extended through the Sydney CBD to Circular Quay and Kingsford and Randwick in the eastern suburbs, and has recently been extended through the inner west to Dulwich Hill.

The NSW Government is also investigating a new light rail line for Parramatta and Western Sydney to support Sydney's second CBD and improve transport links. Four potential routes have been shortlisted:

- Parramatta to Macquarie Park via Carlingford.
- Parramatta to Castle Hill via Old Northern Road.
- Parramatta to Bankstown.
- Parramatta to Sydney Olympic Park and Strathfield/Burwood.

Each route is currently being investigated to decide which offers the best long-term solution for Parramatta and Western Sydney. A light rail connection to Parramatta would contribute to an improvement for the overall public transport network in Western Sydney, as well as strengthen the role of Parramatta as Sydney's second CBD.

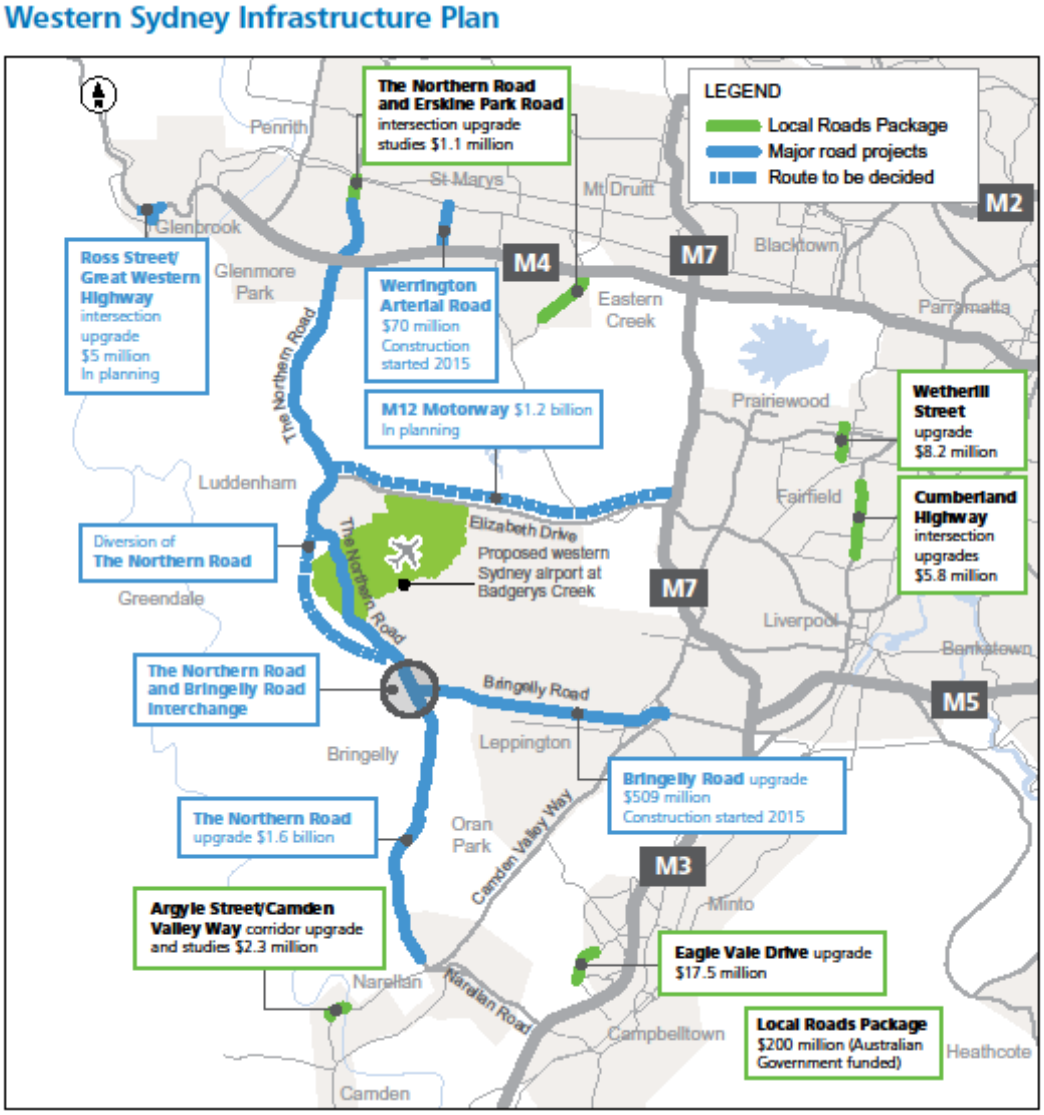
Western Sydney Infrastructure Plan

Under the Western Sydney Infrastructure Plan the Australian and NSW governments are investing $3.6 billion in a number of road upgrades and new roads in Western Sydney to support the proposed airport and improve transport connections for the community of Western Sydney. The package includes:

- upgrade of The Northern Road to a minimum of four lanes from Narellan to Jamison Road;
- construction of a new east-west motorway to the airport between the M7 Motorway and The Northern Road;
- upgrade of Bringelly Road to a minimum of four lanes between The Northern Road and Camden Valley Way;
- construction of the Werrington Arterial Road between the M4 Motorway and the Great Western Highway;
- upgrade of Ross Street and Great Western Highway intersection at Glenbrook; and
- a $200 million package for local roads upgrades.

Together, the package of new roads and upgrades aims to ease congestion and relieve pressure on existing roads while improving connections between major hubs (Department of Infrastructure and Regional Development 2015).

Figure 5-8 shows a map of the location of the roads and upgrades.

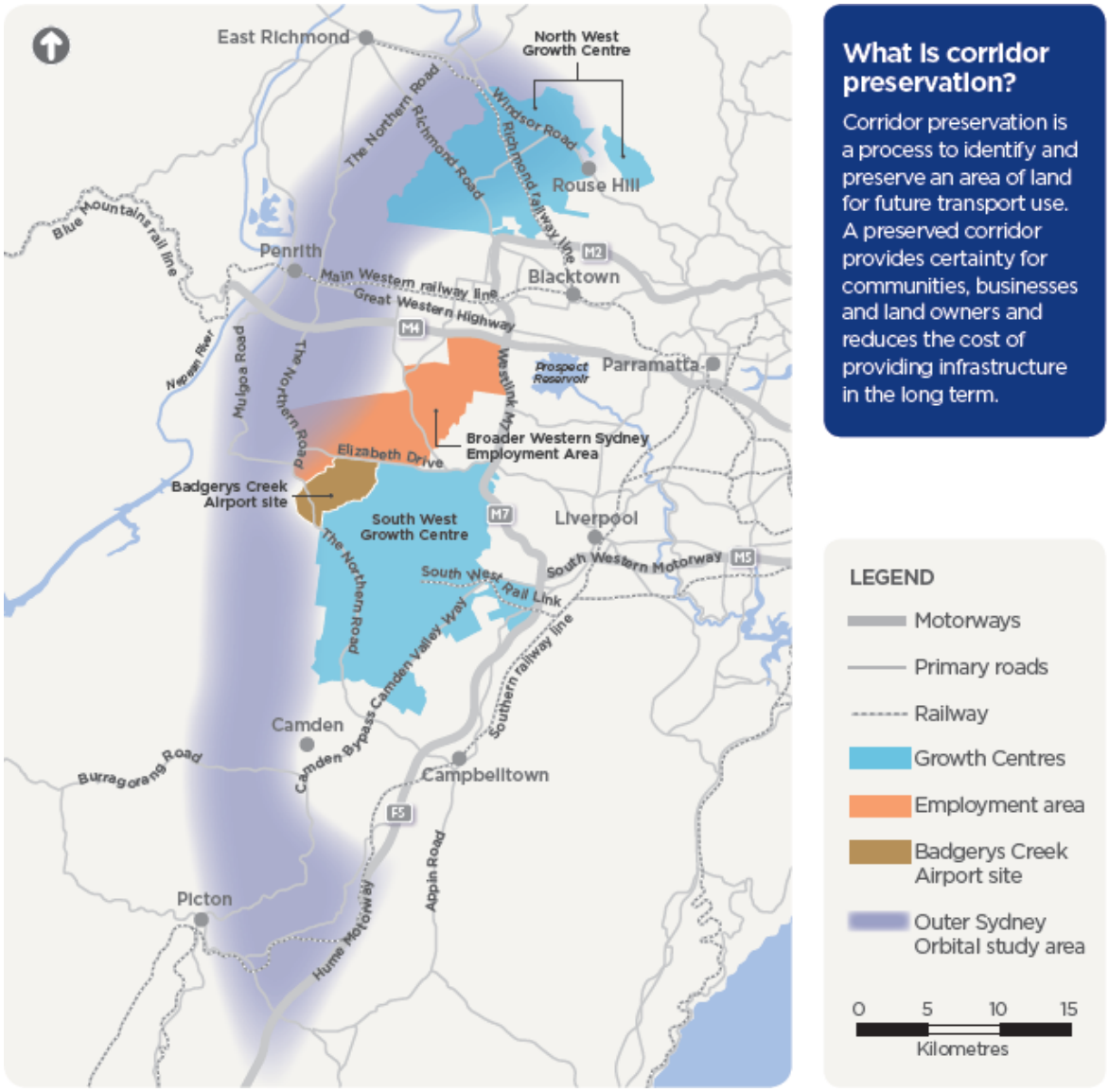


(Source: RMS, 2015, http://www.rms.nsw.gov.au/documents/projects/sydney-west/infrastructure-plan/western-sydney-infrastructure-plan-map.pdf)

Figure 5-8 Locations of new roads and upgrades as part of the Western Sydney Infrastructure Plan

Outer Sydney Orbital – Potential Corridor Preservation

The Outer Sydney Orbital is a corridor being investigated by the NSW Government to provide a north – south connection for a future motorway, freight rail, and where practical a passenger rail line. The corridor would provide increased capacity for the road network to improve accessibility to housing and employment, and the freight rail would connect from Port Kembla to the South Line, Western Line and Northern Line. The area under investigation, shown in Figure 5-9, starts at the NWPGA in the north, finishes in the south near Picton in Wollondilly LGA, and travels to the west of the proposed airport site.



(Source: Transport for NSW, 2015c)

Figure 5-9 Investigation corridor for the proposed Outer Sydney Orbital

5.7 Summary of socio-economic profile of the Western Sydney region

As highlighted in Appendix E, the existing communities of the Western Sydney region are diverse, from densely populated and highly urbanised areas, to semi-rural and recreational/natural areas. Many communities are known for and proud of their cultural diversity, heritage (both Indigenous and non-Indigenous), strong and cohesive communities, natural areas and recreational values, or connections to the employment hubs of Parramatta and Sydney CBDs.

The major employment, residential and transport infrastructure projects proposed for Western Sydney demonstrate the critical role the Western Sydney region plays in Sydney's future. These projects will support the proposed Western Sydney Airport, which is recognised as a significant catalyst for increased and faster growth for Western Sydney, and t Greater Sydney more broadly. These projects, along with the Western Sydney Airport, have the potential to bring significant change to Western Sydney communities. These social impacts and opportunities are discussed in the next section.

5.8 Summary of demographic profile of communities in local study area

It is likely that some communities within the Western Sydney region will experience impacts and benefits more noticeably than others, which may change the existing character and social amenity of these communities. To understand these potential impacts and changes, Table 5-1 below displays information on selected demographic indicators to provide a snapshot of the social local study area communities which are located within five kilometres of the airport site and/or within likely noise contours for overflights. These communities/suburbs include - Arndell Park, Austral, Badgerys Creek, Bringelly, Chatsworth, Cobbitty, Eastern Creek, Erskine Park, Glenfield, Greendale, Horsley Park, Kemps Creek, Leppington, Luddenham, Mount Vernon, Mulgoa, North St Marys, Orchard Hills, Penrith, Prospect, Rossmore, Silverdale, South Penrith, St Clair, St Marys, Theresa Park, Wallacia, Werombi and Werrington.

Further to the demographic summary below, detailed social profiles of representative communities/villages are described in Appendix G.

Table 5-1 Selected demographic indicators for suburbs within the local study area

2011 State Suburb (SSC)	LGA	Usual resident population	Median age	Indigenous population	Born in non-main English speaking country	Speaks other language and speaks English very well or well	Need for assistance	Median household Income	Unemployment rate	Completion of Year 12	Lived at same address 5 years ago	Living in social housing	SEIFA score of advantage and disadvantage
Arndell Park* (comprises Huntingwood)	Blacktown	12	34	0.0%	83.3%	50.0%	0.0%	-	0.0%	75%	50%	0.0.%	-
Austral	Liverpool	3,026	39	1.4%	28.3%	15.5%	10.4%	$1,191	4.7%	27%	65%	0.0%	961
Badgerys Creek**	Liverpool	454	34	3.7%	14.9%	6.6%	4.4%	$1,172	6.1%	18%	62%	11.5%	914
Bringelly	Liverpool Camden	2,390	37	1.1%	16.6%	10.9%	3.6%	$1,540	3.7%	29%	62%	0.0%	1029
Chatsworth	Penrith	216	50	0.0%	0.0%	0.0%	7.4%	$693	7.6%	27%	58%	0.0%	961
Cobbitty	Camden	1,060	39	1.5%	9.2%	5.1%	3.9%	$1,472	4.1%	41%	63%	4.8%	1067
Eastern Creek	Blacktown	803	31	3.1%	19.6%	14.5%	5.3%	$1,068	8.2%	32%	59%	8.1%	937
Erskine Park	Penrith	6,665	31	1.7%	16.4%	12.4%	2.7%	$1,858	5.2%	40%	70%	7.4%	1049
Glenfield	Campbelltown	7,547	36	1.5%	34.5%	27.6%	8.6%	$1,394	6.8%	49%	51%	18.9%	1004
Greendale	Liverpool	354	37	0.0%	13.6%	9.9%	1.7%	$1,275	3.6%	29%	60%	0.0%	976
Horsley Park	Fairfield	1,935	39	0.8%	24.6%	16.1%	5.2%	$1,361	33.4%	28%	65%	8.7%	997
Kemps Creek	Penrith Liverpool	2,307	38	1.1%	25.1%	16.6%	6.9%	$1,148	3.5%	30%	68%	0.0%	982
Leppington	Liverpool Camden	2,384	40	0.6%	22.1%	12.6%	5.4%	$1,040	5.2%	28%	64%	4.6%	961
Luddenham**	Penrith Liverpool	1,495	36	2.3%	9.5%	6.0%	3.7%	$1,562	4.3%	33%	59%	2.5%	1024
Mount Vernon	Penrith	1,034	39	0.8%	22.6%	16.4%	3.7%	$1,773	3.2%	36%	72%	0.0%	1080
Mulgoa	Penrith	1,786	37	2.0%	10.9%	4.9%	2.8%	$1,783	4.7%	42%	63%	0.0%	1058

2011 State Suburb (SSC)	LGA	Usual resident population	Median age	Indigenous population	Born in non-main English speaking country	Speaks other language and speaks English very well or well	Need for assistance	Median household Income	Unemployment rate	Completion of Year 12	Lived at same address 5 years ago	Living in social housing	SEIFA score of advantage and disadvantage
North St Marys	Penrith	3,688	35	5.7%	15.6%	11.1%	6.1%	$994	10.3%	27%	60%	47.6%	847
Orchard Hills	Penrith	1,911	40	1.4%	17.7%	11.6%	4.2%	$1,512	3.5%	35%	72%	0.0%	1051
Penrith	Penrith	11,804	37	4.0%	13.6%	8.8%	7.7%	$949	7.6%	36%	47%	23.1%	920
Prospect	Blacktown	4,621	35	1.1%	28.2%	21.1%	3.5%	$1,594	5.3%	48%	67%	5.9%	1031
Rossmore	Liverpool Camden	2,415	37	1.7%	23.5%	14.4%	4.3%	$1,284	5.9%	30%	63%	1.7%	984
Silverdale	Wollondilly	3,443	35	2.2%	5.9%	2.8%	2.5%	$1,806	2.7%	35%	67%	0.0%	1074
South Penrith	Penrith	11,644	36	2.9%	8.7%	5.1%	4.3%	$1,377	5.2%	38%	61%	16.4%	1017
St Clair	Penrith	19,841	32	2.6%	18.0%	12.8%	3.1%	$1,670	5.1%	42%	66%	5.0%	1029
St Marys	Penrith	10,960	35	4.0%	22.1%	15.7%	5.9%	$996	8.2%	34%	48%	18.3%	881
Theresa Park	Wollondilly	548	40	1.1%	7.3%	3.8%	3.6%	$1,793	2.4%	41%	71%	0.0%	1083
Wallacia	Penrith Wollondilly	1,689	39	1.4%	8.1%	5.2%	3.8%	$1,309	3.4%	31%	65%	0.0%	1038
Warragamba	Wollondilly	1,238	35	3.2%	5.3%	2.3%	4.9%	$1,073	5.1%	24%	60%	0.0%	941
Werombi	Wollondilly	841	37	1.1%	5.5%	3.0%	3.2%	$1,814	3.1%	37%	64%	0.0%	1088
Werrington	Penrith	3,847	32	3.5%	18.2%	14.1%	4.2%	$1,078	7.7%	40%	47%	14.6%	918

* Limited information is available for this area due to its small population.

**The population may now be reduced as a result of tenants relocating from the Commonwealth owned land (Project site).

6. Identification and assessment of socio-economic impacts

This section identifies, describes and assesses the potential socio-economic impacts arising from the proposed airport development, including site preparation and terminal development activities, operation of the Stage 1 development and operation of the indicative longer term development.

This impact assessment has been carried out by first describing the social and economic issues, analysing if these issues are caused by the proposed airport, and then making a determination on the nature and significance of each impact (refer to section 2.2.6). It should be noted that where social issues are identified that are not considered to be directly caused by the proposed airport, they have been discussed but not assessed for their significance.

Mitigation measures and management strategies to address the potential social impacts are described in section 7.

6.1 Economic benefits

The economic benefits of the project would be substantial in both the short and longer term (SGS, 2015 provided in Appendix B). As stated in the *A Study of Wilton and RAAF Base Richmond for Civil Aviation Operations* undertaken by the Australian Department of Infrastructure and Transport (2013), an airport at Badgerys Creek was forecast to generate $23.9 billion Gross Domestic Product (GDP) and approximately 60,585 jobs in Australia by 2060.

The economic impacts of the proposed Western Sydney Airport Stage 1 report (EY, 2015) shows major growth in gross value added (GVA) which is a measure of income earned from the production of goods and services in the area. The value-add from construction of the proposed airport would peak in 2022 with benefits to Western Sydney reaching $450 million, a further $90 million to the rest of Greater Sydney in that year. Over the construction period (2016-2024) the cumulative value-add from the construction of the Stage 1 development is expected to be $1.9 billion for Western Sydney and an additional $400 million for the rest of the Greater Sydney region (EY, 2015). This includes direct spending from the development, spending from industries supplying the project and flow on benefits.

During operations, the value-add is also expected to increase commensurate with passenger movements. In 2031 (roughly aligning with the end of Stage 1), the proposed airport is estimated to generate an additional $205 million in value-add per year across Australia. Of this, $77 million of value –add will be generated in the Western Sydney region. In 2063, the proposed airport would increase value-add in the Australian economy by $5.8 billion. Of this, approximately $1.5 billion would be generated in the Western Sydney region.

6.2 Employment opportunities

The Stage 1 and longer term development would generate a large number of direct, indirect and induced jobs.

During construction, the direct jobs would be anticipated to require skills in:

- Non-Residential Building Construction - construction of non-residential buildings such as hotels, motels, or other buildings

- Heavy and Civil Engineering Construction - construction or general repair of roads, bridges, aerodrome runways or parking lots
- Construction Services – a range of services provided as part of construction activities, including installation, finishing, management and others.

During operations, direct jobs would be those that are entirely related to, and dependent on, the proposed airport. Examples would be airport ground staff and baggage handlers. Indirect jobs are those businesses which supply goods and services to the airport. Examples might include catering companies, valet services, airport security, cleaning companies, waste management services and others. Further to this are the induced jobs that would be created by the expenditure from employees of industries servicing the airport development. This could be through expenditure at retail stores, restaurants, professional services, etc which would result in the creation of new job opportunities.

As estimated in the economic impact of the proposed Western Sydney Airport Stage 1 (EY, 2015), the estimated construction workforce during Stage 1 construction would be expected to peak at 758 direct full time equivalent (FTE) jobs in 2022 in Western Sydney, which corresponds to approximately 3,200 cumulative person-years in Western Sydney over the construction period (from 2016-2024) (EY, 2015). There would be indirect and induced employment generated for 8,000 person years in Western Sydney over the construction period between 2016 and 2024 (EY, 2015). An additional 2,200 person years in the rest of Greater Sydney over the construction period between 2016-2024 (EY, 2015).

The potential demand for labour at its peak in approximately 2022, represents only a small proportion of the total construction workforce that is forecast to be available in Western Sydney region and Greater Sydney (based on forecasts by industry and employment in Appendix B). Forecasts for 2020 were used as the bases for comparison as that was the closest year for which forecast data was available.

The Surface Transport and Access Study (GHD, 2015) states a ratio of 750 airport employees per million annual passengers (MAP). The application of this ratio results in a total of 7,500 direct FTE jobs would be required by the end of Stage 1 in 2030 for airport operations. In addition, a further 4,440 FTE jobs are forecast to be generated from commercial activities on business parks on the airport site (EY, 2015). Considering the forecasted availability of the labour pool in the Western Sydney region in 2025, it is evident that such workforce demand will be comfortably met. Airport operation activities will generate demand for a variety of skilled and un-skilled jobs for airport ground services, aviation services and inflight services.

By around 2063, it is forecast that the proposed airport could serve approximately 82 MAP. It is anticipated that approximately 61,500 FTE direct jobs would be required in the longer term in 2063 for airport operations. A further 27,150 FTE jobs would be generated from commercial activities on business arks on the airport site (EY, 2015). While it is possible that the number of jobs required in 2063 may reduce due to factors such as changes in technology in airport and aviation services, other non-aviation related developments on the site not included in these calculations would potentially substantially increase these aviation specific forecasts. The development of non-aeronautical commercial activities on the airport site may further increase employment opportunities during Stage 1 and the longer term development.

Population forecast data for 2065 shows a higher rate of increase in overall population and working age population in the Western Sydney region compared to the rest of Greater Sydney. This would create a large labour pool which could meet the workforce demand from the proposed Western Sydney Airport. Potential shortfalls would be absorbed by the broader labour pool available in Greater Sydney.

Stakeholder consultation, several studies and local and regional plans (refer to section 3.1 and section 5) reveal that the majority of the residents of Western Sydney undertake prolonged commutes on a daily basis to access work opportunities in other parts of Sydney. The proposed developments in Western Sydney, including the proposed airport, would bring much needed employment opportunities for the current and future residents of Western Sydney. This could mean that residents currently employed in other parts of Sydney may release those jobs to take up opportunities closer to home which itself would create job vacancies in other parts of Greater Sydney. Unemployment rates and population forecasts, highlighted in section 5.2, show that such job vacancies could be easily matched given the availability of, and future growth in, the labour pool in Greater Sydney.

6.3 Impacts on other industries

The Stage 1 and longer term development would create demand for goods and services from the Western Sydney region, Greater Sydney and the wider NSW and Australian economies. This increased demand would provide a stimulus to business growth and development and generate a positive impact on other industry sectors such as construction, utilities, trade, transport and services, accommodation, retail, professional services and public administration (SGS, 2015). It is considered that overall, benefits for the Western Sydney region and Greater Sydney businesses and industries would be more pronounced than for NSW and Australia. Development of the proposed airport may also stimulate the growth of tourism activities in the surrounding region including the Blue Mountains.

The proposed airport and other planned growth and developments in the regional area would result in changes to land use. It is likely that the combined effect of this would lead to a further decline in industry sectors such as agriculture and manufacturing due to competition for land and cost of labour (Appendix B and SIA stakeholder consultations). Stakeholder consultation undertaken as part of the SIA and data trends show that these industries have already been on a slow decline in parts of the Western Sydney region. Impacts on agricultural land are also discussed in the planning and land use report of the EIS.

6.4 Property impacts

The potential adverse effect on property prices associated with aircraft noise (among other factors) is documented in a number of Australian and international studies. A study of potential property price effects was conducted as part of the 1997 EIS and concluded that, depending on the level of noise affectation, expressed in terms of the noise contour band known as ANEF, the effect could range from 0 to -24.3%, with the latter applying to the most noise affected properties (JLL, 2015).

A review of more recent literature and revised analysis was conducted for the current draft EIS to explore the potential price devaluation effects on lower density, large lot land holdings similar to those found at Badgerys Creek (JLL 2015). Comparable examples including Melbourne (Tullamarine and Avalon) and Perth airports were analysed for a potential relationship between price and noise effects. However the analysis failed to establish a statistically significant relationship between noise exposure and property prices (JLL, 2015). Possible reasons for this might include the lesser significance of the dwelling in the context of large land areas, land used for primary production may be less affected by noise and/or the wider range of factors influencing price that cannot be analysed. Table 6-1 presents a summary of the report findings.

Table 6-1 Assessment of property values by land use

Land use	ANEF/ANEI 20-25	ANEF/ANEI 25-30	ANEF/ANEI 30-35
Residential	-9.5%	-14.7%	-19.8%
Large lot land holdings	No discernible effect	No discernible effect	No discernible effect

Source: JLL 2015

Note: Compared to noise levels < 20 ANEI/ANEF where the price change is assumed to be zero.

The potential effects of a reduction in property values as seen in the table above could affect a range of people given the nature of the development and the scale of the noise envelope. The affect will be different depending upon where people are located as well as individual circumstances. However, analysis of long run house prices in Sydney since 1991 found no appreciable difference in growth rate between median prices in suburbs subject to in excess of 20 ANEF and those in similar areas not exposed to aircraft noise (JLL, 2015). As stated in the JLL study, this could be because:

- Housing pressures restrict housing choices.
- The benefits of living close to the city outweigh possible noise effects in the minds of potential purchasers.
- Noise attenuation measures to dwellings in above 20 ANEF noise contours may have reduced the impact of noise on residents.
- Aircraft noise sharing protocols and rising ambient noise levels in many suburbs may reduce the perceived impact of noise.

Overall, the property price analysis in JLL failed to establish conclusive evidence of a negative impact on large lot land property prices as a result of aircraft noise at levels of 20-25 ANEF. This suggests that the development of the proposed airport may not have a major adverse impact on property prices in the vicinity.

The property values report (JLL 2015) indicates that over the past 12 months since the announcement that the Commonwealth owned land at Badgerys Creek will be the site for a new airport for Western Sydney, there has been a spike in house prices in areas closer to the airport site. Analysis of longer term growth rates of residential sales in the suburbs around Badgerys Creek between 1991 and 2015 indicates that despite short term fluctuations, property prices have increased at a similar rate to the wider Western Sydney and metropolitan regions. Further, rather than suffering a slowing of growth as a result of possible fears of noise (or other impacts), residential prices in the suburbs around Badgerys Creek grew strongly in the period following the announcement in April 2014, increasing by almost 24 per cent, which was substantially greater than the average increase in both Western Sydney and the Sydney metropolitan regions.

In view of the potential future opening of a second runway at the proposed airport, the long term time series analysis of Sydney Airport suggests no material difference exists in property pricing of noise versus non-noise affected areas. That is likely because factors of much greater significance would influence property values in the future than any incremental increase in noise over the period. More specifically, it is considered that the positive influences of in-area employment as well as improved infrastructure and services would more than likely make up for any additional noise from a second (future) runway. The property values report further noted that there have been advancements in aircraft technology over the last 20 years that have resulted in a material reduction in noise footprints across all major Australian airports, despite increasing aircraft movements. It is considered reasonable therefore that advancements in technology would also be made in the future which will further reduce aircraft noise. For these

reasons, an adverse impact on property prices in the longer term was not identified as a result of opening of a future second runway at the proposed airport.

6.5 Lifestyle and amenity

The proposed airport would bring increased employment and income generation opportunities in the Western Sydney region (refer to section 6.1). Consultation revealed that a large proportion of the population undertake long commutes on a daily basis to access work opportunities in other parts of Greater Sydney region, leading to long drives, sedentary lifestyles and less family or leisure time. During the Stage 1 and longer term development, the proposed airport would provide much needed employment opportunities closer to home for residents of the Western Sydney region, reducing travel time and offering prospects for improved lifestyle.

Lifestyle and social amenity impacts have been assessed with consideration of the following issues associated with the airport development:

- aircraft noise impacts
- Ground-based noise impacts
- Air quality impacts
- Traffic and access impacts
- Landscape and visual amenity impacts
- Community health impacts.

6.5.1 Aircraft operation noise

The impacts of aircraft operation noise including take off, reverse thrust on landing and overflight noise have been assessed in the *Aircraft Overflight and Operational Noise Study* (Wilkinson Murray, 2015a). The introduction of aircraft operations at the proposed airport would result in changes to the pattern of aircraft noise in the Western Sydney region, due to required new aircraft flight paths and airport operating modes. The changes would result in noise impacts which may be pronounced in some areas. In addition, projected future growth in air traffic would result in increased numbers of aircraft operations at the airport, so noise impacts will also generally increase in the future, although this would likely be mitigated to some extent by the introduction of new, quieter aircraft into the fleet over time. Key findings from the Aircraft Overflight Noise Study (Wilkinson Murray, 2015a) and an interpretation of the predicted consequential social impacts are summarised below.

Terminology relevant to understanding noise levels and associated social impacts

Aircraft noise impacts are measured using the A-weighted decibels (dBA) unit. N70 – the average number of aircraft noise events per day with maximum noise levels exceeding 70 dBA. A noise level of 70dBA outside a building would generally result in an internal noise level of approximately 60dBA if windows are open to a normal extent. This noise level is sufficient to disturb conversation, in that a speaker would generally be forced to raise their voice to be understood, or some words may be missed in speech from a television or radio (Wilkinson Murray, 2015).

N60 – the average number of aircraft noise events per day with maximum noise levels exceeding 60 dBA during the night-time period 10pm-7am. An external noise level of 60dBA represents an internal level of approximately 50dBA if windows are open to a normal extent. An internal noise level of 50dBA is commonly used as an indicator of potential sleep disturbance (for example in Australian Standard 2021) (Wilkinson Murray, 2015a).

ANEC - a standard measure of aircraft noise exposure used in Australia used to define land use planning around airports based on hypothetical operating scenarios. In the ANEF system areas outside the 20 ANEF contour are 'acceptable' for new residential development. Between ANEF 20 and 25 new residential development is considered 'conditionally acceptable'. Above ANEF 25 new residential development is considered "unacceptable".

Study approach

The airspace design for the proposed airport will not be finalised until much closer to operations commencing at the airport. Therefore the overflight noise study has been based on an indicative proof-of-concept airspace design undertaken by Airservices Australia, which incorporates a 'point merge' system for arriving aircraft (meaning all arriving aircraft pass over a single point before commencing their final approach to the airport). The overflight noise assessment assumes that all arrivals at the proposed Western Sydney Airport would use a continuous descent approach which enables aircraft to be configured to reduce the need for power settings above flight idle.

Noise impacts from the airport would depend on the airport operating strategy adopted by Air Traffic Control, and the direction in which aircraft would arrive and depart. The airport could operate in a number of strategies:

- Prefer 05 direction – aircraft approach and depart predominantly in a south-west to north-east direction;
- Prefer 23 direction – aircraft approach and depart predominantly in a north-east to south-west direction (i.e. opposite of 05); and
- Head-to-Head – aircraft both approach from and depart to the south-west (generally at night when air traffic levels are low).

The above modes are not mutually exclusive. Depending on weather conditions and other factors, in particular wind direction, it is possible that all three modes would be used in any 24 hour period. The noise report includes four scenarios combining the above modes to investigate the possible noise impacts of overflights.

Summary of indicative impacts from aircraft operational noise

Aircraft operational noise impacts have been assessed for nominal years 2030, 2050 and for the longer term development.

Key findings of the overflight noise report for the initial stage development stage (2030) include:

- A relatively large area surrounding the airport site would be impacted by noise associated with aircraft take-off, engine run-up and reverse thrust noise including Luddenham, Badgerys Creek, Bringelly, Wallacia and Greendale. Social infrastructure that would be affected by one or more types of operational noise are primarily located in Luddenham including one child care centre, two primary schools, three churches, three parks, and three recreation facilities. These are identified in Appendix H. Figure 6-1 identifies the social infrastructure and residences surrounding the site that could be potentially impacted by worse case operational noise.
- Maximum noise levels (worst case) - For the loudest and most common aircraft operations (Boeing 747 and A320 aircraft or equivalent), maximum noise levels over 85 dBA would be experienced at a small number of residential locations close to the airport site, in the area of Badgerys Creek. Maximum noise levels of 70 – 75 dBA can be expected within built-up areas in St Marys and Erskine Park, which are predicted to occur once per day in 2030. For aircraft like Airbus A320 or equivalent noise levels are predicted to be 60 – 70 dBA in built-up areas around St Marys and Erskine Park, and

over 70 dBA in some adjacent rural residential areas to the south-west of the airport, such as Greendale. In the case of departures to the south contours extend towards The Oaks, Lake Burragorang and Bringelly.

- Noise impact over 24 hours - In 2030, the airport operating strategy is predicted to have a minor impact on the total number of residents affected at various noise levels over 24 hours232, although the location of the affected residents differs. Under any of the considered operating strategies, approximately 1,500 people are predicted to be exposed to at least 5 aircraft operations per day with maximum noise levels exceeding 70 dBA. None of these are in built-up residential areas.
- Night time noise impact – it is estimated that approximately 4,300 residents may be exposed to five events of above 60 dBA, which could potentially correspond to an internal noise level of approximately 50 dBA in rural residential areas to the south-west of the airport, including Greendale and parts of Silverdale and to the north-east of the airport around Horsley Park. Airport operating strategies that do not include a 'head-to-head' mode are predicted to result in substantially greater numbers of residents impacted by night time noise, and in particular, a 'Prefer 05' strategy would result in large parts of St Marys experiencing more than 5 aircraft noise events per night above 60 dBA in 2030.
- Greater Blue Mountains World Heritage Area (GBMWHA): Given the indicative airspace design for the proposed airport, parts of the GBMWHA area would be subjected to a large increase in aircraft overflights. The aircraft would be at heights generally greater than 5,000 feet above ground level. Maximum noise levels may occasionally reach 60 dBA at some points, but levels directly under a flight track would typically be below 55 dBA, and often much lower. Nevertheless, given the range of amenity issues that complement the biodiversity values and integrity of the World Heritage Area, a substantial increase in the number of audible overflights may be considered intrusive by recreational and tourist visitors to the property locations directly under indicative flight tracks, the number of audible aircraft overflights could be over 70 per day in 2030. The township of Blaxland could expect to experience aircraft overflights at significant altitude (typically over 5000 ft.) almost 100 times per day, with maximum noise levels ranging up to 55 dBA.

To provide an indicative 'worst case' representation, Figure 6-1 presents an overview of the annual average noise scenarios (N70 – daytime; N60 – night time) for operational noise impacts in 2030. It should be noted that these figures are composite Prefer 05 and Prefer 23 contours and consequently, show a larger combined area of noise impact than would be expected if one of the operating modes was adopted as a preferred mode.

Key findings of the overflight noise report for the nominal capacity of the first runway (2050) include:

- In a worst case scenario, the loudest aircraft operations may lead to maximum noise levels once every two days in 2050 and less often in earlier years for a small number of residential locations close to the airport site in Badgerys Creek (over 85dBA) and built-up areas in St Marys and Erskine Park (Penrith LGA) (75 – 80dBA).
- Noise impacts over 24 hours, the Prefer 05 scenario would impact more residents compared to the Prefer 23 scenario in 2050 (30,000 compared to 5,000 residents experiencing more than five events per day over 70dBA), with the majority located to the north in St Marys and Erskine Park. The Prefer 23 scenario would have a greater impact on residents to the south-west including Greendale (Liverpool LGA) and parts of Silverdale (Wollondilly LGA). These residents would be affected to a greater extent than those to the north – an estimated 700 residents in this area would experience more than 100 events per day above 70 dBA, compared with 300 residents under the "Prefer 05" scenario.

- Night time noise impacts would largely depend on the operating strategy in use. A Prefer 23 with Head-to-Head scenario would have the least impact in terms of total population affected, with approximately 40,000 residents in 2050 experiencing an average of more than five aircraft noise events per night above 60dBA in 2050, which would correspond to approximately 50dBA internal noise levels. Under this scenario, residents most affected would be in areas to the north-east of the airport including Horsley Park (Fairfield LGA), Blacktown and St Marys, with 5 – 10 noise events.
- Other night time operating scenarios would result in a greater number of residents impacted by night time noise. In particular, a Prefer 05 scenario would result in large parts of St Marys experiencing more than 20 aircraft noise events per night above 60dBA in 2050.
- Parts of the Greater Blue Mountains World Heritage Area (GBMWHA) would be subjected to a number of aircraft overflights, with maximum noise levels occasionally reaching 60dBA at some points, but generally below 55dBA, and often much lower. Locations directly under indicative flight tracks within the GBMWHA may experience over 200 audible flights per day in 2050, with worst-case locations being under one of two approach paths emanating from a 'point' merge in the lower Blue Mountains Based on the current nominal location of the proposed merge point, residents of Blaxland in 2050 may experience up to 230 overflights per day with noise levels ranging up to 55dBA.

The aircraft noise impacts in the longer term development would be similar to those described above. However, the total number of residents affected is generally higher, largely as a result of population growth and ongoing housing development. Ongoing land use planning would assist in managing population growth in areas likely to experience high noise levels.

It is important to keep in mind that these findings are based on indicative flight path design. If the proposed Western Sydney Airport is approved, the Australian Government would go through a process of finalising the indicative flight tracks having regard to the environmental impacts of aircraft noise exposure. This would enable a more accurate estimate of noise affected areas to be completed, and strategies to address noise issues would be developed.

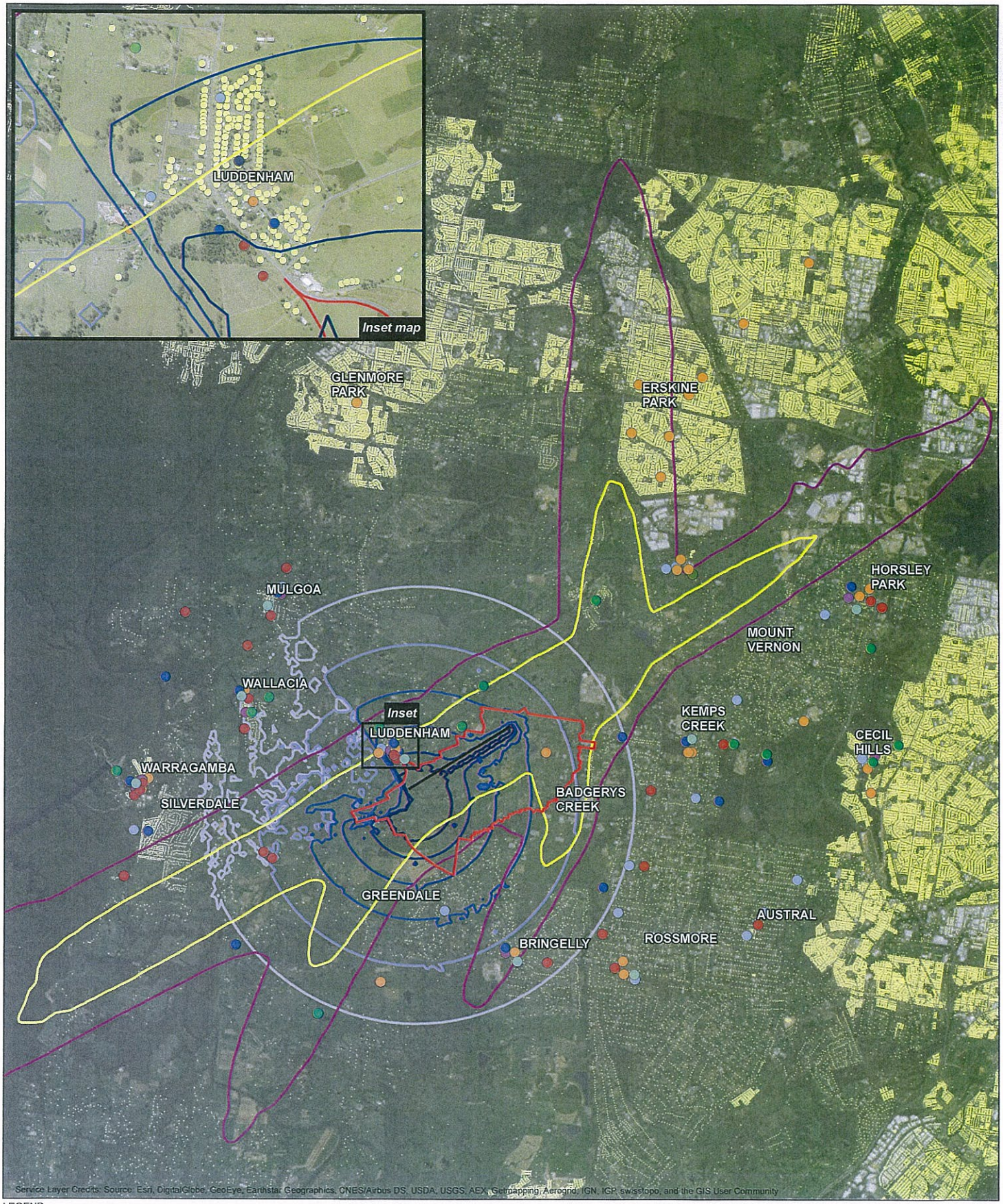
Assessment of impacts on social amenity and lifestyle

Based on the findings of the aircraft noise report, the proposed airport could lead to a reduction in social amenity and impacts on existing lifestyle for some communities in the local study area and Western Sydney region depending on the operating scenario adopted. The communities that could be most impacted by aircraft noise include areas of Badgerys Creek, Luddenham, Bringelly, Wallacia, St Marys and Erskine Park in the Penrith LGA, Greendale in Liverpool LGA, Silverdale in Wollondilly LGA, Horsley Park in Fairfield LGA, and parts of Blacktown. Many of these areas (particularly Greendale, Silverdale and Horsley Park) are semi-rural and large lot suburban areas with lower population density and therefore offer a relatively quiet lifestyle. It is likely that some sensitive social infrastructure in affected areas could also be subject to noise (including childcare centres, schools, churches, parks and recreation facilities, hospitals and other health care facilities) which may impact on their users. However, long standing land use planning controls have been applicable to the majority of these areas and have prevented incompatible development. The impacts of noise on health including sleep disturbance is discussed in section 6.5.6.

The uncertainty over the location of flight paths and airport operating modes that may be adopted could cause anxiety among the local community. This could be exacerbated due to the timeframes required to develop and certify a comprehensive airspace design for the proposed Western Sydney Airport, which is expected to occur prior to operations commencing at the airport.

The amenity of the GBMWHA is also expected to be impacted by an increase in overflight aircraft noise. Although the noise levels are expected to be lower than levels that would interrupt conversation, noise is expected to be audible. An increase in the number of audible overflights may be considered intrusive by recreational and tourist visitors to the property and communities in the GBMWHA more generally. Substantial areas within the GBM World Heritage property predicted to be by aircraft overflight noise are ‘Special Areas’ managed by WaterNSW. Public access to these areas is prevented, and therefore overflight noise impacts would not impact people in these designated ‘Special Areas’.

Other recreational areas that are valued for environmental and lifestyle value and which may also be impacted by aircraft noise are discussed and assessed in section 6.8 and 6.10 and identified in the planning and land use assessment. Particular areas in rural or more isolated locations such as the Bents Basin Recreational Area in Greendale, Rossmore Grange, Twins Creek Golf and Country Club, Whalan Reserve at St Marys, Burragorang State Conservation Area and a small part of the Western Sydney Parklands and Prospect Nature Reserve would likely have a reduction in amenity for users.



LEGEND

- Airport site

Sensitive receivers

- Residential
- Aged Care
- Childcare
- Community Centre
- Education
- Park
- Recreation
- Religious Facility
- Shopping Centre

- 24 hours overflight noise impacts, N70 (n = 5-10) 2030
- Night time overflight noise impacts, N60 (n = 5-10) 2030

Ground Engine Run-Up Single Runway 2030

- 45dBA
- 50dBA
- 55dBA
- 60dBA
- 65dBA
- 70dBA

Paper Size A3

0 1,000 2,000 4,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

Social infrastructure and residences potentially affected by worst case operational noise envelope in 2030

Job Number	21-24265
Revision	A
Date	30 Sep 2015

Figure 6-1

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6.5.2 Ground-based airport noise sources

The *Assessment of Ground-Based Operational Noise* (Wilkinson Murray 2015b) considers the impacts associated with ground running of aircraft engines, taxiing of aircraft, road traffic changes in the surrounding area including construction generated traffic, and construction noise.

Terminology

For the purpose of the ground-based noise study, an overall noise criterion of 50dBA is adopted for indoor levels and 60dBA for outdoor levels for residential and other sensitive receivers such as schools and churches. 60dBA is also adopted for parks and recreation areas, as this is the level a person may need to raise their voice to be heard properly in conversation.

Summary of ground-based noise impacts

Predicted impacts of ground-based noise are summarised below.

- Construction noise would be mostly confined to the airport site, however some impact to the west of the airport site near Luddenham, and to the north-east around Badgerys Creek is expected.
- Increases in road traffic noise levels from construction vehicles (heavy and light) using Elizabeth Drive would be minimal, and vibration from construction is not likely to damage buildings.
- Apart from the M12, road traffic increases on regional roads would not result in notable noise level increases.
- In 2030 under worst case meteorological conditions, the impact from aircraft engine ground running at high power levels and taxiing has the potential to affect Luddenham, Mulgoa, Badgerys Creek, Bringelly, Wallacia and Greendale.

Impacts on social amenity and lifestyle

Based on the outcomes of the ground-based noise study, the proposed airport may lead to minor changes in social amenity and impact on existing lifestyles for communities close to the airport site, particularly Luddenham, Mulgoa, Badgerys Creek, Bringelly, Wallacia and Greendale. The impacts of ground-based noise in these communities would be expected to lead to changes to the semi-rural and relatively quiet nature of these areas. In addition, noise impacts would be expected for a number of community facilities in Luddenham and Mulgoa including five schools and child care facilities, three places of worship, six recreational areas/parks. However it is possible that with the other planned developments in the Western Sydney region (section 5.6) the semi-rural character of these areas is also likely to change in the future.

6.5.3 Air quality

The *Local Air Quality and Greenhouse Gas Assessment* (Pacific Environment 2015a) found that there would be reduced air quality as a result of the operation of the proposed airport for some areas within five kilometres of the airport site. Aside from off airport road vehicle emissions (which would make up the majority of anticipated emissions), aircraft movements were found to be the largest source of pollutants during the Stage 1 development. Other factors contributing to reduced air quality were on-site equipment, power sources, and ground operations.

During operation of Stage 1, there are no predicted exceedances of the air quality criteria at any receptors for any reporting periods. Receptors to the north and north-east of the airport site (including those in the towns of Luddenham, Wallacia) would be likely to have the greatest

exposure to increased emissions levels due to the prevalence of south-westerly winds and the proximity of these receptors to the proposed airport. Increased road traffic due to population growth and airport-related traffic on surrounding roads is also expected to contribute to reduced air quality for receptors located near these roads.

During the longer term development, Greendale, Badgerys Creek, parts of Rossmore, south of Wallacia, north east of Luddenham and Mt Vernon would be expected to experience minor reduction in air quality associated with exceedance of short term (one hour average) objective for nitrogen oxide concentrations. These elevated concentrations would only be predicted to occur for between 1 and 2 hours per year as a result on emissions from the airport together with emissions from roadways and background sources.

Construction air quality impacts are expected to be temporary and isolated in nature, with routine mitigation measures employed on other construction sites considered capable of addressing these issues. However given the long construction period, the assessment recommends particular attention be given to controlling particles generated by vehicles travelling on unsealed roads and transporting materials onto the road network.

Management and mitigation measures to address air quality impacts associated with aircraft taking off and landing would mostly be beyond the remit of the proposed airport operator, however the study identifies potential measures which could be implemented by terminal operators and individual airlines. To address community concerns about potential air quality related impacts, the report recommends undertaking air quality monitoring within or in the vicinity of the proposed airport to provide robust data which demonstrates that local air quality changes associated with the proposed airport are within regulatory guidelines.

Impacts on the regional air quality (such as ozone) from the airport are assessed in Regional Air Quality Assessment (Ramboll Environ, 2015). The report predicts that both the 2030 Base Case and the 2030 Airport Case were above the National Environmental Protection Measure (NEPM) criterion of 100 ppb for all but one day of analysis. The peak predicted 4-hour ozone concentration was unchanged between the 2030 Airport Case and the 2030 Base Case on seven days and increased on five days, by a maximum of 0.1ppb.

The highest change in daily maximum 4-hour ozone concentration, from the addition of airport emissions, was 2.3 ppb, while the second highest was 1.1 ppb. The average of the 2nd to 4th highest change in daily maximum 4-hour ozone was 0.8 ppb, which is below the maximum allowable increment of 1 ppb.

Decreases in daily maximum ozone occur only in the vicinity of the airport site for the 2030 Airport Case and are attributable to ozone suppression by NOx emissions. Increases in ozone occur downwind of the airport site which, on most days, is to the south.

For the longer term development a hypothetical scenario was developed and assessed. The maximum predicted one hour ozone concentration was unchanged between the 2030 base case and the 2063 ‘with airport’ case for seven of the analysis days. On five days, the peak predicted one hour ozone concentration increased, by a maximum of 0.3 parts per billion (ppb). Both the 2030 base case and the 2063 ‘with airport’ case were above the NEPM criterion of 100 ppb for all but one day of analysis.

Larger ozone increases were modelled for the 2063 ‘with airport’ case than for the 2030 ‘with airport’ case. The average of the second to fourth highest increases in daily maximum one hour ozone rose from 1.1 ppb for 2030 to 4.7 ppb for 2063. This is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

The peak predicted four hour ozone concentration was unchanged in seven days and increased by five days, by a maximum of 0.3 ppb. The highest change in daily maximum four hour ozone concentration, from the addition of 2063 airport emissions, was 6.8 ppb, while the second

highest was 5.9 ppb. The average of the second to fourth highest increases in daily maximum four hour ozone is 4.0 ppb, which is significantly above the maximum allowable increment of 1 ppb defined in the NSW tiered procedure for ozone assessment.

In the 2063 'with airport' case, reductions in daily maximum ozone, due to ozone suppression by NOx emissions, occur in the vicinity of the airport and on some days extend to the aircraft flight corridor and areas downwind of the airport site. Areas of ozone reduction are more expansive for the 2063 than for 2030 because NOx emissions from the airport are higher in 2063. Increases in ozone occur downwind of the airport and also are larger for the 2063 than for the 2030. Based on this assessment the effects of ozone on communities is discussed in the community health section below (6.5.6).

Impacts on social amenity and lifestyle

Based on the outcomes of the air quality study, development of the proposed airport Stage 1 operations and longer term development may lead to changes in air quality for communities close to the airport site, including the townships and surrounding areas of Luddenham, Wallacia, Greendale, Badgerys Creek, Rossmore, Mt Vernon and Kemps Creek. However it should be noted that emissions from the proposed airport's operations will be within the permissible levels. As semi-rural areas, these areas are likely to value the clean, fresh air afforded by the location compared to more urbanised areas. Impacts of changes in air quality can result in health impacts for communities, which are discussed in section 6.5.6 below.

6.5.4 Transport and access

The *Surface Transport and Access Study* (GHD, 2015) found that the proposed airport would lead to an increase of traffic on the local road network during both construction and longer term operation. The key major roads surrounding and connecting to the site would include the M7 Motorway, The Northern Road, Elizabeth Drive, Bringelly Road, Badgerys Creek Road, Adams Road and Mamre Road. The study found that the strategic road network (i.e. the M7 Motorway and other arterial motorways including the M4 and M5) currently experiences capacity constraints during peak periods, however the immediate area surrounding the site does not exhibit much congestion.

The construction phase would lead to an increase of construction traffic by additional 1,254 vehicle movements per day on the road network surrounding the airport site. Currently, there are approximately 70,000 vehicle movements on the existing road network. The expected distribution and volume of construction traffic would suggest that there would be approximately 160 additional vehicle movements (to and from the airport site) on Elizabeth Drive during the AM peak and 150 additional vehicle movements (to and from the airport site) on Elizabeth Drive during the PM peak which would mean an additional 310 vehicles per day (which is an average of 4 per cent increase in the daily vehicle movements). It is expected that this would have a minor to negligible impact on the semi-rural lifestyles of residents in properties surrounding the site, due to an increase in vehicles on the road and the associated increase in noise and decrease in air quality.

Although Stage 1 operation would result in an increase in passenger, employee and freight trip generation, this is considered to be small based on current traffic movements. Overall there would not be a notable decrease in the level of service of the road network due to the proposed upgrades as part of the WSIP as well as those identified in the WSEA (refer to section 5.6.3). Together, these projects would provide sufficient capacity to cater for the expected airport passenger and employee traffic demand in 2031 as well as general traffic in the area. The public transport and walking and cycling systems proposed by the NSW Government and local councils would also have sufficient capacity to cater to the expected airport passenger and employee demand.

The longer term airport operations and forecast development growth in Western Sydney would have cumulative impact on both the roads and transport systems. The longer term airport operations will also rely reliant on the extension of the South West Rail Link. Even so, the expected increases in demand for 2063 suggest that planning is required to preserve additional corridors and transport upgrades to cater for the population and travel growth associated with the airport and surrounding developments.

Impacts on social amenity and lifestyle

Based on the outcomes of the traffic and access study outlined above, the proposed airport may lead to an increase in traffic on roads surrounding the site. This would be expected to have a minor impact the social amenity and lifestyle of these semi-rural areas, particularly during Stage 1 construction. Stage 1 operation would also result in an increase in traffic, however with the planned upgrades of surrounding roads and introduction of new roads in areas surrounding the site, the increase in traffic would not be expected to result in major capacity issues.

The longer term operation would lead to an increase of traffic on roads in Western Sydney, which along with future population growth, may lead to road capacity issues if planning is not undertaken sufficiently early. This would require future planning beyond current road upgrade plans and the potential extension of public transport such as the South West Rail Link to reduce impacts on Western Sydney communities.

6.5.5 Landscape character and visual

The landscape and visual assessment (RPS, 2015) concludes that visual impacts will occur during Stage 1 and longer term development of the proposed airport. The construction and operation of the airport would result in landscape changes at the site, views of overflights, and impacts from construction and operation lighting on-site. The assessment indicates varying levels of impact on different communities depending on their distance and elevation from the airport site, the presence of visual obstructions such as vegetation or terrain, their cultural and recreational values and their location with respect to the orientation of the runways and flight paths.

Key findings from the visual assessment include:

- The proposed airport development would involve substantial modification of the landscape and the existing rural visual quality in the area to a more urbanised and commercial character.
- The Stage 1 and longer term development would likely have the most visual impacts on areas to the north such as Luddenham and Badgerys Creek due to their relatively proximity to the airport as well as areas to the south of the airport such as Bringelly, Greendale and Bents Basin due to aircraft overflights.
- Surrounding rural residential areas at higher elevations such as Mount Vernon, Silverdale and Rossmore would experience moderate to low visual impact due to views of the airport site. The impact would, however, be increased by aircraft overflights.
- Visual impacts at selected important cultural and recreational areas, including the Bents Basin State Recreation Area and Blue Mountains would range from moderate to high due to the high sensitivity ratings of the viewpoints and the effect of aircraft overflights.

Impacts on social amenity and lifestyle

Based on the outcomes of the visual and landscape study outlined above, the proposed airport would lead to changes to the visual landscape at the site. This would be likely to impact on semi-rural communities close to the site to the north (Luddenham and Elizabeth Drive) which

previously enjoyed a rural landscape, including those communities which have a view over the site (Mount Vernon, Silverdale and Rossmore). Areas to the south of the site (e.g. Bringelly and Greendale) would be likely to experience reduced visual amenity as a result of overflights. As discussed in section 6.5.1, the value of recreational areas such as Bents Basin State Recreation Area may also be reduced for users as a result of the visual impact due to the proximity of overflights.

6.5.6 Community health

A community health risk assessment (HRA) aims to quantify the impacts of hazards on human health. The HRA is a document that assembles and synthesises scientific information to determine whether a potential hazard exists and/or the extent of possible risk to human health.

While there are a number of potential pathways by which the airport development may influence human health, this study has focussed on air quality, noise and surface and groundwater. The health risk assessment for the proposed airport has been conducted in accordance with the Australian Government *Health Risk Assessment Guidelines* (enHealth, 2012) as well as publications and information from other agencies such as the National Environment Protection Council (NEPC) and World Health Organisation (WHO). Consultation was also conducted with NSW Health and local area health services and additional advice and requirements have also been incorporated into this report. Findings from the HRA report (Pacific Environment, 2015b) are summarised below with regard to their relevance to social impacts. It should be noted that all predicted outcomes of the health assessment are based on worse case scenarios/values with no mitigation measures in place.

Air quality

The potential health effects attributable to emissions of particulate matter (PM_{10} and $PM_{2.5)}$, nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon monoxide (CO) generated by the airport were assessed. Baseline health statistics for Sydney were used in the assessment. The risk was assessed for the areas and receptors used in the EIS local air quality assessment, which are generally within 5 km of the airport site boundary.

To calculate the likely effect of the emissions on people, exposure-response functions measured by Australian studies for each outcome were used. These functions are a measure of the change in the health outcome within the population for a given change in emission concentration. Using the predicted concentrations of emissions at representative receptors and the exposure-response functions, the health effects attributable to emissions were calculated. The number of attributable cases is the increase in the number that may arise from exposure, for example hospital admissions for respiratory disease.

The health risk assessment has shown that the highest risk would arise from exposure to PM_{10}, $PM_{2.5}$ and NO_2. A summary of these issues is provided below.

Particulate matter

The results of epidemiological studies have shown that a wide range of health effects are associated with exposure to PM_{10}. These include increases in daily mortality, hospital admissions for respiratory disease, cardiovascular disease, cardiac disease, pneumonia and bronchitis and emergency room attendances for asthma.

The largest source of PM_{10} and $PM_{2.5}$ (and other emissions) from aviation activities are aircraft movements, with the majority of emissions occurring during take-off and landing.

For operation of the Stage 1 development, the predicted number of attributable cases from PM_{10} is low. The highest risk is predicted for Kemps Creek with an additional 1 death per 10 years

predicted in a 2011 population of 2,309. All other risks would be lower than the risk predicted for long-term mortality.

The predicted number of attributable cases from $PM_{2.5}$ would also be low. The highest predicted risk would be for all-cause mortality and cardiopulmonary mortality from long-term exposures with between one additional death per 1000 years and six additional deaths per 100 years attributable to $PM_{2.5}$. The highest risks are predicted for Kemps Creek and Rossmore which is a total population of 4,721. All other risks would be lower than that predicted for these outcomes.

Construction risks for both PM_{10} and $PM_{2.5}$ were also modelled and analysis showed that construction emissions were lower than those for the operational scenarios. For construction, the highest PM_{10} and $PM_{2.5}$ impacts would be expected at Luddenham, Bringelly, Kemps Creek and Badgerys Creek.

NO_2

There has recently been increased interest in the health effects of nitrogen dioxide. WHO investigated the new studies of both long-term and short-term exposure to NO_2 and associations with mortality, hospital admissions and respiratory symptoms and concluded that these new studies show that short-term exposure to NO_2 is associated with increases in these outcomes. Studies of the long-term effects of exposure to NO_2 have also shown associations with both mortality and morbidity outcomes.

The main sources of NO_2, with the exception of roadways external to the airport site, would be aircraft engines for both Stage 1 and the longer term development scenarios. The operation of Auxiliary Power Units (APUs) and ground support equipment (GSE) would have an influence on the predicted pollutant concentrations.

The results of the health risk assessment show that the risk predicted from NO_2 emissions during operation would be higher than that predicted for PM_{10} and $PM_{2.5}$. The highest predicted risk would be for long-term mortality in people over 30 years of age with between six additional deaths every 100 years and six additional deaths in 10 years predicted for 2030. Similar risks are also predicted for 2063. The most affected areas are likely to be Luddenham, Bringelly, Kemps Creek, Wallacia and Rossmore. It should be noted that the expected NO_2, PM_{10} and $PM_{2.5}$ emissions will be below the relevant air quality standards in Australia.

The vast majority of NO_2 emissions from the airport (approximately 90 per cent) would be generated from aircraft engines. The air quality modelling was conservative by assuming the majority of the APU and GSE fleet were diesel-powered, whereas it is recommended that the proposed airport adopt best industry practice and utilise electric-powered APUs wherever possible. Other mitigation measures as part of the air quality and surface transport and access studies will also act to reduce overall emission levels including for particulates and NO_2.

The calculations also assume that fuel quality standards and engine emissions do not change in the future. This is another conservative factor embedded in both the emissions calculations and the health risk assessment.

Ozone

Ozone is a secondary pollutant and is formed from precursors such as oxides of nitrogen and volatile organic compounds. Baseline monitoring results in Sydney indicate that while there is significant year-to-year variability in the ozone levels in cities, there are exceedances of the NEPM standards observed each year. Ozone levels are influenced by hot summers (temperature) and bushfires.

The main health effects associated with exposure to ozone are effects on the respiratory tract. There are both long-term and short-term effects of ozone on health. Studies reviewed by WHO

have shown that long-term exposure to ozone has an impact on people with existing disease, in particular people with chronic obstructive pulmonary disease, diabetes, congestive heart failure and myocardial infarction. Long term exposure to ozone has also been associated with an increase in asthma incidence, asthma severity, hospital care for asthma and lung function growth, lung damage and persistent structural airway muscle tissue changes.

Short-term effects associated with daily maximum one hour and eight-hour ozone concentrations with all cause, cardiovascular and respiratory mortality as well as cardiovascular and respiratory hospital admissions.

The regional air quality assessment (Ramboll Environ, 2015) predicted changes to ozone concentrations for airport operations in both 2030 and 2063. The adopted methodology follows the NSW EPA tiered assessment procedure which has, however, some limitations when used for health risk assessment purposes. A health risk assessment requires a full year of predicted concentrations which takes into account the variability in ozone from day to day and season to season. However the NSW EPA procedure specifies only a limited number of days is required within the peak ozone formation period. Using this as the basis of the health risk assessment therefore is challenging and may underestimate or overestimate the risk. The health risk assessment has been conducted based on the predicted maximum ozone concentrations in each year to provide an indication of the potential risk associated with increases in ozone concentrations from airport operations.

For the projected base case in 2030, the corresponding health risk for the outcomes assessed is between 2 in a million (respiratory mortality) and 1.8 in 100,000 (emergency department attendances). For 2030 operations, the increase in risk ranges from 1 in 1 million (respiratory mortality) to 9 in 1 million (emergency department attendances).

There is general agreement by international agencies, including the WHO and USEPA, that acceptable risk levels fall between 1 in a million and 1 in 100,000. The predicted increases in risk fall within these limits.

The regional air quality assessment also indicates that there is no difference in maximum predicted ozone concentrations between 2030 and 2063, This is because the peak predicted daily ozone is largely unchanged between base case (all other emissions source) and the airport case and for both 2030 and 2063 the base case is the same. The largest predicted ozone concentration changes from the airport occur in a different location to the predicted daily peak ozone concentrations. Decreases in daily maximum ozone occur only in the vicinity of the airport and are attributable to ozone suppression by fresh NOx emissions. Increases in ozone occur downwind of the airport which, on most days, is to the south and southwest.

The risk assessment has shown that for selected days of analysis there are small increases in risk of daily mortality from all causes, cardiovascular and respiratory causes as well as emergency department visits for asthma in children. The risk estimates for these days are within acceptable risk levels generally accepted by international agencies.

Surface and groundwater

There are 42 registered groundwater bores within a five kilometre radius of the centre of the airport site. Twelve of these bores are registered as being used for domestic, stock, industrial, farming and irrigation purposes. The depth of registered extraction bores indicates that the majority of groundwater users extract water from the Bringelly Shale and Hawkesbury Sandstone aquifers, which due to high salinity levels is considered unsuitable for potable use.

The site has historically been used for a wide range of agricultural, industrial, commercial and rural-residential activities which have the potential to generate a range of contaminants in soil and groundwater. There is likely to be considerable overlap of those contaminants associated

with historical site activities and the potential contaminants that may be associated with future construction and operation of the airport. Baseline groundwater data are necessary to enable identification of the current baseline conditions from which to monitor future performance of the airport.

The contaminating activities which may occur during construction and operation of the airport may also have the potential to result in surface water contamination. Aircraft movements at the site during operation may result in increased deposition of particulates in surrounding waterways. Based on the results of the air quality modelling for the operation of the airport, the potential for deposition of particulates is very low with the maximum annual concentration of PM_{10} for Warragamba predicted to be 0.02µg/m^3.

The outcomes of the risk assessment suggest that there is a need to collect additional data to fill identified data gaps and enable a more robust assessment of current and potential future risks to groundwater and surface water receptors, including rain water tanks. Construction risks can be reduced by the implementation of standard construction mitigation measures which are typically effective in reducing identified risks.

Consideration should be given to a pre- and post-construction monitoring program to test the quality of local tank water and monitor any changes to the quality of the water over time. This would enable informed decisions to be made about implementation of any necessary mitigation measures in a timely manner.

Fuel jettisoning

Fuel jettisoning instances are very rare for commercial aircraft and only occur in emergency situations where an unscheduled landing is required. Where fuel jettisoning is considered necessary, the pilot is required to contact air traffic control and to take any reasonable precautions to ensure the safety of people and property on the ground and in the air, and where possible, undertake fuel jettisoning at a minimum altitude of 6,000 ft. Most fuel is considered to evaporate within 100 metres with only a small amount of fuel likely to reach ground level from this height (if at all). There has been no recorded instance in Australia of jettisoned fuel reaching the ground.

Most aircraft which fly shorter haul, domestic routes do not have the capability to jettison fuel as they can land fully fuelled. However, larger aircraft used on longer domestic and international flights do have fuel jettisoning capacity.

Noise

In recent years, evidence has accumulated regarding the health effects of environmental noise. Epidemiological studies have found that cardiovascular diseases are consistently associated with exposure to environmental noise. The WHO has released two reports on the health effects of environmental noise: *Guidelines for Community Noise* (1999) and the *Burden of Disease from Environmental Noise* (2011). In these documents, the main health effects associated with environmental noise are:

- annoyance;
- sleep disturbance;
- cardiovascular disease; and
- cognitive impairment.

A number of representative residential locations and education facilities were selected to analyse the potential health risks from airport ground-based and overflight noise. This comprised eleven residential and fourteen schools in areas predicted to be affected by varying

levels of airport noise - both within the area immediately surrounding the airport as well as further afield. Both night time and daytime noise levels and effects on people were considered as well as possible short and long term effects.

For night-time noise, the draft EIS aircraft overflight noise report concluded that the extent of night time noise impact would depend on the airport operating strategy, and in particular, the adoption of a possible “head-to-head” operating mode.

In terms of total population affected, the operating strategy with least impact is “Prefer 23 with Head-to-Head”. Under this strategy, as estimated 4,300 residents may be exposed to five events per night of above 60 dBA in 2030, in areas to the south-west of the airport, including Greendale and parts of Silverdale and to the north-east of the airport around Horsley Park and an estimated 41,000 residents would experience an average of more than five aircraft noise events per night above 60 dBA in 2050. Under the above scenario, the affected residents would be largely in areas to the north-east of the airport, including Horsley Park and parts of Blacktown. However some residents to the south-west of the airport would be more severely affected.

The alternative airport operating scenario, Prefer 05, is predicted to result in substantially greater numbers of residents impacted by night time noise, including large parts of St Marys experiencing more than 20 aircraft noise events per night above 60 dBA in 2050, but remain the same as above under either of the scenario in 2030.

Sleep disturbance has been described in terms of both EEG awakenings and full awakenings. An EEG awakening is a measure of disturbed sleep whereas a full awakening is indicative of a fully wakened state.

In terms of EEG awakenings, for Stage 1 development, aircraft overflights were estimated to result in 0-40 EEG awakenings under either airport strategy including head to head operations. In the longer term, the Prefer 05 operating strategy would result in 0-110 EEG awakenings per person per year particularly in Greendale and Luddenham while the Prefer 23 would result in 0-50 EEG awakenings per person per year, particularly in Luddenham.

For ground-based noise sources, the results indicate that there would be between 0-380 EEG awakenings for the proposed Stage 1 development and between 0-790 for the longer term development. In both cases, the most severe effect would be experienced in Luddenham.

EEG awakenings cannot be considered a health effect in themselves, however they are considered to be early warning signals for other health effects when the values rise above the background levels of around 24 EEG awakenings per night (EEA, 2010). It should also be noted that the dose-response curves used in this analysis are derived from European studies where in general the buildings are better insulated due to climatic conditions. This means that the calculated number of additional awakenings may underestimate the impact in areas surrounding the proposed airport.

In terms of full awakenings, the number of predicted additional awakenings per year due to aircraft overflight noise would be between 0-5 per person in 2030 and between 0-10 per person in 2063. A higher number of awakenings are predicted for 2063 with the most affected areas including Luddenham, Greendale and Horsley Park.

The noise from ground based operations would have a greater impact in the suburbs closest to the proposed airport, in particular Luddenham. In 2030, the number of additional awakenings is calculated to be between 0-18 and in 2050 between 0-20. The combined effects of aircraft overflight and ground based operations noise is predicted to lead to an additional 30 awakenings per person per year in Luddenham in 2050. Other affected areas include Greendale, Rossmore and Bringelly.

As with the EEG awakenings, the dose-response curves have been derived from European studies and may underestimate the impact in the area surrounding the proposed airport.

As outlined in the noise technical reports and this SIA, there will be a process of finalising the indicative flights tracks which will enable a more accurate estimate of noise affected areas to be completed prior to commencement of operations.

Potential risks to potable water supply

There is a potential that aircrafts may fly over the catchment of the Warragamba Dam and Prospect Reservoir and accordingly, the airport operations activities may impact on the quality of water within these storages. However, there is currently no data available which can be used to assess whether emissions from aircraft operations would result in increased loading of contaminants to surface waters (including tank water supplies).

6.6 Demographics

As discussed in section 6.2, it is anticipated that the majority of the Stage 1 and longer term development workforce requirements for the proposed airport would be met by the existing and forecast labour pool in the Western Sydney region and the Greater Sydney.

Population growth has been forecast for Western Sydney and Greater Sydney even without the airport (from 2016 to 2063 and beyond). The growth in Western Sydney is anticipated due to factors such as housing affordability, availability of land for residential developments and the various development initiatives planned for Western Sydney (refer to Appendix B, section 3.1 and 5.4).

The proposed airport accelerate this growth, but would not be the sole factor contributing to the growth in Western Sydney and Greater Sydney. It is anticipated that the majority of the proposed airport workforce would be existing residents of Western Sydney, with some moving into the area permanently with their families and a small proportion commuting to the proposed airport on a daily basis from other parts of Greater Sydney. It is quite common in larger metropolitan cities for people to commute longer distances for competitive work opportunities.

The Economic Impacts of WSA Stage 1 (EY, 2015) states that by 2031 the proposed airport will result in an additional population of 17,823 in Western Sydney area. Strongest growth is estimated to occur in the following LGAs:

- Penrith
- The Blue Mountains.
- Blacktown
- Wollondilly
- Camden.

This population will be redistributed away from other parts of Sydney and NSW. The LGAs which will see a slowing of population growth as a result of this redistribution include Sydney, Parramatta, Bankstown and Hornsby.

Based on the population forecast data (Appendix B), it is predicted that the population in Western Sydney will continue to be younger than in other parts of Sydney and may also have a lesser proportion of the population over 65 years of age compared to the rest of Sydney. This could be because relatively cheaper housing in Western Sydney has and will continue to attract younger people starting out in life, in particular young families or soon-to-be families who wish to raise a family in areas that are less densely populated. Additionally, employment opportunities

generated by the proposed Western Sydney Airport and other development in Western Sydney will continue to attract a younger population.

6.7 Housing and accommodation

As discussed in sections 3.2 and 5.4, the majority of the Stage 1 and longer term development workforce for the construction and operation of the proposed airport would likely be sourced from Western Sydney and the Greater Sydney region. It is expected that these workers will be existing residents of these areas and will commute to work on a daily basis. It is possible that a small number of technical specialists may be sourced from other parts of NSW, Australia, or internationally and may require temporary short or long term accommodation. It is anticipated that these workers would be housed in existing or proposed new housing in the Western Sydney region or Sydney. Since such demand is expected to be very small, it is not likely to impact on the availability of either temporary or permanent accommodation facilities in the Greater Sydney region as a whole.

The SIA stakeholder consultation identified that the Western Sydney region has the capacity to develop additional accommodation facilities and associated services to take advantage of the potential increase in demand for such facilities and services from the operation of the airport. This is a natural development associated with international airports, with business travellers, flight crews, and international tourists being most likely to use this form of accommodation.

The proposed airport workers who are anticipated to be residents of the Western Sydney region may comprise:

- Long term residents of the region availing of work opportunities at the proposed airport during Stage 1 and longer term development
- Some long term residents of the region, working in other parts of Sydney, would give up their employment to take advantage of work opportunities closer to home
- Some who would move to the Western Sydney region as part of the overall growth of the region and
- Some who would move to the region specifically to work at the proposed airport.

It is not possible to accurately predict exactly how many workers and their families would move to the area specifically due to work opportunities at the proposed airport versus those who would move to the region as part of the overall development growth. However, as the total workforce required for the proposed airport Stage 1 is only a small proportion of the total labour pool available and forecast for the Western Sydney region, it can be assumed that during Stage 1 there would be a small number of the proposed airport workers who may choose to move to the region, therefore generating a small demand for long term housing in the Western Sydney. It is possible that this small demand for housing from the proposed airport Stage 1 operational workforce could be absorbed by the housing development proposed for the Western Sydney region.

As identified in Appendix C and E, Western Sydney offers housing that is more affordable compared to the rest of Sydney. Average incomes in Western Sydney including Western Sydney are lower than the Greater Sydney region average income, with some of the LGAs showing high socio-economic disadvantage on the SEIFA index. It is likely that the overall population growth in Western Sydney (with the proposed airport as a catalyst) may increase overall demand for long term housing potentially creating housing availability and affordability issues, which may particularly disadvantage groups who are already vulnerable or disadvantaged.

6.8 Impacts on social infrastructure

As discussed in sections 6.2 and 6.5.5, the proposed airport is likely to result in a small increase in the population of Western Sydney due to some of the operational workforce moving into the region. This small increase in population would generate additional demand on social infrastructure in the region. For the purpose of this assessment, social infrastructure incorporates the facilities and services that are used for the physical, social, cultural or intellectual development or welfare of the community. It includes physical infrastructure such as libraries, community centres and cultural facilities that facilitate the delivery of social services and activities, as well as open spaces, parks, recreation areas and sport fields that support sport, recreational and leisure uses. Importantly, social infrastructure also incorporates the services, activities and programs that operate within these built facilities. Social infrastructure is not limited to that provided by Federal, State and Local Governments. It also includes those services and facilities that are operated by non-profit community organisations as well as the private sector.

It is anticipated that construction of the Stage 1 development would not generate demand for social infrastructure in the areas near the airport site, because of the local and temporary nature of construction work it is anticipated that the workers will be residents of the Western Sydney or Greater Sydney and will access social infrastructure facilities and services at their area of residence.

The Stage 1 and longer term operational workforce at the proposed airport may impose additional demand on social infrastructure in areas near the airport. For example, workers at the airport may choose to use local services such as child care, medical services (e.g. General Practitioners, dentists, pharmacies), and recreational facilities (e.g. swimming pools, gymnasiums, public parks) and this may increase competition with existing residents. This was raised as a potential impact during stakeholder consultation for the SIA.

Consultation with the NSW Department of Education and Communities (DEC) indicated there may be some impact on demand for schools as a result of the operational workforce. Some workers may prefer their children to attend a school near their workplace, which is an existing trend at schools near Sydney (Kingsford Smith) Airport (Sydney Airport). While DEC catchments for public schools are based on where students live, DEC may allow students to attend a school near their parent's workplace if there is capacity at the school, however this would be at the discretion of the DEC and require a policy review.

As discussed in 5.4 and Appendix B, the population of the Greater Sydney region is expected to grow significantly over the coming decades, with much of this growth expected to occur in Western Sydney. This population growth will lead to increased demand for all types of social infrastructure.

Planning is currently underway by the NSW Government and relevant Councils to determine what is required to service the existing and future populations of the areas already identified for new growth (e.g. Growth Centres).

However, with the announcement in April 2014 that Badgerys Creek will be the site of the proposed airport, it is likely that some of these agencies have not yet probably considered the impact of the proposed airport on future population growth, which was confirmed during consultation with agencies for this SIA. As a catalyst for development in Western Sydney, the proposed airport may result in the following changes to the expected population growth:

- A faster rate of population growth.
- Additional population growth.
- Changes in the expected profile of future residents and workers.

- Some locations may experience more or less growth.

All of these factors would impact on social infrastructure planning and provision, and therefore on the lives of Western Sydney residents and workers. To meet the increasing demand, NSW Government agencies and Councils will need to plan for the appropriate, timely and well-located provision of social infrastructure for Western Sydney communities, to meet the future needs for both the proposed airport workforce and overall growth in Western Sydney. I

In addition to impacts posed by demand factors, as discussed in section 6.5, airport operational activities such as take-offs, landing, overflights and increased road traffic are likely to generate noise, visual and air quality impacts for sensitive social infrastructure such as child care, schools, hospitals, recreational spaces and places of worship. Impacts on such sensitive receivers are discussed in section 6.5 and in the respective draft EIS technical studies. These technical studies also discuss mitigation measures for such impacts.

6.9 Impacts on emergency services

The *Draft WSA Hazard and Risk Review* (R2A Due Diligence Engineers 2015) outlines that the lead construction contractor and future operator of the proposed airport would develop and implement safety protocols including an Emergency Response Plan. It is anticipated this would be developed in collaboration with all NSW emergency services and the Australian Federal Police (AFP) if required (see below). DIRD is also currently updating a Bushfire Management Plan for the site. It is anticipated that together, these plans will cover emergency response, first aid and basic medical services, fire prevention, firefighting equipment, and security.

An Airservices Aviation Rescue Fire Fighting Services (ARFFS) station is proposed for each runway at the proposed Western Sydney Airport, with a mutual aid agreement with the Rural Fire Service (RFS) expected to be in place before airport operations commence (R2A Due Diligence Engineers, 2015). During consultation, NSW Fire and Rescue services indicated that currently at KSA they are required to respond to situations surrounding the airport and some issues on-site e.g. situations at retail outlets in terminal buildings. This leaves the on-site ARFFS resources available to respond to airside operational emergencies. It is anticipated there would be similar arrangements at the proposed airport. NSW Fire and Rescue services anticipate that should local resources be required to assist with an emergency situation at the proposed airport, NSW Fire and Rescue would manage and re-distribute its resources from other areas to ensure that their ability to service local community is not impacted.

The *Draft Hazard and Risk Review* indicates that NSW Police have primary responsibility for security and safety issues associated with the proposed airport. However it has been suggested that consideration be given to providing an AFP station at the proposed airport similar to that at Sydney Airport (R2A Due Diligence Engineers, 2015). It is important to note that the decision on whether AFP services should be provided at the proposed airport will be a matter for the AFP and the Australian Government. An agreement regarding the respective roles of the AFP and NSW Police will be established as part of detailed operational planning for the airport.

NSW Ambulance was also consulted during the SIA process, to understand potential demand from the proposed airport in light of their current arrangements at Sydney Airport. The SIA was informed that NSW Ambulance does not have an on-site station at Sydney Airport. The existing station at Mascot responds to emergencies at Sydney Airport when a 000 call is received. NSW Ambulance does not expect an on-site station to be provided at the proposed airport unless there is major commercial and residential development at the airport. NSW Ambulance does not expect the proposed airport to directly impact its ability to service the local community.

The lead construction contractor of the airport would develop and implement safety protocols including an Emergency Response Plan in collaboration with all NSW emergency services and the Australian Federal Police. The Department of Infrastructure and Regional Development is

also currently preparing a Bushfire Management Plan for the site. It is anticipated that together, these plans will cover emergency response, first aid and basic medical services, fire prevention, firefighting equipment, and security.

In summary, the ability of emergency services to respond to local community needs are not expected to be impacted during the course of normal day to day Stage 1 and longer term activities at the proposed airport.

6.10 Summary of socio-economic impacts and assessment

Table 6-2 summarises the socio-economic impacts discussed in section 6 and assesses their significance rating as per the methodology outlined in section 2.2.6 for Western Sydney and the local study area communities.

Table 6-2 Summary of social impacts and their significance rating

Impact description	Western Sydney Airport development phase	Nature of impact	Impacted stakeholder groups/communities	Likelihood	Consequence	Significance rating
Economic, employment and industry benefits and impacts						
Economic benefits: During operations of the proposed airport, the value-add is expected to increase commensurate with passenger movements. In 2031 (roughly aligning with the end of the Stage 1 development), the proposed airport is estimated to generate an additional $205 million in value-add per year across Australia. Of this, $77 million of value –add will be generated in the Western Sydney region. In 2063, the proposed airport would increase value-add in the Australian economy by $5.8 billion. Of this, approximately $1.5 billion would be generated in the Western Sydney region.	Stage 1 construction Stage 1 operation Longer term development	Positive	Western Sydney and Greater Sydney communities	Almost certain	Major	Very high
Employment opportunities: The proposed airport development will generate a number of direct, indirect and induced jobs including: • Peaking of construction employment at 758 direct FTE jobs in 2022 in Western Sydney, which corresponds to approximately 3,200 cumulative person-years in Western Sydney over the construction period (from 2016-2024) (EY, 2015) • There would be indirect and induced employment generated for 8,000 person years in Western Sydney over the construction period between 2016-2024 (EY, 2015) • An additional 2,200 person years in the rest of Greater Sydney over the construction period between 2016-2024 (EY, 2015) • A total of approximately 7,500 direct FTE jobs would be required by the end of Stage 1 in 2030 for airport operations. In addition, a further 4,440 FTE jobs are forecast to be generated from commercial activities on business parks on the airport site (EY, 2015) • A total of approximately 61,500 direct FTE jobs would be required in the longer term in 2063 for airport operations. A further 27,150 FTE jobs would be generated from commercial activities on business arks on the airport site (EY, 2015).	Stage 1 construction Stage 1 operation Longer term development	Positive	Western Sydney and Greater Sydney labour pool	Almost certain	Major	Very high

Impact description	Western Sydney Airport development phase	Nature of impact	Impacted stakeholder groups/communities	Likelihood	Consequence	Significance rating
Employment opportunities: Stage 1 operations and longer term development may lead to some workers potentially giving up existing jobs to take up work at the proposed airport which may create vacancies/shortfalls in those industries. Given the availability of, and future growth in, the labour pool, job vacancies would be easily filled.	Stage 1 operation Longer term development	Negative	Existing industries/businesses in Western Sydney and Greater Sydney	Possible	Negligible	Low
Impacts on other industries: Business growth and development in other industry sectors such as construction, utilities, trade, transport and services, accommodation, retail, professional services and public administration is anticipated. This is anticipated to occur from the sourcing of goods and services for the proposed airport and well as through indirect and induced economic impacts.	Stage 1 construction Stage 1 operation Longer term development	Positive	Business/services in Western Sydney and Greater Sydney	Almost certain	Major	Very high
Impacts on other industries: Potential increase in tourism to GBMWHA and other surrounding recreational areas due to proximity to the airport and associated transport network.	Stage 1 operations Longer term development	Positive	Communities in and users of GBMWHA and other recreational areas	Almost certain	Moderate	High
Impacts on other industries: Changes to land use in Western Sydney due to the proposed airport development and other planned development may result in competition for land and labour and a consequential decline in industry sectors such as agriculture and manufacturing. Existing trends show that these industries are already in decline in Western Sydney.	Stage 1 operation Longer term development	Negative	Industry sectors such as agriculture and forestry and manufacturing	Likely	Minor	Medium
Demographic impacts						
Employment opportunities generated by the proposed airport may contribute to population growth by additional 17,800 persons by 2031 in Western Sydney, and will continue to grow in the future with new residents likely to be younger people attracted to employment opportunities and more affordable housing opportunities in Western Sydney.	Stage 1 operation Longer term development	Positive	Western Sydney communities	Possible	Negligible	Very low
Lifestyle, amenity and health impacts						
Lifestyle and amenity impacts: Reduced social amenity and rural/semi-rural residential lifestyle as a result of construction ground-based noise for areas close to the airport site	Stage 1 construction	Negative	Areas to the west (Luddenham) and north-east (Badgerys Creek) of the site	Almost certain	Moderate	High

Impact description	Western Sydney Airport development phase	Nature of impact	Impacted stakeholder groups/communities	Likelihood	Consequence	Significance rating
Lifestyle and amenity impacts: Reduced social amenity and rural/semi-rural lifestyle as a result of operational ground-based noise for areas close to the airport site.	Stage 1 operation Longer term development	Negative	Communities close to the airport site, particularly Luddenham, Mulgoa, Badgerys Creek, Bringelly, Wallacia and Greendale	Almost certain	Major	Very high
Lifestyle and amenity impacts: Reduced amenity of sensitive social infrastructure as a result of operational ground-based noise in areas close to airport site including five schools and child care centre, three places of worship, three parks, and three recreation facilities in Luddenham and Mulgoa.	Stage 1 operation Longer term development	Negative	Users of social infrastructure in Luddenham and Mulgoa	Almost certain	Moderate	High
Lifestyle and amenity impacts: Depending on the operating strategy adopted for the proposed airport, communities that may experience reduction in amenity as a result of aircraft overflights and operational noise could be Badgerys Creek, St Marys and Erskine Park in the Penrith LGA, Greendale in Liverpool LGA, Silverdale in Wollondilly LGA, Horsley Park in Fairfield LGA, parts of Blacktown, Blaxland (Blue Mountains). Some of these areas are semi-rural and large lot suburban areas with lower population density. It is expected that users of sensitive social infrastructure (e.g. childcare, schools, health facilities, churches, parks and recreation) in these areas would also be impacted by aircraft noise.	Stage 1 operation Longer term development	Negative	Badgerys Creek, St Marys and Erskine Park in the Penrith LGA, Greendale in Liverpool LGA, Silverdale in Wollondilly LGA, Horsley Park in Fairfield LGA, and parts of Blacktown, Blaxland (Blue Mountains)	Almost certain	Major	Very high
Lifestyle and amenity impacts: Reduced recreational value of nearby recreational areas (e.g. Bents Basin Conservation Area) as well as wilderness value of GBMWHA due to aircraft noise and visual impacts	Stage 1 operation Longer term development	Negative	Communities in Bents Basin Conservation Area, Burragorang State Conservation Area, Gulguer Conservation Area and Blue Mountains.	Likely	Moderate	Medium
Lifestyle and amenity impacts: Reduced visual amenity for areas close to the site due to permanent change in landscape from semi-rural to an airport and associated development	Stage 1 construction Stage 1 operation Longer term operation	Negative	Communities close to the site including Luddenham and Elizabeth drive	Almost certain	Moderate	High
Lifestyle and amenity impacts: Reduced visual amenity for elevated areas with views over the site due to permanent change in landscape from semi-rural to an airport and associated development	Stage 1 construction Stage 1 operation Longer term operation	Negative	Mount Vernon, Silverdale, Rossmore	Almost certain	Minor	Medium

Impact description	Western Sydney Airport development phase	Nature of impact	Impacted stakeholder groups/communities	Likelihood	Consequence	Significance rating
Lifestyle and amenity impacts: Reduced amenity for areas to the north and south of the site due to visual impact due to proximity of overflights.	Stage 1 operation Longer term operation	Negative	Bringelly, Greendale, Erskine Park, Horsley Park, Greendale, Silverdale, Luddenham, Badgerys Creek, Theresa Park. Communities in Bents Basin Conservation Area, Burragorang State Conservation Area and Gulguer Conservation Area	Almost certain	Moderate	High
Lifestyle and amenity impacts: Temporary change in air quality in areas around the site due to construction activities, vehicles travelling on unsealed roads and transporting materials onto the road network.	Stage 1 construction	Negative	Sensitive receivers along roads carrying construction material surrounding the site	Almost certain	Minor	High
Lifestyle and amenity impacts: Reduced air quality of semi-rural communities close to airport operations	Stage 1 operation Longer term development	Negative	Luddenham, Wallacia, Greendale, Badgerys Creek, Rossmore, Mt Vernon and Kemps Creek	Almost certain	Moderate	High
Lifestyle and amenity impacts: Increase in traffic on roads surrounding the site during construction leading to reduced social amenity and lifestyle for semi-rural areas	Stage 1 construction	Negative	Communities in areas surrounding site	Almost certain	Major	Very high
Lifestyle and amenity impacts: Increase in traffic on roads surrounding site during Stage 1 operations however with the planned upgrades of surrounding roads and introduction of new roads in areas surrounding the site, the increase in traffic is not expected to result in capacity issues.	Stage 1 operation	Negative	Communities in areas surrounding site	Likely	Moderate	Medium
Lifestyle and amenity impacts: Potential increase in traffic on roads in Western Sydney during longer term operations which, along with future population growth, may lead to road capacity impacts.	Longer term operation	Negative	Western Sydney communities	Possible	Moderate	Medium

Impact description	Western Sydney Airport development phase	Nature of impact	Impacted stakeholder groups/communities	Likelihood	Consequence	Significance rating
Lifestyle and amenity impacts: The proposed Western Sydney Airport will provide employment opportunities closer to home for the residents of Western Sydney, reducing their travel time and offering improved lifestyle and amenity	Stage 1 construction Stage 1 operation Longer term development	Positive	Proposed airport employees and their families who are/will be residents of Western Sydney	Almost certain	Moderate	High
Lifestyle and amenity impacts: Potential for anxiety amongst local community due to the uncertainty of flight paths and airport operating modes which could be exacerbated because of the timeframes required to develop and certify an airspace design for the proposed Western Sydney Airport Stage 1 operations.	Pre-construction	Negative	Local communities impacted by lifestyle and amenity impacts	Likely	Minor	Medium
Community health impacts: There are health impacts associated with changes in air quality. Prolonged exposure to PM_{10}, $PM_{2.5}$, NO_2 and SO_2 emissions could result in adverse impacts on health, resulting in hospital admissions from respiratory causes. There would be approximately three additional admissions per thousand years and potentially increasing all-cause mortality and cardiopulmonary mortality by 2- 5 additional deaths per 1000 years and 3-6 additional deaths per 10 years. This risk is considered to be higher during the longer term development.	Stage 1 operation Longer term development	Negative	Bringelly, Luddenham, Rossmore and Kemps Creek.	Likely	Minor	Medium
Community health impacts: There is a potential that aircrafts may fly over the catchment of the Warragamba Dam and Prospect Reservoir, the airport operations activities may impact on the quality of water within these storages. However, there is currently no data available which can be used to assess whether emissions from aircraft operations would result in increased loading of contaminants to surface waters (including tank water supplies).	Stage 1 construction Stage 1 operation Longer term development	Negative	Warragamba Dam and Prospect Reservoir	-	-	-
Community health impacts: It is considered unlikely that fuel jettisoning will occur or result in impacts on communities and surface water bodies surrounding the proposed airport site.	Stage 1 operations Longer term development	Negative	Communities and recreational areas in Western Sydney region	Unlikely	Negligible	Very low

Impact description	Western Sydney Airport development phase	Nature of impact	Impacted stakeholder groups/communities	Likelihood	Consequence	Significance rating
Community health impacts: Impacts on human health are associated with airport construction and ground based operations noise and aircraft noise. Noise impacts on health may include sleep disturbance, cardiovascular disease, cognitive impairment, tinnitus, annoyance and hearing impairment. Night time sleep disturbance effects, known as awakening events, will increase in the areas surrounding the airport site and areas under the flight path near the airport site. The health risk assessment shows that the number of awakenings events due to the airport development in most cases will be lower than the usual awakenings per person even during an undisturbed 8-hour night sleep, with the exception of Luddenham.	Stage 1 operation Longer term development	Negative	Luddenham, Greendale and Horsley Park	Likely	Moderate	Medium
Property values, housing and accommodation benefits and impacts						
Property values: Overall no discernible effect on property values as a result of other positive factors which offset the adverse impacts of noise	Stage 1 construction Stage 1 operation Longer term development	Neutral	Communities in Western Sydney particularly St Marys and Erskine Park, Greendale, Silverdale, Horsley Park, Luddenham, Wallacia, Greendale, Badgerys Creek, Rossmore, Mt Vernon and Kemps Creek and parts of Blacktown.	-	-	-
Housing and accommodation impacts: Potential increase in demand for accommodation facilities (hotels/motels) and associated services (entertainment) close to the airport. SIA stakeholder consultation has indicated that Western Sydney has the capacity to develop these to meet demand.	Stage 1 operation Longer term development	Positive	Western Sydney accommodation industry	Likely	Moderate	Medium
Housing and accommodation impacts: Majority of construction and operational workforce is expected to be sourced from Western Sydney and the Greater Sydney region. Some technical specialists may be sourced from other parts of Australia or internationally, and may require temporary short or long term accommodation. It is expected that existing or proposed new housing in the Western Sydney region would accommodate this demand.	Stage 1 construction Stage 1 operation Longer term operation	Neutral	Construction and operational workforce	Possible	Negligible	Very low

Impact description	Western Sydney Airport development phase	Nature of impact	Impacted stakeholder groups/communities	Likelihood	Consequence	Significance rating
Housing and accommodation impacts: Some workers at the airport may choose to move from other parts of Sydney or outside of Sydney to areas in Western Sydney, resulting in a small increase in demand for housing.	Stage 1 operation Longer term development	Negative	Existing and future residents of Western Sydney	Unlikely	Minor	Low
Housing and accommodation impacts: Decreasing housing availability and affordability issues in some areas potentially due to the proposed airport and wider Western Sydney development may lead to inadequate affordable housing options for socially disadvantaged groups.	Stage 1 operation Longer term development	Negative	Socially disadvantaged residents in Western Sydney	Remote	Negligible	Very low
Impacts on social infrastructure:						
Impacts on social infrastructure: Increase in construction workers unlikely to lead to demand for social infrastructure in areas near the proposed airport (e.g. child care, emergency services, medical services, schools) due to small number of workers and temporary nature of construction work.	Stage 1 construction	Neutral	Communities in areas close to airport site and service providers	Unlikely	Negligible	Very low
Impacts on social infrastructure: Increase in workers resulting in increased demand for social infrastructure in areas near the proposed airport (e.g. child care, emergency services, medical services, schools). It is anticipated that future social infrastructure provision should have capacity to meet future demand as a result of the long timeframe of development allowing appropriate planning by service providers. It is likely that such demand will stimulate further growth in the region.	Stage 1 operation Longer term development	Positive	Communities in areas close to airport site and service providers	Likely	Minor	Medium
Impacts on emergency services: Potential impact on ability of NSW emergency services to service Western Sydney communities during an emergency at the proposed airport. However during SIA consultation, all providers (NSW Police, Fire and Rescue, Ambulance) indicated there are existing procedures to bring in additional resources if needed.	Stage 1 construction Stage 1 operation Longer term operation	Neutral	NSW emergency services Western Sydney communities	Unlikely	Minor	Low

7. Mitigation and management measures

7.1 Introduction

The Australian Government is committed to maximising the potential benefits and opportunities and reducing potential socio-economic impacts that would be associated with the proposed airport development. This section outlines recommended mitigation measures and management strategies that have been identified to address the socio-economic impacts arising from the proposed airport. The management strategies developed in this section are based on existing industry practices and stakeholder feedback received during the SIA consultation.

The Department of Infrastructure and Regional Development will be responsible for development, implementation and monitoring of the social impact management strategies which are within its control until an airport lease is granted for the proposed airport. Some responsibilities will be devolved to relevant construction contractors, by way of their terms and conditions of engagement. After an airport lease is granted, the airport lessee company will generally be responsible for those strategies that relate to operation of the airport site.

Given the nature of this SIA, some of the mitigation measures identified in this SIA are not measures which the Commonwealth Government or an airport operator could implement. For example, some are measures which the NSW Government or local councils may be able to implement. In this regard, this SIA recommends that consideration be given to the measures proposed in this SIA in development of future policy and decision-making, where appropriate.

Due to the proposed timeframes of the proposed Western Sydney Airport development, it is expected that the associated socio-economic impacts may vary over time, subject to changes outside of the control of DIRD. Socio-economic impacts would be monitored on an ongoing basis through the complaints management mechanism and ongoing stakeholder engagement. The management strategies proposed are adaptive and will be reviewed and updated as required.

The socio-economic impact management strategies are outlined below in sections 7.2 to 7.5 and in will be finalised following the exhibition of the Draft EIS.

7.2 Regional employment and business development

The development of a local procurement policy would encourage the proposed airport contractors to, where possible, source their workforce and their suppliers for goods and services locally. To facilitate this, as part of contractor terms and conditions, contractors would be asked to develop a local industry participation plan in accordance with an Australian Industry Participation Plan. Local recruitment services with appropriate training programs would be engaged as required. The proposed airport development would follow equal opportunities policy. Indigenous participation and participation of people with disadvantages would be considered equally in the training and recruitment programs.

To realise the full benefit from the proposed airport development, a number of economic and employment strategies and plans developed by the Australian Government, NSW Government and local governments in the Western Sydney region (refer to section 3.1) need to be aligned. Skills development and training programs for industries supporting the airport development as well as other existing industries in the region will better provide long term sustainability of the region. Through the draft EIS public exhibition and the proposed Western Sydney Airport Communication and Engagement Strategy and Plan, DIRD will inform key stakeholders about the proposed airport's developments, timeframes and requirements.

7.3 Stakeholder engagement and complaints management

A detailed proposed Western Sydney Airport Communication and Engagement Strategy has been developed. Within this overarching strategy, a Community and Stakeholder Engagement Plan has been developed to support the EIS. The Plan describes how stakeholders in the Western Sydney region and broader Greater Sydney communities and government stakeholders have been and continue to be engaged during the preparation and exhibition of the draft EIS. It also includes important procedures and protocols such as the proposed Western Sydney Airport information enquiry channels and complaint management processes and indicates that similar stakeholder engagement strategies and plans and complaints management protocols for construction will be developed post EIS exhibition.

Early and continued engagement with government agencies and service providers has been occurring to allow them to align their development plans and service provision to meet the demands generated by the proposed Western Sydney Airport, as a catalyst for growth. The proposed Western Sydney Airport's Community and Stakeholder Engagement Plan for the draft EIS and post EIS will maintain careful stakeholder analysis to ensure all relevant agencies continue to be included in the engagement program. These stakeholders and their requirements are identified in the EIS Community and Stakeholder Engagement Plan, and include Western Sydney local government agencies, NSW Government agencies (e.g. Department of Planning and Environment, Transport for NSW, Department of Education and Communities, Community Services, Roads and Maritime Services) and other organisations (e.g. Western Sydney Business Chamber, educational facilities including universities and TAFE).

7.4 Planning interventions

Co-ordination between various government agencies, co-ordinated planning interventions and commitment of appropriate investments from various government agencies will be necessary to realise the full potential of benefits from the proposed airport development and minimise impacts on the Western Sydney region. These agencies may include Western Sydney local government agencies, NSW Government agencies (e.g. Department of Planning and Environment, Transport for NSW, Department of Education and Communities, Community Services), tourism agencies, agencies responsible for affordable housing and other organisations (e.g. Western Sydney Business Chamber, educational facilities including universities and TAFE).

7.5 Lifestyle and amenity impacts

The likely impacts on people's lifestyle and social amenity due to noise, air quality, traffic, visual and community health impacts have been addressed in the respective technical studies included in the draft EIS.

The technical studies indicate that many social amenity and lifestyle impacts, such as those caused by increased noise and decreased air quality, are expected to be unavoidable for certain Western Sydney communities, particularly those in areas close to the airport site. In addition, the mitigation or management of some impacts, such as air quality and overflight/ground-based aircraft impacts as a result of aircraft operations is beyond the control of the Australian Government and/or the airport operator. However there are measures which could be implemented by other key stakeholders (e.g. airline operators) to assist with reducing amenity and lifestyle impacts on communities. Where relevant, these have been identified in the technical studies.

A key measure to address community concerns about amenity and health impacts is the proposed Western Sydney Airport Communication and Engagement Strategy and EIS Community and Stakeholder Engagement Plan. Providing timely information to communities whose lifestyle and amenity may be impacted by the proposed airport allows them to

understand how they may be impacted, prepare for the impacts, and make decisions. Other mitigation measures which may address community concerns include measures such as air quality monitoring within or in the vicinity of the proposed airport to provide robust data that demonstrates that local air quality changes associated with the proposed airport are within regulatory guidelines.

Communities around the site are likely to be impacted during the construction phase, particularly Luddenham, and people living along the roads in the local area. It is anticipated that standard construction mitigation measures would address most of these, however as mentioned above, impacts on visual amenity are unlikely to be fully mitigated for these communities.

An additional aspect which may reduce anxiety in the community is the mitigation to be provided for noise impacts. There remains uncertainty over the location of flight paths and airport operating modes which may be adopted and which would have a substantial bearing on the level and location of population exposure. This uncertainty extends to other impacts also such as residential and large land lot holding property values. A priority action, would be to exhibit the proposed noise mitigation policy to be adopted, noting that the development of a comprehensive airspace design for the proposed airport cannot occur until much closer to the commencement of Stage 1 operations.

7.6 Summary of social impacts and corresponding management measures

Table 7-1 summarises the social impact management measures as they relate to specific impacts identified in Table 6-2.

Table 7-1 Summary of social impacts and mitigation measures

Impact description	Western Sydney Airport development phase	Nature of impact	Mitigation/management measures
Economic, employment and industry benefits and impacts			
Economic benefits: During operations of the proposed airport, the value-add is expected to increase commensurate with passenger movements. In 2031 (roughly aligning with the end of the Stage 1 development), the proposed airport is estimated to generate an additional $205 million in value-add per year across Australia. Of this, $77 million of value –add will be generated in the Western Sydney region. In 2063, the proposed airport would increase value-add in the Australian economy by $5.8 billion. Of this, approximately $1.5 billion would be generated in the Western Sydney region.	Stage 1 construction Stage 1 operation Longer term development	Positive	Develop and implement a local industry participation plan as part of an Australian Industry Participation Plan for the construction period, including skills training to ensure high local and regional participation levels in the workforce.
Employment opportunities: The proposed Western Sydney Airport development will generate a number of direct, indirect and induced jobs including: • Peaking of construction employment at 758 direct FTE jobs in 2022 in Western Sydney, which corresponds to approximately 3,200 cumulative person-years in Western Sydney over the construction period (from 2016-2024) (EY, 2015) • There would be indirect and induced employment generated for 8,000 person years in Western Sydney over the construction period between 2016-2024 (EY, 2015) • An additional 2,200 person years in the rest of Greater Sydney over the construction period between 2016-2024 (EY, 2015) • A total of approximately 7,500 direct FTE jobs would be required by the end of Stage 1 in 2030 for airport operations. In addition, a further 4,440 FTE jobs are forecast to be generated from commercial activities on business parks on the airport site (EY, 2015) • A total of approximately 61,500 direct FTE jobs would be required in the longer term in 2063 for airport operations. A further 27,150 FTE jobs would be generated from commercial activities on business arks on the airport site (EY, 2015).	Stage 1 construction Stage 1 operation Longer term development	Positive	Develop and implement a local industry participation plan as part of an Australian Industry Participation Plan for the construction period, including skills training to ensure high local and regional participation levels in the workforce. Develop an equal opportunities policy including training and suitable employment opportunities for Indigenous people and people with disadvantages during the construction period. Communicate employment opportunities and required skills to local governments and community. Continue to liaise with relevant agencies that may include local and State government agencies, tourism agencies, agencies responsible for affordable housing, Western Sydney Business Chamber and educational facilities including universities and TAFE, to inform agency planning activities and allocation of funding to programs that may benefit or otherwise be affected by the proposed airport.

Impact description	Western Sydney Airport development phase	Nature of impact	Mitigation/management measures
Employment opportunities: Stage 1 operations and longer term development may lead to some workers potentially giving up existing jobs to take up work at the proposed airport which may create vacancies/shortfalls in those industries. Given the availability of, and future growth in, the labour pool, job vacancies would be easily filled.	Stage 1 operation Longer term development	Negative	Develop and implement a local industry participation plan as part of an Australian Industry Participation Plan for the construction period, including skills training to ensure high local and regional participation levels in the new workforce. Communicate employment opportunities and required skills to the local governments and community to develop appropriate training programs for direct and indirect employment opportunities with the proposed airport including for industries that will supply goods and services to the proposed airport. Continue to liaise with relevant agencies that may include local and State government agencies, tourism agencies, agencies responsible for affordable housing, Western Sydney Business Chamber and educational facilities including universities and TAFE, to inform agency planning activities and allocation of funding to programs that may benefit or otherwise be affected by the proposed airport.
Impacts on other industries: Business growth and development in other industry sectors such as construction, utilities, trade, transport and services, accommodation, retail, professional services and public administration is anticipated. This is anticipated to occur from the sourcing of goods and services for the proposed airport and well as through indirect and induced economic impacts.	Stage 1 construction Stage 1 operation Longer term development	Positive	Develop and implement a local industry participation plan as part of an Australian Industry Participation Plan for the construction period including skills training to ensure high local participation levels in the supply of goods and services for the proposed airport. Communicate employment opportunities and required skills to the local governments and community to develop appropriate training programs for direct and indirect employment opportunities with the proposed airport including for industries that will supply goods and services to the proposed airport.
Impacts on other industries: Potential increase in tourism to GBMWHA and other surrounding recreational areas due to proximity to the airport and associated transport network.	Stage 1 operation Longer term development	Positive	Communicate growth plans of the airport with the local governments and other state agencies such as tourism agencies to engage in appropriate planning and development of tourism in GBMWHA, Wollondilly LGA and other surrounding LGAs
Impacts on other industries: Changes to land use in Western Sydney due to the proposed airport development and other planned development may result in competition for land and labour and a consequential decline in industry sectors such as agriculture and manufacturing. Existing trends show that these industries are already in decline in Western Sydney.	Stage 1 operation Longer term development	Negative	Engage in ongoing interaction with NSW Government and the local governments about airport development and associated land use to facilitate their actions to explore opportunities for alternative locations and/or value add opportunities to maintain industry sector presence in the wider region and to attract appropriate investment in other industries through Government policy coordination

Impact description	Western Sydney Airport development phase	Nature of impact	Mitigation/management measures
Demographic impacts			
Employment opportunities generated by the proposed Western Sydney Airport may contribute to population growth by 17,800 persons by 2031 in Western Sydney, and will continue to grow with new residents likely to be younger people attracted to employment opportunities and more affordable housing opportunities in Western Sydney.	Stage 1 operation Longer term development	Positive	Develop and implement a local industry participation plan as part of an Australian Industry Participation Plan for the construction period including skills training to ensure high local participation levels in the new workforce. Communicate employment opportunities to the local governments and community.
Lifestyle, amenity and health impacts			
Lifestyle and amenity impacts: Reduced social amenity and rural/semi-rural residential lifestyle as a result of construction ground-based noise for areas close to the airport site	Stage 1 construction	Negative	Implement the impact mitigation measures outlined in the EIS ground based noise report and chapter, including: A Construction Noise and Vibration Management Plan would be developed by the construction contractors. This plan would address construction hours, equipment noise controls and complaint / response procedures.
Lifestyle and amenity impacts: Reduced social amenity and rural/semi-rural lifestyle as a result of operational ground-based noise for areas close to the airport site.	Stage 1 operation Longer term development	Negative	Implement the impact mitigation measures outlined in the EIS ground based noise report and chapter, including management mechanisms for aircraft and airport operations, planning mechanisms for surrounding areas and specific mitigation measures such as noise shields in appropriate areas of the airport.
Lifestyle and amenity impacts: Reduced amenity of sensitive social infrastructure as a result of operational ground-based noise in areas close to airport site including five schools and child care centre, three places of worship, three parks, and three recreation facilities in Luddenham and Mulgoa.	Stage 1 operation Longer term development	Negative	Implement the impact mitigation measures outlined in the EIS ground based noise report and chapter, including management mechanisms for aircraft and airport operations, planning mechanisms for surrounding areas and specific mitigation measures such as noise shields in appropriate areas of the airport.

Impact description	Western Sydney Airport development phase	Nature of impact	Mitigation/management measures
Lifestyle and amenity impacts: Depending on the operating strategy adopted for the proposed airport, communities that may experience reduction in amenity as a result of aircraft overflights and operational noise could be Badgerys Creek, St Marys and Erskine Park in the Penrith LGA, Greendale in Liverpool LGA, Silverdale in Wollondilly LGA, Horsley Park in Fairfield LGA, parts of Blacktown, Blaxland (Blue Mountains). Some of these areas are semi-rural and large lot suburban areas with lower population density. It is expected that users of sensitive social infrastructure (e.g. childcare, schools, health facilities, churches, parks and recreation) in these areas would also be impacted by aircraft noise.	Stage 1 operation Longer term development	Negative	Impact mitigation measures as outlined in the EIS aircraft noise report and chapter including – Use operating strategies to minimise impacts on communities when weather conditions permit. Ensure noise issues are considered in the planning and design of new development. Provision of information to existing and potential residents of areas likely to be impacted by operational noise. Engage with the NSW Government and local governments to involve in appropriate land use planning of the airport development, associated development and other proposed Western Sydney growth and development plans
Lifestyle and amenity impacts: Reduced recreational value of nearby recreational areas (e.g. Bents Basin Conservation Area) as well as wilderness value of GBMWHA and some communities like Blaxland due to overflight noise ranging up to 55 dBA and visual impacts from flights at a height of more than 5000 feet	Stage 1 operation Longer term development	Negative	Implement the impact mitigation measures as per Air Noise Report including – Preferentially use operating strategies to minimise impacts on these areas when possible. Engage in ongoing interaction with NSW Government and the local governments about airport development and associated land use to support their actions to explore opportunities for alternative locations and/or value add opportunities to maintain industry sector presence in the wider region and to attract appropriate investment in other industries through Government policy coordination
Lifestyle and amenity impacts: Reduced visual amenity for areas close to the site due to permanent change in landscape from semi-rural to an airport and associated development	Stage 1 construction Stage 1 operation Longer term operation	Negative	Engage with the NSW Government and local governments to involve in appropriate land use planning of the airport development, associated development and other proposed Western Sydney growth and development plans Implement the impact mitigation measures as per Landscape and Visual Impact Report including – Reduce visual impacts through appropriate tree plantings and incorporation of other screening solutions where appropriate
Lifestyle and amenity impacts: Reduced visual amenity for elevated areas with views over the site due to permanent change in landscape from semi-rural to an airport and associated development	Stage 1 construction Stage 1 operation Longer term operation	Negative	Implement the impact mitigation measures as per Landscape and Visual Impact Report including – Reduce visual impacts through appropriate tree plantings and incorporation of other screening solutions where appropriate

Impact description	Western Sydney Airport development phase	Nature of impact	Mitigation/management measures
Lifestyle and amenity impacts: Reduced amenity for areas to the north and south of the site from visual impact due to proximity of overflights.	Stage 1 operation Longer term operation	Negative	Implement the impact mitigation measures as per Landscape and Visual Impact Report including – Reduce visual impacts through appropriate tree plantings and incorporate other screening solutions where appropriate Engage with the NSW Government and local governments to involve in appropriate land use planning of the airport development, associated development and other proposed Western Sydney growth and development plans
Lifestyle and amenity impacts: Temporary change in air quality in areas around the site due to construction activities, vehicles travelling on unsealed roads and transporting materials onto the road network.	Stage 1 construction	Negative	Implement the impact mitigation measures as per Air Quality Report including - Implement measures to Australian Standards to maintain permissible air quality to sensitive receivers. Implement standard practice to control dust/particulate impacts Establish an ambient air quality monitoring station to collect robust data on air emissions
Lifestyle and amenity impacts: Reduced air quality of semi-rural communities close to airport operations	Stage 1 operation Longer term development	Negative	Implement the impact mitigation measures as per Air Quality Report including - Implement leading emission technology during airport operations. Establish an ambient air quality monitoring station to collect robust data on air emissions.
Lifestyle and amenity impacts: Increase in traffic on roads surrounding the site during construction leading to changes to existing social amenity and lifestyle for semi-rural areas	Stage 1 construction	Negative	Implement traffic management plan to address impacts during construction. Ensure traffic issues are considered in the planning and design of new development. Ongoing consultations with relevant state agencies such as RMS and local governments
Lifestyle and amenity impacts: Increase in traffic on roads surrounding site during Stage 1 operations however with the planned upgrades of surrounding roads and introduction of new roads in areas surrounding the site, the increase in traffic is not expected to result in capacity issues.	Stage 1 operation	Negative	Ongoing engagement with NSW Government to support their functions to identify and implement appropriate public transport solutions to reduce vehicle movements and for the implementation of the WSIP designed to alleviate traffic in the proposed Western Sydney Airport region. Ensure traffic issues are considered in the planning and design of the airport development. Ongoing consultations with RMS and local governments

Impact description	Western Sydney Airport development phase	Nature of impact	Mitigation/management measures
Lifestyle and amenity impacts: Potential **i**ncrease in traffic on roads in Western Sydney during longer term operations which, along with future population growth, may lead to road capacity issues.	Longer term operation	Negative	Ongoing engagement with NSW Government and local governments to support their functions to Identify and implement appropriate public transport solutions to reduce vehicle movements and for the implementation of the WSIP designed to alleviate traffic in the proposed Western Sydney Airport region Ongoing monitoring and planning for improved road capacity beyond implementation of WSIP. Ongoing consultations with RMS and local governments
Lifestyle and amenity impacts: The proposed airport will provide employment opportunities closer to home for the residents of Western Sydney, reducing their travel time and offering improved lifestyle	Stage 1 construction Stage 1 operation Longer term development	Positive	Develop and implement a local industry participation plan as part of an Australian Industry Participation Plan for the construction period to ensure high local and regional participation levels in the new workforce. Communicate employment opportunities to the local community.
Lifestyle and amenity impacts: Potential for anxiety amongst local community due to the uncertainty of flight paths and airport operating modes which could be exacerbated because of the timeframes required to develop and certify an airspace design for the proposed airport Stage 1 operations.	Pre-construction	Negative	Regular ongoing communication and the proposed airport development updates as per the Communication and Engagement Strategy to be provided to local communities through various stages of the development
Community health impacts: There are health impacts associated with changes in air quality. Prolonged exposure to PM_{10}, $PM_{2.5}$, NO_2 and SO_2 emissions could result in adverse impacts on health, resulting in hospital admissions from respiratory causes. There would be approximately three additional admissions per thousand years and potentially increasing all-cause mortality and cardiopulmonary mortality by 2- 5 additional deaths per 1000 years and 3-6 additional deaths per 10 years. This risk is considered to be higher during the longer term development.	Stage 1 operation Longer term development	Negative	The proposed airport would utilise electric-powered APUs wherever possible Future improvements in aircraft technology and fuel standards would also reduce risk. Implement mitigation measures as per traffic and air quality reports
Community health impacts: There is a potential that aircrafts may fly over the catchment of the Warragamba Dam and Prospect Reservoir, the airport operations activities may impact on the quality of water within these storages. However, there is currently no data available which can be used to assess whether emissions from aircraft operations would result in increased loading of contaminants to surface waters (including tank water supplies).	Stage 1 construction Stage 1 operation Longer term development	Negative	Ongoing management and monitoring of Sydney's water supply will continue to be undertaken by Water NSW
Community health impacts: It is considered unlikely that fuel jettisoning will occur close to proposed airport or result in impacts on communities and surface water bodies surrounding the proposed airport site	Stage 1 operation Longer term development	Negative	Ensure airline operators adhere to Airservices Australia protocols if fuel jettisoning needs to occur. Existing applicable requirements regarding fuel dumping will provide sufficient mitigation

Impact description	Western Sydney Airport development phase	Nature of impact	Mitigation/management measures
Community health impacts: Impacts on human health are associated with airport construction and ground based operations noise and aircraft noise. Noise impacts on health may include sleep disturbance, cardiovascular disease, cognitive impairment, tinnitus, annoyance and hearing impairment. Night time sleep disturbance effects, known as awakening events, will increase in the areas surrounding the airport site and areas under the flight path near the airport site. The health risk assessment shows that the number of awakenings events due to the airport development in most cases will be lower than the usual awakenings per person even during an undisturbed 8-hour night sleep, with the exception of Luddenham.	Stage 1 operation Longer term development	Negative	Implement the impact mitigation measures as per Noise Report including – Use operating strategies to minimise impacts on communities when weather conditions permit. Ensure noise issues are considered in the planning and design of new development. Provision of information to existing and potential residents of areas likely to be impacted by operational noise. Incorporate noise mitigation package that meets Australian Standards for offsite receptors.
Property values, housing and accommodation benefits and impacts			
Property values: Overall no discernible effect on property values as a result of other positive factors which offset the adverse impacts of noise.	Stage 1 construction Stage 1 operation Longer term development	Neutral	No action required
Housing and accommodation impacts: Potential increase in demand for accommodation facilities (hotels/motels) and associated services (entertainment) close to the airport site. SIA stakeholder consultation has indicated that Western Sydney has the capacity to develop these to meet demand.	Stage 1 operation Longer term development	Positive	Ongoing engagement with NSW Government and local governments to support their planning process to meet these future demands from airport development
Housing and accommodation impacts: Majority of construction and operational workforce is expected to be sourced from Western Sydney and the Greater Sydney region. Some technical specialists may be sourced from other parts of Australia or internationally, and may require temporary short or long term accommodation. It is expected that existing or proposed new housing in Sydney and Western Sydney would accommodate this demand.	Stage 1 construction Stage 1 operation Longer term operation	Neutral	Develop and implement a local industry participation plan to ensure high local participation levels in the new workforce. Communicate employment opportunities to the local community. Ongoing engagement with NSW Government and local governments to support their planning process to meet these future demands from airport development
Housing and accommodation impacts: Some workers at the airport may choose to move from other parts of Sydney or outside of Sydney to areas in Western Sydney, resulting in a small increase in demand for housing.	Stage 1 operation Longer term development	Negative	Engage with NSW Government and local governments to inform about the project development stages and workforce requirements and potential housing and accommodation requirements to plan for future housing requirements from the proposed airport and other developments in Western Sydney. Appropriate state government agencies will need to be involved in such communication to assist them in planning for affordable housing options in Western Sydney

Impact description	Western Sydney Airport development phase	Nature of impact	Mitigation/management measures
Housing and accommodation impacts: Decreasing housing availability and affordability issues in some areas potentially due to the proposed airport and wider Western Sydney development may lead to inadequate affordable housing options for socially disadvantaged groups.	Stage 1 operation Longer term development	Negative	Liaise with relevant agencies to inform their planning allocation of funding to programs that may benefit from the proposed airport. Relevant agencies may include local and State government agencies, tourism agencies, agencies responsible for affordable housing and other organisations (e.g. Western Sydney Business Chamber, educational facilities including universities and TAFE).
Impacts on social infrastructure:			
Impacts on social infrastructure: Increase in construction workers unlikely to lead to demand for social infrastructure in areas near the proposed airport (e.g. child care, emergency services, medical services, schools) due to small number of workers and temporary nature of construction work.	Stage 1 construction	Neutral	No further consideration at this stage as additional services are likely to be provided in nearby development precincts
Impacts on social infrastructure: Increase in workers resulting in increased demand for social infrastructure in areas near the proposed Western Sydney Airport (e.g. child care, emergency services, medical services, schools). It is anticipated that future social infrastructure provision should have capacity to meet future demand as a result of the long timeframe of development allowing appropriate planning by service providers. It is likely that such demand will stimulate further growth in the region.	Stage 1 operation Longer term development	Positive	Engage with NSW Government and local governments to inform about the project development stages and workforce requirements and potential housing and accommodation requirements to plan for future housing requirements from the proposed airport and other developments in Western Sydney. Appropriate state government agencies will need to be involved in such communication to assist them in planning for affordable housing options in Western Sydney Additional services likely to be provided in nearby development precincts to consider airport development and demand from airport workforce the proposed airport development (airport operator) during detailed design to consider provision of some such services for their workforce
Impacts on emergency services: Potential impact on ability of NSW emergency services to service Western Sydney communities during an emergency at the proposed airport. However during SIA consultation, all providers (NSW Police, Fire and Rescue, Ambulance) indicated there are existing procedures to bring in additional resources if needed.	Stage 1 construction Stage 1 operation Longer term operation	Neutral	Engage with emergency service providers for ongoing planning for the airport development.

8. Conclusions

8.1 Summary of key social and economic benefits

This report has assessed the social and economic benefits and impacts arising from the development of the proposed airport in the local study area communities surrounding the airport site, the Western Sydney region including the LGAs that are likely to have a social interaction with the proposed airport and the wider area of influence (GMS).

The majority of benefits for the Western Sydney region and Greater Sydney communities would be related to economic development and employment opportunities. Key benefits would include:

- Increased opportunities for local, regional and broader business through direct, indirect and induced spending from the airport development.
- Increased benefit for other industry sectors such as construction, utilities, trade, transport and services, accommodation, retail, professional services, public administration and tourism.
- The value-add from construction of the proposed airport would peak in 2022 with benefits to Western Sydney reaching $450 million, and a further $90 million to the rest of Greater Sydney in that year.
- The cumulative value-add for Western Sydney from Stage 1 construction is estimated to be $1.9 billion (EY, 2015).
- During operations of the proposed airport, the value-add is expected to increase commensurate with passenger movements. In 2031 (roughly aligning with the end of the Stage 1 development), the proposed airport is estimated to generate an additional $205 million in value-add per year across Australia. Of this, $77 million of value –add will be generated in the Western Sydney region.
- In 2063, the proposed airport would increase value-add in the Australian economy by $5.8 billion. Of this, approximately $1.5 billion would be generated in the Western Sydney region..
- Increase in average incomes in Western Sydney. By the time the airport is fully operational, incomes in Western Sydney are expected to increase to just over 95 per cent of the average for Greater Sydney, compared to 90 per cent in 2014 (SGS, 2015).
- The proposed Western Sydney Airport development will generate a number of direct, indirect and induced jobs in Western Sydney and Greater Sydney including –
    - Peaking of construction employment at 758 direct FTE jobs in 2022 in Western Sydney, which corresponds to approximately 3,200 cumulative person-years in Western Sydney over the construction period (from 2016-2024) (EY, 2015).
    - There would be indirect and induced employment generated for 8,000 person years in Western Sydney over the construction period between 2016-2024 (EY, 2015).
    - An additional 2,200 person years in the rest of Greater Sydney over the construction period between 2016-2024 (EY, 2015).
    - A total of approximately 7,500 direct FTE jobs would be required by the end of Stage 1 in 2030 for airport operations. In addition, a further 4,440 FTE jobs are forecast to be generated from commercial activities on business parks on the airport site (EY, 2015).

- A total of approximately 61,500 direct FTE jobs would be required in the longer term in 2063 for airport operations. A further 27,150 FTE jobs would be generated from commercial activities on business arks on the airport site (EY, 2015).
- Reduced travel times and improved satisfaction (e.g. increased time spent with families, recreation and leisure as well as increases in household income) for future employees throughout the construction and operational phases.
- Employment opportunities may contribute to population growth in Western Sydney by additional 17,800 persons, with new residents likely to be younger people attracted to more affordable housing in Western Sydney.
- Potential increase in tourism in the Blue Mountains recreation areas and related attractions and services due to the proximity of the airport.
- Future growth in property prices due to changes in land use and related infrastructure improvements eg utilities and services, improved road and rail connections and other infrastructure.

8.2 Summary of key social and economic impacts

The proposed airport is likely to result in a range of impacts on communities in the local study area within Western Sydney, particularly on the social amenity and lifestyle of communities close to the airport site. Key social amenity impacts would include:

- Amenity and lifestyle impacts resulting from construction dust, noise, changes to visual amenity, traffic and related health impacts, particularly on communities surrounding the site.
- Noise impacts from ground based noise during Stage 1 construction and operations on dwellings and community infrastructure particularly in Luddenham, Mulgoa, Badgerys Creek, Wallacia and Bringelly.
- Depending on the operating strategy adopted for the proposed Western Sydney Airport, communities that may experience aircraft noise at varying levels during the daytime and night time include areas of Luddenham, Badgerys Creek, Bringelly, St Marys and Erskine Park, Greendale, Silverdale, Horsley Park and parts of Blacktown. Many of these areas (particularly Greendale, Silverdale and Horsley Park) are semi-rural areas and place a high value on the amenity provided by this lifestyle.
- Overflight noise and visual impacts may lead to reduced amenity and enjoyment of recreational areas located in Western Sydney e.g. Bents Basin Conservation Area, Burragorang State Conservation Area as well as the Blue Mountains.
- Visual amenity of communities close to the site, including Luddenham, residents on Elizabeth Drive, Mount Vernon, Silverdale and Rossmore would be permanently changed due to the proposed change in use of the site.
- Increased emissions and odour during airport operation for communities close to the airport site including in Luddenham, Wallacia, Mulgoa, Greendale, Badgerys Creek, Rossmore, Mount Vernon, Kemps Creek and Badgerys Creek.
- Increased traffic on local and regional roads as a result of the airport development.
- Changes to air quality due to aircraft emissions could increase the risk of health impacts on communities near the site, particularly in Bringelly, Luddenham, Rossmore and Kemps Creek.

- The risk of health effects resulting from daytime and night time (sleep disturbance) noise will increase, particularly in areas surrounding the site both as a result of aircraft overflights and ground based airport activities. The risks are highest in Luddenham, Greendale, Bringelly, Rossmore, Badgerys Creek and Horsley Park. The specific impacts from aircraft overflights will be determined by the preferred airport operating strategy following the final EIS.
- There is a potential that aircrafts may fly over the catchment of the Warragamba Dam and Prospect Reservoir, however, there is currently no data available which can be used to assess whether emissions from aircraft operations would result in increased loading of contaminants to surface waters (including tank water supplies).Overall no discernible effect on property values as a result of other positive factors which offset the adverse impacts of noise.
- Changes to current land use at the airport site and other planned and future development in adjacent areas may limit the amount of land available for other industry sectors, such as agriculture.
- There may be a minor impact on some businesses as workers change jobs to take up employment at the proposed Western Sydney Airport creating job vacancies in the businesses they have left.
- The proposed Western Sydney Airport employees may choose to relocate to live closer to the future airport, which may increase demand for housing locally in Western Sydney. This could potentially affect housing availability and affordability for socially disadvantaged groups.

8.3 Key impact management strategies

To realise the full scale of the social and economic benefits from the proposed airport development, a number of strategies and plans developed by the Australian Government, NSW Government, and Western Sydney local governments would need to be aligned.

Continued engagement is required with these agencies and service providers to allow them to align their development plans and services provision to meet the demands generated by the proposed Western Sydney Airport and act as a catalyst for growth.

The detailed Western Sydney Airport Communication and Engagement Strategy and EIS Community and Stakeholder Engagement Plan will be key tools in managing and mitigating the social impacts of the proposed airport, particularly as many social amenity and lifestyle impacts for Western Sydney communities, especially those close to the airport site, are unavoidable. Providing timely information to communities whose lifestyle and amenity may be impacted by the proposed airport would allow them to understand how they may be impacted, prepare for the impacts, and make decisions.

An additional aspect which would reduce anxiety in the community is the mitigation to be provided for noise impacts. There remains uncertainty over the location of flight paths and airport operating modes which will have a substantial bearing on the level and location of population noise exposure. This uncertainty extends to impacts also such as changes in property values. A priority action would be to prepare a noise mitigation policy in line with the development of a comprehensive airspace design for the proposed airport, which is expected to occur closer to the commencement of Stage 1 operations.

Other mitigation measures which may address community concerns include measures such as - air quality monitoring within or in the vicinity of the proposed airport to provide robust data which demonstrates that local air quality changes associated with the proposed airport are within regulatory guidelines and monitoring of water quality in surface waters.

8.4 Contribution to economic and employment issues for Western Sydney

The following section summarises the impact of the proposed airport on the broad opportunities and challenges identified and considered in this SIA that relate to economic and employment issues in the Western Sydney region.

Opportunities	Impact of proposed Western Sydney Airport
• Development of employment lands and development of residential precincts bringing new infrastructure to enable population growth • Investment in education, the health sector and aged care opportunities • Promotion of the agricultural and farming sectors • Development of local employment initiatives which target service gaps and employment barriers for migrants and refugees. • Harnessing the increasingly educated population, including vocational and trade qualifications • Encouraging a wider variety of businesses to locate in the area to improve access to services.	• By providing a major transport mode, the proposed airport would provide all types of employment opportunities for regional workers, including the skilled, unskilled and youth sectors. • New industries will develop in response to the new opportunities, including new agricultural ventures to capitalise on emerging markets and transport opportunities. • A key mitigation measure is to develop and implement a local industry participation plan as part of an Australian Industry Participation Plan for the construction period to ensure high local participation levels in the new workforce for all types of workers, reducing commute times. • The proposed airport, in conjunction with other local and regional employment and housing initiatives, would help transform the economic prosperity of the Western Sydney region, and NSW.
Challenges	**Impact of proposed Western Sydney Airport**
• Reducing the high rates of unemployment and limited job opportunities, particularly the high rates of youth unemployment • Finding work for unskilled or semi-skilled occupations, particularly for new migrants and refugees who have low English levels, low skill levels, or skills not recognised in Australia. • Replacing jobs lost in the decline of manufacturing and trade industries • Managing the loss of agricultural land and associated industries as a result of development • Ensuring sufficient jobs, services and facilities and infrastructure are provided in time to meet the needs of a growing population, and to reduce the incidence of long distance commuting (particularly by car).	• By providing a major transport mode, the proposed airport would provide all types of employment opportunities for regional workers, including the skilled, unskilled and youth sectors. • New industries would develop in response to the new opportunities, including new agricultural ventures to capitalise on emerging markets and transport opportunities. • A key commitment is to develop and implement a local industry participation plan as part of an Australian Industry Participation Plan for the construction period to ensure high local participation levels in the new workforce for all types of workers, reducing commute times. • The proposed airport, in conjunction with other local and regional employment and housing initiatives, would help transform the economic prosperity of the Western Sydney region, and NSW.

8.5 Contribution to lifestyle and amenity issues for Western Sydney

The following section summarises the impact of the proposed airport on the broad opportunities and challenges identified and considered in this SIA that relate to lifestyle and amenity issues in the Western Sydney region.

Opportunities	Impact of the proposed Western Sydney Airport
• Celebrating cultural and linguistic diversity to create a unique community identity, with strong connections and networks (e.g. through coordinated activities, public artworks and festivals). • Engaging young people and providing accessible, youth-specific spaces. • Implementing health and wellbeing programs which encourage physical activity. • Providing safe and accessible public transport networks which are functional, accessible and acceptable to the community with designated pedestrian and bike paths • Highlighting the proximity to the Greater Blue Mountains World Heritage Area, with its environmental, cultural and recreational significance as a major tourism destination. • Preserving cultural and built heritage. • Enjoying the variety of cuisines, cafes, and local businesses that reflect the diverse population. • Provision and promotion of high quality community facilities including libraries and child care centres which meet the needs of families.	• The proposed airport, in conjunction with other local and regional employment and housing initiatives, would help transform the economic prosperity of the Western Sydney region, and NSW. It is likely this transformation would celebrate and capitalise on the region's unique cultural and linguistic diversity, and preserve the regions rich built heritage. This would lead to further development of industries like tourism in the region. • The proposed airport would provide much needed employment opportunities in Western Sydney and reduce travel time to work places, providing the opportunity for active family lifestyle. • The growing regional population and improvements in economic prosperity would improve social infrastructure, servicing youth, families and the aged, and improve health and wellness initiatives. • Through comprehensive planning, improvements to the road network in conjunction with new public transport infrastructure would create connected communities, reducing commute times. • The proposed airport would create tourism opportunities for the whole of NSW. Given its proximity, it is expected the Greater Blue Mountains World Heritage Areas would further grow as a major tourism destination.

Challenges	Impact of the proposed Western Sydney Airport
• Managing population growth effectively and ensuring new development is supported by transport infrastructure and services to meet community, health, education, economic and recreational needs (social infrastructure) • Improving community identified issues with transport infrastructure (need to improve frequency and accessibility of public transport services and links between centres and key destinations, roads, parking, accessibility, access afterhours including lighting, pedestrian and cycle facilities and footpaths) to reduce car dependency, traffic and congestion • Catering to the ageing population and large proportion of young children requiring higher quality and supply of health services • Addressing concerns around safety in public areas and reducing vandalism. • Providing services and support to the increasingly culturally diverse community e.g. translation services, support networks • Conserving natural, built and cultural heritage in the context of limited resources and responding to increased pressures for change and growth. • Providing more accessible recreation and entertainment options to encourage a healthier lifestyle	• The proposed airport, in conjunction with other local and regional employment and housing initiatives, would help transform the economic prosperity of the Western Sydney region, and NSW. It is likely this transformation would celebrate and capitalise on the regions unique cultural and linguistic diversity, and preserve the regions rich built heritage. • The growing regional population and improvements in economic prosperity would improve social infrastructure, servicing youth, families and the aged, and improve health and wellness initiatives. • Through comprehensive planning, improvements to the road network in conjunction with new public transport infrastructure will create connected communities, reducing commute times. • The proposed airport would create tourism opportunities for the whole of NSW. Given its close proximity, it is expected the Greater Blue Mountains World Heritage Areas will further grow as a major tourism destination.

8.6 Contribution to housing and accommodation issues for Western Sydney

The following section summarises the impact of the proposed Western Sydney Airport on the broad opportunities and challenges identified and considered in this SIA that relate to housing and accommodation issues in the Western Sydney region.

Opportunities	Impact of the proposed Western Sydney Airport
• Significant urban revitalisation projects driven from new transport infrastructure construction • Housing and land more affordable than other areas of Sydney, leading to new population growth and high numbers of young families	• The proposed airport, in conjunction with other local and regional employment and housing initiatives, would help transform the economic prosperity of the Western Sydney region. It is likely a range of housing types and lifestyles would be developed in response to market forces. • Comprehensive planning, improvements to the road network in conjunction with new public transport infrastructure would create connected communities, reducing commute times and providing opportunities for an active lifestyle. • Growing regional population and improvements and economic prosperity would improve social infrastructure, servicing youth, families and the aged, and improve health and wellness initiatives.
Challenges	**Impact of the proposed Western Sydney Airport**
• Addressing the fall in housing affordability in areas previously known as affordable, and reducing the incidence of housing stress • Housing the significant population of newly arrived migrants and refugees, many of whom experience multiple disadvantages e.g. poverty, housing stress unemployment • Providing affordable housing and a mix of housing types so residents can still live in the area when circumstances change • Avoiding and improving pockets of significant socio-economic disadvantage e.g. large social housing areas.	• The proposed airport, in conjunction with other local and regional employment and housing initiatives, would help transform the economic prosperity of the Western Sydney region. It is likely a range of housing types and lifestyles would be developed in response to market forces. • Through comprehensive planning, improvements to the road network in conjunction with new public transport infrastructure would create connected communities, reducing commute times. • Growing regional population and economic prosperity would improve social infrastructure, servicing youth, families and the aged, and improve health and wellness initiatives.

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Appendices

Appendix A – Preliminary scoping of social impacts and benefits

Issues	Pre-construction			Construction			Operation		
	Local study area	Western Sydney	Greater Sydney	Local study area	Western Sydney	Greater Sydney	Local study area	Western Sydney	Greater Sydney
Impact on properties									
Change in land use, access/availability of land	X	-	-	X	-			-	
Sterilisation of land	X	-	-	X	-			-	
Impacts on land tenants									
Relocation/resettlement/livelihoods	X	-	-	X	-			-	
Access/severance issues	-	-	-	-	-			-	
Viability and productivity of land	X	-	-	-	-			-	
Amenity issues - noise, air, visual, lights	-	X	-	-	X			-	
Stress and anxiety due to impacts on land and home	X	-	-	X	X			X	
Lifestyle and values - loss of connections to land and neighbourhood	X	-	-	X	-			-	
Economic benefits									
Employment opportunities	-	X	X	-	X			X	
Business opportunities	-	X	X	-	X			X	
Flow on effects	-	X	X	-	X			X	
Economic impacts									
Workforce draw	-	-	-	-	-			-	
Industries impacted due to workforce draw- IO model	-	-	-	-	-			-	
Project impacts on other industries in the region - tourism, transport, storage, agriculture, University of Sydney farm for agricultural studies, manufacturing and retail	-	X	X	-	X			-	
Changes in land value	X	X	-	-	X			-	
Demographic impacts									
Changes to population - outmigration of those who lose land under project, population in area under flight path, area, profile of this population	X	-	-	X	X			-	
In-migration of people for opportunities - potential profile of this population	-	-	-	-	X			-	
Housing and accommodation impacts									
Demand for accommodation facilities	-	-	-	-	-			-	
Demand for housing	-	-	-	-	X			X	
Amenity impacts									
Noise and vibration- impacts on sensitive receptors including homes and social infrastructure e.g. child cares, schools, hospitals , aged	-	X	X	-	X			X	

Issues	Pre-construction			Construction			Operation		
	Local study area	Western Sydney	Greater Sydney	Local study area	Western Sydney	Greater Sydney	Local study area	Western Sydney	Greater Sydney
care									
Visual - light and landscape	-	X	X	-	X			X	
Air quality	-	X	X	-	X			X	
Recreational value	X	-	-	X	X			-	
Social infrastructure									
Increase in demand for infrastructure due to increase in population in the area - health and medical services, hospitals, schools, child care and recreational facilities	-	-	-	-	-			X	
Increase in demand for infrastructure due to services required for airport - transport services (access roads, public transport, taxis), accommodation facilities	-	-	-	-	X			X	
Emergency services									
Police	-	-	-	X	X		X	X	
Fire and rescue	-	-	-	X	X		X	X	
Ambulance	-	-	-	X	X		X	X	

Appendix B – Western Sydney population and demographic analysis report

Western Sydney population and demographic analysis

Final report

Ernst & Young

July 2015

SGS Economics & Planning

Independent insight.



This report has been prepared for Ernst & Young. SGS Economics and Planning has taken all due care in the preparation of this report. However, SGS and its associated consultants are not liable to any person or entity for any damage or loss that has occurred, or may occur, in relation to that person or entity taking or not taking action in respect of any representation, statement, opinion or advice referred to herein.

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TABLE OF CONTENTS

GLOSSARY		**1**
1	**INTRODUCTION AND BACKGROUND**	**2**
1.1	Economics and demographics of Western Sydney	2
1.2	Impact of airport on Western Sydney	2
1.3	Key assumptions and limitations	3
2	**METHODOLOGY**	**4**
2.1	Data sources	4
	Total population	4
	Population by age group	4
	Employment forecasts	5
2.2	Income forecasts	5
	Household income brackets	5
	Mean household incomes	6
2.3	Economic activity forecasts	6
2.4	Transport times and costs	7
3	**POPULATION FORECASTS**	**8**
4	**INCOME FORECASTS**	**10**
5	**EMPLOYMENT FORECASTS**	**12**
6	**ECONOMIC ACTIVITY FORECASTS**	**15**
7	**APPENDIX**	**17**

LIST OF TABLES

TABLE 1 SYDNEY GMA POPULATION GROWHT BY AIRPORT CATCHMENT, 2015-2075 8
TABLE 2 SYDNEY MEAN INCOMES, 2015-2075 10
TABLE 3 SYDNEY EMPLOYMENT FORECASTS, 2015-2075 12
TABLE 4 GROWTH IN EMPLOYMENT, 2015-2045 14
TABLE 5 SYDNEY ECONOMIC ACTIVITY, 2010-2070 15
TABLE 6 SYDNEY ECONOMIC ACTIVITY, 2010-2080 17
TABLE 7 SYDNEY GMA POPULATION BY SLA, 2005-2075 1
TABLE 8 MEAN INCOME BY SLA, 2005-2075 5
TABLE 9 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2010 8
TABLE 10 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2015 11
TABLE 11 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2020 14
TABLE 12 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2025 17
TABLE 13 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2025 20
TABLE 14 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2030 23
TABLE 15 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2035 26
TABLE 16 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2040 29
TABLE 17 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2045 32
TABLE 18 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2050 35
TABLE 19 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2055 38
TABLE 20 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2060 41
TABLE 21 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2065 44
TABLE 22 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2070 47
TABLE 23 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2075 50
TABLE 24 SYDNEY AGE GROUP BY SLA, 2015 TO 2075 53

LIST OF FIGURES

FIGURE 1 GENERATING EMPLOYMENT FORECASTS 5
FIGURE 2. SYDNEY POPULATION BY AIRPORT CATCHMENT, 2005-2075 8
FIGURE 3. POPULATION BY AGE GROUP, WSA AND OTHER SYDNEY, 2015-2075 9
FIGURE 4. MEAN HOUSEHOLD INCOMES BY CATCHMENT 10
FIGURE 6. SYDNEY EMPLOYMENT FORECASTS BY CATCHMENT AREA 13
FIGURE 5. EMPLOYMENT BY INDUSTRY 13
FIGURE 7. GROSS VALUE ADDED, SYDNEY, 2010 - 2080 15

GLOSSARY

ABS: Australian Bureau of Statistics

BTS: NSW Bureau of Transport Statistics

DPE: NSW Department of Planning and Environment

GMA: Greater Metropolitan Area of Sydney. A wide classification of Sydney, stretching from Newcastle in the north to Kiama in the south and Blue Mountains in the west. Sydney GMA is broken into four catchments: the WSA catchment, KSA catchment, Marginal catchment and Other.

GVA: Gross value added. A measure of economic activity produced in an area. It is calculated as output minus intermediate consumption in the area.

KSA: Kingsford Smith Airport. People living in the KSA catchment are located in the east of Sydney and face lower travel costs to get to KSA than WSA.

LGA: Local Government Area. Geographical classification based on areas serviced by local governments. These closely align with SLAs.

Marginal: This catchment area contains SLAs that face similar travel costs to visit KSA or WSA. When WSA is built, these people are unlikely to show strong preferences for one airport based on travel costs to the airport alone.

Other: These are in the outer areas of the Sydney GMA and are not part of the three main airport catchments, KSA, WSA and Marginal. They face high travel costs to visit either airport. These areas were not in scope for some of SGS' modelling.

SA3: Statistical Area Level 3. Statistical Areas Level 3 (SA3s) are built from aggregations of whole Statistical Area Level 2 (SA2) boundaries to represent regions of between approximately 30,000 people and 130,000 people to cover the whole of Australia. These boundaries reflect a combination of widely recognised informal regions as well as existing administrative regions such as State Government Regions in rural areas and local Government Areas in urban areas.

SA4: Statistical Area Level 4. These areas have large populations, over 100,000 people in each, and are designed to reflect one or more whole labour markets.

SLA: Statistical Local Area. The Statistical Local Area (SLA) is an Australian Standard Geographical Classification (ASGC) defined area which consists of one or more Collection Districts (CDs). SLAs are Local Government Areas (LGAs), or parts thereof. Where there is no incorporated body of local government, SLAs are defined to cover the unincorporated areas. SLAs cover, in aggregate, the whole of Australia without gaps or overlaps

WSA: Western Sydney Airport. People living in the WSA catchment are located in the west of Sydney and face lower travel costs to get to WSA than KSA. The SLAs included in the WSA catchment are Bankstown SLAs, Baulkham Hills SLAs, Blacktown SLAs, Blue Mountains, Camden, Campbelltown SLAs, Fairfield SLAs, Hawkesbury, Holroyd, Liverpool SLAs, Inner, North-West and South Parramatta, Penrith SLAs, Sutherland Shire West and Wollondilly.

1 INTRODUCTION AND BACKGROUND

SGS Economics and Planning generated a series of demographic and economic forecasts for the Sydney Greater Metropolitan Area (GMA) out to 2075. These forecasts were prepared at the Statistical Local Area (SLA) level, projecting population, employment, income, economic activity and transport costs, given the establishment of a second Sydney airport at Badgerys Creek, Western Sydney Airport (WSA). Where necessary, these have been converted to SA3 by LEK for use in their analysis. This report provides a summary of the demographic and economic forecasts used by SGS in modelling the impact of the planned new airport and Badgerys Creek in Western Sydney.

The population of Sydney is forecast to grow to over 9 million by 2075. Along with this increase in population, other demographic changes will occur: longer life expectancies will result in an ageing population, and Sydneysiders will continue to chase lower cost housing in the west of the city. As a result, we can expect to see changes in the city's demographic and economic makeup. The population aged 65 and over is expected to increase from 13% in 2015 to 21% in 2075, as a result the Health and Social Assistance industry is expected to be the fastest growing over this period, more than doubling the number of employees.

1.1 Economics and demographics of Western Sydney

At present, the Western Sydney Airport (WSA) catchment is quite different to the Kingsford Smith Airport (KSA) catchment and the Marginal catchment (areas which have similar travel costs to Kingsford Smith and the proposed Badgerys Creek airport). The population is younger in the WSA catchment, with 28% of its population aged 19 and under compared to 22% elsewhere in Sydney. Only 60% of WSA's population are aged between 20 and 64, the prime working age, compared to 65% of the KSA catchment. This suggests that the WSA catchment is popular with young families, potentially attracted by the relative affordability of lower cost freestanding dwellings. Incomes are also lower in the WSA catchment than other areas, only around 75% of those found in the KSA catchment and 95% of those found in the Marginal catchment, and although the WSA catchment has 44% of Sydney's population, it only has 34% of the jobs.

1.2 Impact of airport on Western Sydney

The establishment of the new airport at Badgerys Creek is expected to add approximately another 18,000 jobs around the Western Sydney area, concentrated near the airport site. As a result of this boost to the economy in the area, Western Sydney is expected to show higher growth in gross value added (GVA) than other areas of Sydney. This is expected to flow through to higher mean household incomes in Western Sydney than would otherwise be the case, however WSA catchment incomes are expected to remain lower than KSA incomes over the long term.

1.3 Key assumptions and limitations

The projections and forecasts in this report are subject to some limitations. They is based on projections from organisations such as the Australian Bureau of Statistics and the NSW Bureau of Transport Statistics. This data are often simply based on projecting existing growth patterns forward in time, and cannot incorporate unforeseen shocks, changes in policy and so forth that can substantially alter growth patterns. These are not predictions of what will happen in the future, but best estimates of what is likely to happen given available information.

Users of the New South Wales GVA industry projections should be aware that the state estimates are likely to be of lower quality than the equivalent Australian estimates. The data sources on which the projections are based are generally are a lower quality at the state level than the national level. Also there are inherent problems associated with the allocation of multi-state activities, especially in industries such as finance, long distance transport and communications.

Income forecasts for a whole city can be difficult to project, as they are heavily dependent on unforeseeable future events that may have nothing to do with Sydney itself. For example, the winding down of the mining boom is likely to result in lower incomes in Sydney than if it had continued, as many mining companies have offices in Sydney. International economic and financial events, exchange rates and even the weather can all fluctuate in unpredictable ways, and affect income forecasts.

Real growth in wages and incomes is estimated at 1% per year. Population growth is assumed to be in line with Series B population growth rates estimated by the ABS in their long term population forecasts for New South Wales (Cat. No. 3222.0). The new airport in Western Sydney is estimated to create a total of 18,100 new jobs.

Industry gross valued added figures are in 2012-13 prices for Australia and New South Wales.

The allocation of SLAs to the WSA, KSA and Marginal catchment areas is based on modelling of current transport times and costs. Substantial changes to either transport times and costs, for example through new road or public transport developments, may change the catchment areas for these airports.

2 METHODOLOGY

2.1 Data sources

The data sources selected were chosen based on the level of detail available in the data and the robustness of the projections. Where necessary, SGS used in-house modelling to generate the forecasts. The main sources of data used were:

- NSW Bureau of Transport Statistics (BTS) http://www.bts.nsw.gov.au/statistics/default.aspx provides employment and population projections to 2041, as well as data on travel times around Sydney. These figures were used as a baseline for most SGS forecasts.
- NSW Department of Planning and Environment (DPE) provides additional household-level data for the Sydney Metropolitan region http://www.planning.nsw.gov.au/en-us/deliveringhomes/populationandhouseholdprojections.aspx
- The 2011 Census Tablebuilder from the Australian Bureau of Statistics was used as a baseline for income projections.
- Australian Bureau of Statistics' Population Projections, Australia, 2012 to 2101 (Cat. No. 3222.0) Series B were used as to forecast population growth beyond 2041.
- Gross value added measures of economic activity were generated using SGS Economics & Planning Australian Cities Accounts 2013-14, Australian System of National Accounts (Cat. No. 5204.0) 2013-14 and Australian National Accounts: State Accounts, 2013-14 (Cat. No. 5220.0). The Volume measure (in real terms accounting for price inflation) Industry gross valued added (1 Digit) are in 2012-13 prices for Australia and New South Wales.
- Forecasting data for changes in GVA was obtained from a variety of sources, including the Australian Bureau of Statistics (ABS), OECD Economic Outlook and Interim Global Economic Assessment, Australia Bureau of Agricultural & Resource Economics (ABARE) and the Joint Economic Forecasting Group (JEFG).Population forecasts

Total population

SGS prepared its forecasts of the total population based on the September 2014 Release of BTS population forecasts, found at http://www.bts.nsw.gov.au/Statistics/Population-Forecasts/default.aspx These forecasts run out to 2041, taking into account Metropolitan Planning Development forecasts for future land use and Department of Planning and Environment population forecasts. These projections were extended out to 2075 by applying Series B population growth rates estimated by the ABS in their long term population forecasts in New South Wales (Cat. No. 3222.0) to the 2041 population as estimated by BTS.

Population by age group

NSW Department of Planning and Environment (DPE) prepares forecasts of population by age group by LGA for the Sydney Metropolitan region, found here: http://www.planning.nsw.gov.au/en-us/deliveringhomes/populationandhouseholdprojections.aspx LGAs are not dissimilar from SLAs, and in many cases their boundaries line up reasonably well. To ensure that these lined up with the BTS forecasts, the DPE population projections were used to calculate the percentage of each LGA's population in each age group. These percentages were then multiplied by the associated SLA population projected by BTS to come up with population by age group by SLA.

For projections beyond 2041, SGS calculated the growth rate for each five year population age group in New South Wales from 2041 to 2075, based on ABS long term population projections by age group for New South Wales (Cat no 3222.0, series B). These were used to calculate the growth of each age group

by SLA. These estimates were adjusted so that they lined up with the total population projections created in the previous section.

Employment forecasts

Employment forecasts were also based on the 2011-2041 (September 2014 Release) BTS forecasts. This uses data from the Census, Journey to Work and data on labour force and employment by industry to forecast total jobs for the Sydney GMA, and then breaks this down by industry shares. This is then broken down by SA4, SA3 and so forth, down to the travel zone level. This produces trend-based forecasts. Then new developments can be used to adjust forecasts at the travel zone level. For example, a new office complex, industrial building or shopping centre that was not complete and operational by the 2011 Census will have an impact on employment, but will not show up in the trend forecasts. The forecasts are adjusted to take into account the impact of these projects on the trend.

However, the employment forecasts generated by BTS did not incorporate the impact of WSA. SGS used the BTS forecasts as a base and altered the data to take into account expected employment growth from WSA. It estimated the additional jobs created by airports in Melbourne, Sydney and Brisbane and used these employment patterns to add additional jobs to the BTS forecasts in accordance with WSA development. SGS estimated that by 2041, the broader South West Sydney area could expect an additional 18,100 jobs, some but not all of which would be at the new airport.
Beyond 2041, projections were made based on trend growth in employment from 2031 to 2041. This process is shown in Figure 1.

FIGURE 1 GENERATING EMPLOYMENT FORECASTS



2.2 Income forecasts

Household income brackets

This series was based on the number of households in each income bracket in each SLA from the 2011 Census. Since a small but significant number of households choose not to report their incomes, we calculated the proportion of households in each income bracket in each SLA, out of those who reported

their incomes, and applied these proportions to the SLA population identified in the BTS population estimates.

To project the population forward to 2075, similar proportions were applied to the total population projections. However, they were modified to take into account changes in the population age distribution. As the population ages, it can be expected that there will be a greater number of people in low income groups, as retirees tend to have lower incomes than working age people. For this reason, the proportion of people in the lower two income groups were allowed to grow at the same rate as the proportion of over-65s in the population.

Income brackets should be indexed to real wage growth, which means that apart from the growth in lower income groups, roughly the same proportion of households will remain in each income bracket.

Mean household incomes

SGS used a different method to estimate mean household incomes by SLA than that used to estimate household income brackets. Mean income by SLA was estimated from the 2011 Census by taking the midpoint in each income bracket, multiplying that by the number of households in that income bracket and dividing that by the total number of households that reported their income.

The projections were made on the assumption that real wage growth would average 1% across the Sydney area (note that this estimate at the conservative end of the possible range). Variation in mean household income growth by SLA was achieved by multiplying the percentage growth in GVA by SLA to mean household income by SLA. This resulted in some SLAs having very high or very low growth, so in such circumstances, growth was averaged across surrounding SLAs. This method was used to project growth out to 2041, since they are indirectly based on BTS employment growth forecasts. After that, income growth of 1% per year is applied to all SLAs.

SGS validated these forecast mean household income estimates by ranking SLAs by income level every five years, and ensuring that there were no unreasonable or unlikely changes in SLA income rankings.

2.3 Economic activity forecasts

SGS Economics and Planning produced New South Wales and Australian level forecasts of Industry gross valued added (at the 1 Digit ANZSIC level) from 2014-15 to 2074-75. The starting point in the forecasting process is to assess the economic environment climate in individual major cities, states, Australia and the world economy as a whole. This is based on data for the most recent completed financial year from SGS Economics & Planning Australian Cities Accounts 2013-14, Australian System of National Accounts (Cat. No. 5204.0) 2013-14 and Australian National Accounts: State Accounts, 2013-14 (Cat. No. 5220.0). The Volume measure (in real terms accounting for price inflation) Industry gross valued added (1 Digit) are in 2012-13 prices for Australia and New South Wales.

Forecasting data was obtained from a variety of sources, including the Australian Bureau of Statistics (ABS), OECD Economic Outlook and Interim Global Economic Assessment, Australia Bureau of Agricultural & Resource Economics (ABARE) and the Joint Economic Forecasting Group (JEFG). This information was used to develop a set of economic forecasts for the Australian economy out to 2020. As a first step relevant new information published since the last projections were produced, such as outlooks for commodity prices (in particular the iron ore, natural gas, oil price), exchange rates and interest rates, fiscal trends and the overall the path of economic activity are examined to see how the recent past has developed differently from what was previously expected.

This data is combined with trend analysis which is used to produce major capital city and balance of state forecasts for Industry gross value added, Ownership of dwellings and Taxes less subsidies on products. For the smaller jurisdictions (Tasmania, Northern Territory and the Australian Capital Territory) estimates are produced at the state level. The estimates from all geographical regionals are then

combined and averaged with the national estimates. This may results in changes to the all geographical regions forecasts and / or the national estimate. This produces a consistent set of forecasts for all industry and all region.

For the period 2025-2045, various employment and demography projections are used to inform the forecasts for each major capital city. State and national population projections, trends in labour force participation and growth in industry productivity are used to produce a set of Industry gross value added, Ownership of dwellings and Taxes less subsidies on products for each geographical region. The estimates from all geographical regionals are combined and averaged with the national estimates. Relative industry and geographical shares are compared to ensure the weight of future growth is achievable given patterns observed over the past thirty years. This may result in changes to the all geographical regions forecasts and / or the national estimate. This produces a consistent set of forecasts for all industry and all region.

For the period 2050-2075 in the absence of other indicator data a trend based approach is used at the national level and state. In the trend based forecasts a higher weight is given to the national level trends as there is more confidence regarding Australian economic growth than individual geographical regions.

2.4 Transport times and costs

Data based on BTS figures was used to estimate the time taken to get from each SA2 to Kingsford Smith Airport and Badgerys Creek by car and public transport. The estimates of travel costs by car were generated from figures on transport distance in kilometres and transport times. Total cost of the trip was estimated by multiplying the distance by 75 cents per kilometre, and adding that to the total time of the trip, multiplied by 50 cents.

The estimates of public transport travel costs were generated from in-vehicle travel time costs generated by BTS. Travel time was multiplied a time cost of 50 cents per minute. The cost of travel was based on adult train fare costs. It was assumed that an airport pass fee of $12.60 would be incorporated into the cost of each ticket. The sum of time costs and fare costs was added together to estimate total costs.

These estimates of transport times and costs was used to divide Sydney GMA into four areas: the KSA catchment, the Marginal catchment, the WSA Catchment and Other (outlying areas of the Sydney GMA, such as Kiama and Newcastle, that face high travel costs and/or long transport times to both airports). As this is used into an input into the other areas of analysis, it is not discussed separately in following chapters.

3 POPULATION FORECASTS

The population of the Sydney GMA is forecast to grow from 5.72 million in 2015 to 11.2 million by 2075. The seven million mark will be passed by 2030, 8 million by 2045 and 10 million by 2060. The population age profile will be different to its present age profile, with a greater share of the population over the age of 65. At present, 62% of Sydney's population is aged from 20-64 and 13% are 65 and older. The share of 65+ is projected to increase to 18% by 2040. 20% by 2060 and 21% by 2075. Over this period, the share of the population aged 20-64 is expected to decline to 56%, and the proportion of the population aged under 20 is expected to decline from the present 25% to 23%.

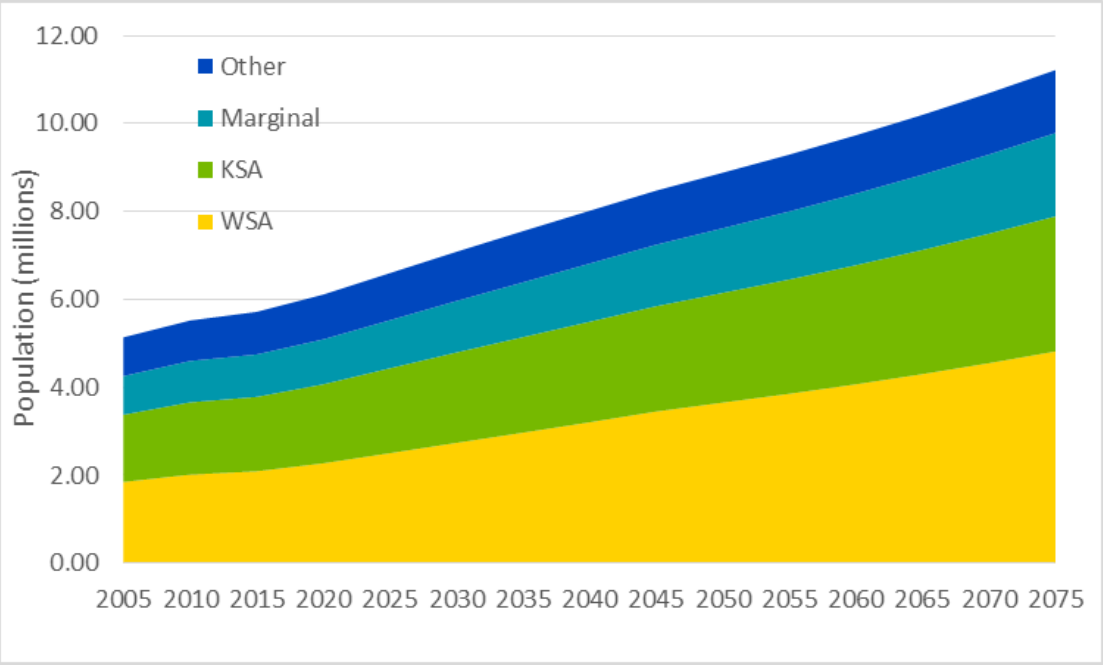
Population forecasts show that population growth is higher in the WSA catchment area than other areas. The overall Sydney GMA population is projected to more than double from 2015 to 2075; however the present KSA catchment is only projected to increase by 82% and marginal areas by 96%, while the WSA catchment is projected to increase by 130%.

TABLE 1 SYDNEY GMA POPULATION GROWHT BY AIRPORT CATCHMENT, 2015-2075

Population	2015	2030	2050	2075
Sydney	5.72m	7.09m	8.88m	11.22
Catchments as a percentage of Sydney				
WSA	37%	39%	41%	43%
KSA	30%	29%	28%	27%
Marginal	17%	17%	17%	17%

Source: SGS modelling

FIGURE 2. SYDNEY POPULATION BY AIRPORT CATCHMENT, 2005-2075



Source: SGS projections, 2015

As discussed in the Methodology section, this is based on BTS forecasts, with some amendments made to cover the additional employment expected to be induced by the new airport. Even without this, Western Sydney was expected to show more population growth than other areas due to high land prices and congestion in central Sydney.

The demographic in the Western Sydney catchment is much younger than that in other areas of Sydney. Twenty-eight percent of Western Sydney's catchment is aged 19 or under, compared to 22% in the KSA and marginal catchment areas. Twelve percent of the WSA catchment is aged 65 and over, compared to 14 percent elsewhere in Sydney. Relatively cheaper housing in Western Sydney attracts younger people starting out in life, in particular young families or soon-to-be families who do not wish to raise a family in an apartment. In contrast, the inner suburbs are more likely to be held by people who purchased years ago when housing was more affordable. These age breakdowns are shown in Figure 3.

FIGURE 3. POPULATION BY AGE GROUP, WSA AND OTHER SYDNEY, 2015-2075



Source: SGS projections, 2015

Into the future, population ageing is apparent across all of Sydney, with the population aged 65 and over increasing from 13% in 2015 to 21% in 2075. The WSA catchment is projected to have a lower share of the aged population, with only 20.8% of its population aged 65+ compared to 22% elsewhere in Sydney in 2075 It is expected to maintain a greater proportion of children and young people than elsewhere in Sydney. By 2075, the proportion of people aged 19 and under in the WSA catchment is expected to have fallen to 26%; elsewhere in Sydney it is expected to have fallen to 20%.

4 INCOME FORECASTS

At the last Census, mean household income was just under $100,000 in Sydney. Assuming real wage growth of 1% per year, forecasts suggest that mean household income will pass the $150,000 mark by 2055, as shown in Table 2.

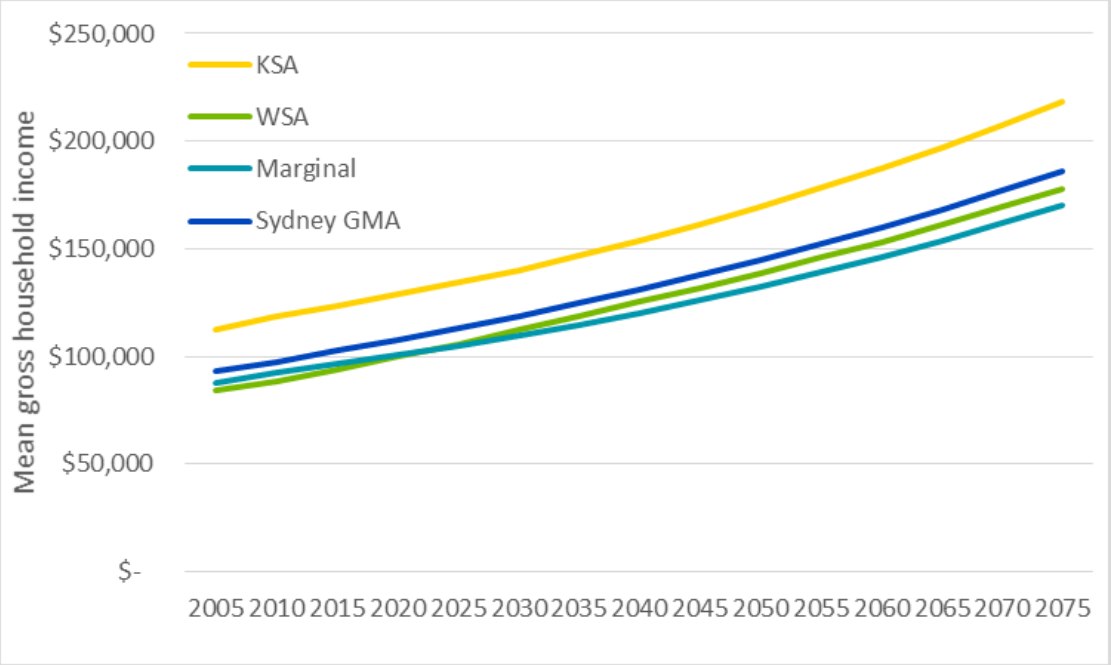
TABLE 2 SYDNEY MEAN INCOMES, 2015-2075

Income	2015	2030	2050	2075
Sydney	$103,000	$119,000	$145,000	$186,000
Mean household income by catchment				
WSA	$94,000	$112,000	$139,000	$178,000
KSA	$124,000	$140,317	$170,000	$218,000
Marginal	$96,000	$115,000	$133,000	$170,000

Source: SGS

At present, the WSA catchment has relatively low incomes, with average household income only three-quarters of that seen in the KSA catchment, and only around 90% of the Sydney GMA average. The employment boost brought on by the airport and further developments in Western Sydney is likely to see incomes increase in Western Sydney relative to the other catchment areas. By the time the airport is fully operational, incomes in the WSA catchment are expected to be four percent higher than in the marginal catchment area, and just over 80% of those in the KSA catchment and 95% of the Sydney GMA average.

FIGURE 4. MEAN HOUSEHOLD INCOMES BY CATCHMENT



Source: SGS projections, 2015

It is expected that the KSA catchment will maintain a lead in mean household incomes over the other catchments. The KSA catchment has attractive features such as proximity to the beaches, the CBD and the harbour, attracting a price premium which forces lower income households out of the catchment.

Although employment growth rates in the WSA catchment are expected to be stronger than those elsewhere in Sydney, it is not expected that this will be sufficient to overtake incomes in the KSA catchment.

5 EMPLOYMENT FORECASTS

As Sydney's population grows, employment grows to support it. Total employment in the Greater Metropolitan Area of Sydney is forecast to grow from just over 3 million in 2015 to over 5.7 million in 2075. This is slower than the rate of population growth: while population is projected to grow by 96% between 2015 and 2075, employment is only expected to grow by 86%. As a result, the employed as a share of total population is expected to fall from 54% to 51%.

A major reason for this is the ageing of the population, resulting in a greater share of the population in the retirement phase of their lives. The working age population – those aged from 20-65 – is projected to grow 85% between 2015 and 2075, slightly lower than the total growth in employment. This suggests that either employment rates will rise among the working age population, or employment will become more common among over-65s.

Table 3 shows the employment forecasts for the Sydney Greater Metropolitan region and the WSA, KSA and Marginal catchments.

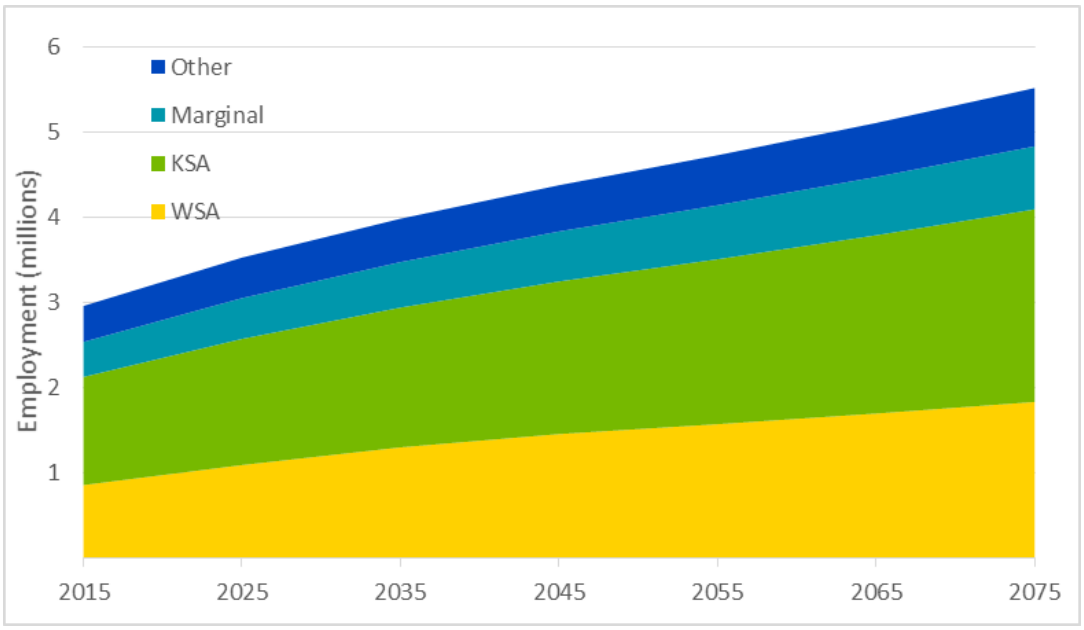
TABLE 3 SYDNEY EMPLOYMENT FORECASTS, 2015-2075

Employment	2015	2030	2050	2075
Sydney GMA	3.08m	3.91m	4.73m	5.73m
Catchments as a percentage of Sydney				
WSA	0.86m	1.20m	1.52m	1.83m
KSA	1.27m	1.56m	1.86m	2.26m
Marginal	0.41m	0.51m	0.61m	0.74m

Source: SGS projections, 2015

The establishment of the Western Sydney Airport and other employment areas in Western Sydney is expected to increase the share of Sydney's jobs located in the WSA catchment area, as shown in Figure 5. At present, 34% of Sydney's jobs are located in the WSA catchment; by 2045, jobs growth around the airport and other Western Sydney employment growth is expected to increase this to 38%. This is associated with a greater share of Sydney's working age population living in Western Sydney.

FIGURE 5. SYDNEY EMPLOYMENT FORECASTS BY CATCHMENT AREA

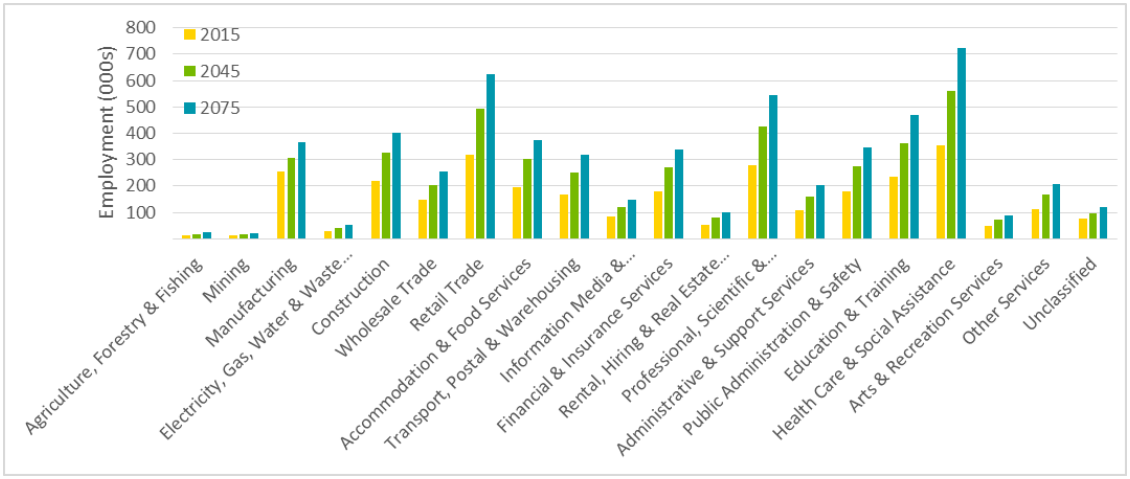


Source: SGS projections, 2015

The share of employment in the KSA catchment is expected to decline from 50% of Sydney's jobs to 47% over 2015-2075, while employment in marginal areas is expected to decline from 16% to 15%.

The industries providing the greatest number of jobs are currently Health Care and Social Assistance (354,000), Retail Trade (320,000), Professional, Scientific and Technical Services (279,000) Education and Training (237,000) and Construction (218,000). Employment in all industries and forecast employment in 2045 and 2075 is shown in Figure 6.

FIGURE 6. EMPLOYMENT BY INDUSTRY



Source: SGS projections, 2015

Unsurprisingly, the industry with the highest forecast growth from 2015 to 2075 is the Health Care and Social Assistance industry, which is projected to more than double its employment numbers over this period. As the population ages, demand for health and support services tends to increase, as the greatest demand for these services comes from older people. Other industries forecast to have high employment growth include Education and Training (98% employment growth) Professional, Scientific and Technical Services (96%) and Retail Trade (95%).

Part of the reason for the higher rates of employment growth in Western Sydney is an expected additional 18,100 jobs focused in the Western Sydney area due to the establishment of the airport. These jobs are likely to be focused in construction (during the establishment phase), transport, accommodation, retail, professional services and public administration. Other jobs growth is due to the increasing population in the WSA catchment, driving demand for local services. Table 4 shows forecast growth in selected industries from 2015 to 2045 that are expected to show comparatively high rates of growth in the WSA catchment.

TABLE 4 GROWTH IN EMPLOYMENT, 2015-2045

Employment	Construction	Accommodation	Transport	Administration	Prof. Services	Retail
Sydney GMA	149%	153%	148%	149%	153%	154%
WSA	160%	183%	193%	190%	219%	182%
KSA	148%	143%	122%	137%	141%	147%
Marginal	147%	146%	138%	141%	154%	140%

Source: SGS

6 ECONOMIC ACTIVITY FORECASTS

Gross value added (GVA), a measure of production, across Sydney is forecast to grow in real terms from $283 billion in 2010 to $1.6 trillion in 2075. Major employment hubs contribute most to GVA, for example the CBD (Inner Sydney SLA) contributes $47 billion alone, while Botany Bay contributes nearly $19 billion. Areas that are predominantly residential, such as Mosman, tend to have the lowest GVA.

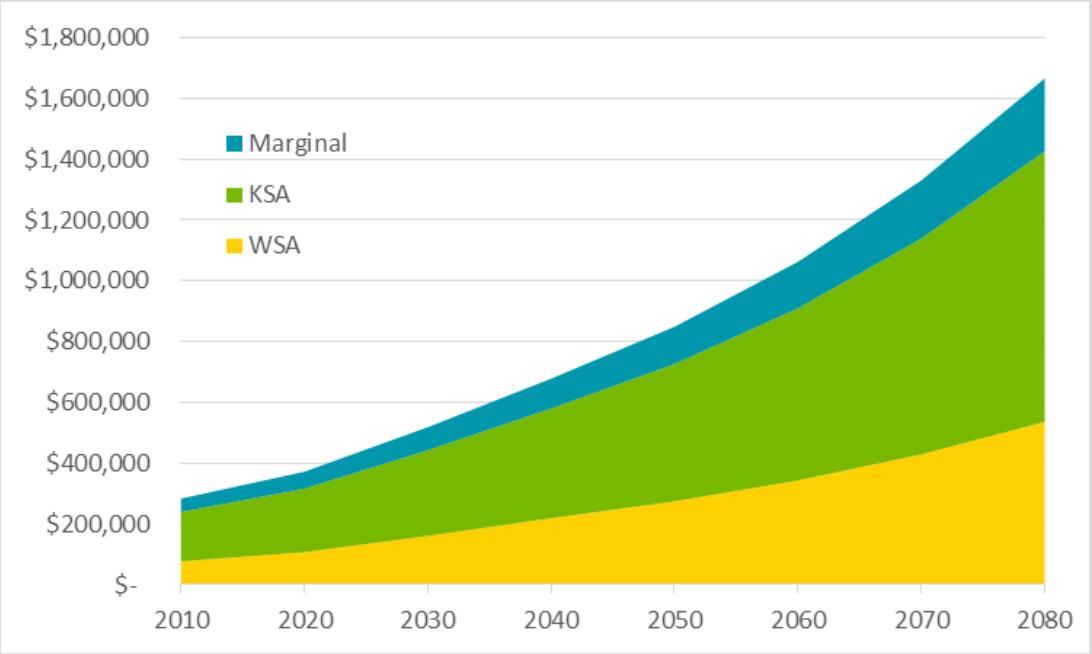
Table 5 shows the economic activity of Sydney and the three airport catchments from 2010 to 2070. By 2070, economic activity in the WSA catchment is expected to be five and a half times greater than it was in 2010, growing from $77 billion to $429 billion. The KSA and Marginal catchments only expect to increase by just over four times over this period.

TABLE 5 SYDNEY ECONOMIC ACTIVITY, 2010-2070

Economic Activity	2010	2030	2050	2070
Sydney	$283bn	$519bn	$849bn	$1,331bn
Catchments as a percentage of Sydney				
WSA	$77bn	$161bn	$275bn	$429bn
KSA	$162bn	$282bn	$452bn	$710bn
Marginal	$44bn	$76bn	$123bn	$192bn

Source: SGS modelling. 2015

FIGURE 7. GROSS VALUE ADDED, SYDNEY, 2010 - 2080



Source: SGS modelling, 2015

Western Sydney expects to see significant growth in GVA due to growing population in the area and new employment hubs, such as those established by the new airport. Between 2020 and 2030, the WSA expects an average of 49% growth in GVA, compared to 35% growth in KSA and marginal catchments; and between 2030 and 2040, growth of 36% is forecast in WSA, greater than the 28% expected in KSA and 30% in the marginal catchments. After this period, growth across all areas is forecast to be similar.

7 APPENDIX

TABLE 6 SYDNEY ECONOMIC ACTIVITY, 2010-2080

GVA	2010	2020	2030	2040	2050	2060	2070	2080
Ashfield (A)	$1,053	$1,366	$1,796	$2,362	$2,964	$3,718	$4,664	$5,851
Auburn (A)	$10,347	$13,186	$18,741	$24,975	$31,326	$39,175	$48,993	$61,273
Bankstown (C) - North-East	$3,225	$3,981	$5,217	$6,601	$8,255	$10,320	$12,901	$16,129
Bankstown (C) - North-West	$3,203	$4,074	$5,288	$6,642	$8,251	$10,270	$12,785	$15,918
Bankstown (C) - South	$2,587	$3,239	$4,118	$5,073	$6,275	$7,774	$9,635	$11,946
Baulkham Hills (A) - Central	$6,092	$9,572	$15,232	$20,707	$25,915	$32,392	$40,490	$50,613
Baulkham Hills (A) - North	$1,491	$2,676	$5,223	$8,218	$10,335	$12,929	$16,176	$20,238
Baulkham Hills (A) - South	$1,168	$1,533	$2,104	$2,755	$3,460	$4,350	$5,470	$6,878
Blacktown (C) - North	$1,776	$2,929	$6,543	$10,432	$13,168	$16,454	$20,562	$25,696
Blacktown (C) - South-East	$8,083	$10,409	$13,991	$18,156	$22,680	$28,328	$35,384	$44,200
Blacktown (C) - South-West	$3,692	$5,953	$9,248	$11,727	$14,632	$18,295	$22,875	$28,604
Blue Mountains (C)	$1,202	$1,492	$1,972	$2,506	$3,147	$3,944	$4,942	$6,194
Botany Bay (C)	$18,678	$24,020	$32,879	$41,708	$52,513	$65,924	$82,762	$103,903
Burwood (A)	$1,285	$1,575	$2,166	$2,868	$3,597	$4,518	$5,673	$7,125
Camden (A)	$1,812	$3,309	$6,118	$8,653	$10,997	$13,757	$17,210	$21,532
Campbelltown (C) - North	$2,786	$3,809	$5,168	$6,638	$8,314	$10,349	$12,884	$16,041
Campbelltown (C) - South	$1,654	$2,084	$2,828	$3,687	$4,638	$5,810	$7,277	$9,116
Canada Bay (A) - Concord	$2,530	$2,929	$4,051	$5,376	$6,726	$8,416	$10,531	$13,178
Canada Bay (A) - Drummoyne	$785	$952	$1,332	$1,782	$2,223	$2,788	$3,496	$4,385
Canterbury (C)	$2,259	$2,866	$3,728	$4,694	$5,848	$7,299	$9,111	$11,374
Fairfield (C) - East	$1,758	$2,164	$2,826	$3,565	$4,462	$5,569	$6,952	$8,683
Fairfield (C) - West	$4,318	$6,210	$9,432	$11,603	$14,474	$18,024	$22,448	$27,961
Gosford (C) - East	$1,358	$1,645	$2,127	$2,664	$3,336	$4,179	$5,234	$6,555
Gosford (C) - West	$3,217	$3,912	$5,023	$6,228	$7,756	$9,687	$12,101	$15,116
Hawkesbury (C)	$1,962	$2,545	$3,426	$4,409	$5,494	$6,859	$8,563	$10,692
Holroyd (C)	$4,540	$5,960	$7,860	$9,995	$12,414	$15,479	$19,302	$24,071
Hornsby (A) - North	$1,202	$1,563	$2,116	$2,745	$3,432	$4,295	$5,375	$6,727
Hornsby (A) - South	$3,106	$4,112	$5,411	$6,889	$8,610	$10,779	$13,496	$16,897
Hunter's Hill (A)	$339	$435	$590	$767	$958	$1,198	$1,499	$1,876
Hurstville (C)	$2,031	$2,536	$3,305	$4,161	$5,199	$6,507	$8,144	$10,193
Kogarah (A)	$1,546	$1,971	$2,608	$3,310	$4,136	$5,177	$6,482	$8,116
Ku-ring-gai (A)	$3,122	$4,016	$5,286	$6,701	$8,393	$10,524	$13,197	$16,549
Lane Cove (A)	$2,563	$3,319	$4,336	$5,461	$6,831	$8,556	$10,716	$13,422
Leichhardt (A)	$2,161	$2,775	$3,728	$4,837	$6,059	$7,593	$9,515	$11,925
Liverpool (C) -	$4,521	$6,490	$9,224	$11,935	$14,944	$18,678	$23,346	$29,184

East								
Liverpool (C) - West	$1,582	$2,761	$6,195	$12,175	$15,450	$19,331	$24,188	$30,266
Manly (A)	$1,277	$1,578	$2,102	$2,699	$3,380	$4,239	$5,317	$6,670
Marrickville (A)	$2,611	$3,495	$4,563	$5,747	$7,179	$8,969	$11,208	$14,006
Mosman (A)	$983	$1,195	$1,603	$2,062	$2,588	$3,249	$4,079	$5,121
North Sydney (A)	$14,811	$18,379	$24,595	$31,608	$39,635	$49,763	$62,481	$78,452
Parramatta (C) - Inner	$9,292	$12,155	$16,648	$21,939	$27,447	$34,347	$42,983	$53,793
Parramatta (C) - North-East	$1,394	$1,840	$2,425	$3,072	$3,824	$4,767	$5,943	$7,409
Parramatta (C) - North-West	$716	$934	$1,204	$1,506	$1,877	$2,351	$2,944	$3,691
Parramatta (C) - South	$1,015	$1,304	$1,706	$2,170	$2,709	$3,388	$4,237	$5,300
Penrith (C) - East	$2,769	$4,180	$8,818	$14,766	$18,527	$23,169	$28,976	$36,240
Penrith (C) - West	$3,219	$4,216	$5,599	$7,067	$8,799	$10,998	$13,747	$17,183
Pittwater (A)	$2,138	$2,705	$3,637	$4,687	$5,858	$7,327	$9,165	$11,464
Randwick (C)	$3,491	$4,256	$5,616	$7,142	$8,959	$11,227	$14,071	$17,636
Rockdale (C)	$5,125	$7,604	$10,864	$15,296	$19,099	$23,946	$30,024	$37,645
Ryde (C)	$14,432	$18,444	$24,848	$32,151	$40,090	$50,080	$62,561	$78,155
Strathfield (A)	$4,918	$6,155	$8,324	$10,877	$13,617	$17,049	$21,347	$26,728
Sutherland Shire (A) - East	$5,100	$6,659	$8,675	$10,833	$13,447	$16,719	$20,789	$25,854
Sutherland Shire (A) - West	$1,973	$2,473	$3,269	$4,150	$5,190	$6,499	$8,140	$10,195
Sydney (C) - East	$6,101	$7,412	$9,866	$12,616	$15,748	$19,731	$24,724	$30,982
Sydney (C) - Inner	$47,618	$60,526	$81,126	$103,044	$128,665	$161,555	$202,857	$254,723
Sydney (C) - South	$9,846	$14,323	$21,429	$27,713	$34,666	$43,398	$54,331	$68,020
Sydney (C) - West	$6,094	$7,620	$10,301	$13,120	$16,434	$20,614	$25,857	$32,435
Warringah (A)	$6,413	$8,222	$10,900	$13,839	$17,294	$21,622	$27,034	$33,803
Waverley (A)	$6,773	$8,824	$11,293	$14,022	$17,520	$21,907	$27,395	$34,257
Willoughby (C)	$3,317	$4,120	$5,428	$6,900	$8,643	$10,840	$13,595	$17,052
Wollondilly (A)	$1,058	$1,416	$1,932	$2,526	$3,169	$3,962	$4,953	$6,193
Woollahra (A)	$2,337	$2,919	$3,841	$4,859	$6,066	$7,611	$9,550	$11,983
Wyong (A) - North-East	$1,554	$2,157	$3,104	$4,425	$5,589	$6,992	$8,747	$10,943
Wyong (A) - South and West	$2,393	$2,904	$3,812	$4,802	$5,997	$7,491	$9,359	$11,692
TOTAL	$283,801	$372,380	$518,763	$678,645	$849,229	$1,063,054	$1,330,790	$1,666,047

Source: SGS modelling. 2015

TABLE 7 SYDNEY GMA POPULATION BY SLA, 2005-2075

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075
Ashfield (A)	41,097	43,134	44,314	44,556	46,950	49,258	51,262	52,966	54,641	56,369	58,151	59,989	61,885	63,842	65,860
Auburn (C)	66,351	77,011	77,880	87,740	100,056	113,083	126,296	139,244	152,459	162,463	172,077	182,261	193,047	204,472	216,572
Bankstown (C) - North-East	57,660	63,721	67,856	72,107	78,441	84,828	90,615	96,256	102,120	109,060	116,656	124,781	133,471	142,767	152,710
Bankstown (C) - North-West	63,651	67,899	69,428	74,046	79,268	83,850	87,685	91,447	95,418	100,082	105,100	110,370	115,903	121,715	127,817
Bankstown (C) - South	53,094	56,198	56,884	58,968	61,154	64,896	68,537	72,090	75,818	78,514	81,004	83,572	86,223	88,957	91,778
Blacktown (C) - North	87,930	103,467	106,426	126,527	159,380	193,348	230,808	270,867	303,978	328,131	351,796	377,167	404,369	433,532	464,798
Blacktown (C) - South-East	93,099	100,143	113,417	121,325	125,666	130,795	135,994	141,192	151,273	158,992	166,058	173,439	181,148	189,199	197,609
Blacktown (C) - South-West	95,900	102,956	104,138	108,774	112,465	115,520	118,529	121,635	128,951	135,643	142,160	148,990	156,147	163,649	171,511
Blue Mountains (C)	76,475	78,062	78,320	81,220	85,741	90,741	95,931	101,891	106,816	111,950	117,419	123,156	129,172	135,483	142,102
Botany Bay (C)	37,456	41,031	41,538	44,534	47,573	51,606	55,289	58,711	62,255	65,371	68,486	71,749	75,167	78,749	82,501
Burwood (A)	31,901	33,922	36,189	39,534	43,018	46,245	48,873	51,063	53,210	57,721	63,208	69,217	75,798	83,003	90,894
Camden (A)	50,322	56,770	60,965	82,251	106,074	131,265	159,127	188,520	218,907	233,355	244,156	255,457	267,281	279,652	292,596
Campbelltown (C) - North	78,225	78,075	78,741	89,471	104,181	117,018	126,884	136,055	145,182	152,524	159,679	167,169	175,011	183,221	191,816
Campbelltown (C) - South	69,973	72,213	73,412	76,816	81,720	86,202	92,037	99,210	107,003	115,445	124,566	134,409	145,030	156,489	168,854
Canada Bay (A) - Concord	31,509	39,503	42,678	50,483	58,617	63,170	66,482	69,522	72,430	74,855	77,223	79,666	82,185	84,785	87,467
Canada Bay (A) - Drummoyne	35,876	38,046	38,718	40,014	41,150	44,105	47,110	49,846	52,455	54,076	55,485	56,931	58,414	59,936	61,497
Canterbury (C)	134,705	143,597	144,851	150,460	159,015	168,313	177,825	186,618	195,330	202,323	209,054	216,009	223,196	230,622	238,295
Cessnock (C)	47,942	51,506	56,391	60,272	63,431	66,403	68,834	70,771	72,392	75,731	79,670	83,815	88,175	92,762	97,588
Fairfield (C) - East	114,223	121,830	127,861	133,576	139,473	147,349	154,007	160,653	167,799	175,836	184,391	193,363	202,771	212,637	222,982
Fairfield (C) - West	72,951	73,468	73,105	76,239	81,844	86,852	90,771	94,699	98,888	104,808	111,471	118,557	126,094	134,110	142,635
Gosford (C) - East	66,847	68,955	68,037	69,447	71,924	73,886	75,234	77,150	78,987	81,491	84,251	87,105	90,055	93,104	96,258
Gosford (C) - West	94,790	98,041	101,636	105,132	108,372	112,322	115,565	120,862	126,581	133,303	140,590	148,276	156,382	164,931	173,947
Hawkesbury (C)	62,108	63,857	66,796	70,141	74,189	78,676	83,332	88,631	93,119	95,451	97,334	99,254	101,213	103,209	105,245
Holroyd (C)	91,646	101,860	102,290	108,369	116,135	123,482	130,905	137,668	144,254	150,279	156,353	162,672	169,247	176,088	183,205
Hornsby (A) - North	67,731	69,386	67,008	68,130	70,697	72,834	75,768	79,304	83,077	86,466	89,853	93,372	97,029	100,829	104,779
Hornsby (A) - South	88,889	93,412	99,642	105,709	111,648	119,363	126,858	132,910	138,559	144,562	150,872	157,457	164,330	171,502	178,987

Hunters Hill (A)	13,777	13,884	13,894	14,433	15,773	16,708	17,583	18,779	19,899	21,041	22,253	23,534	24,889	26,322	27,837
Hurstville (C)	75,947	81,565	87,359	92,684	99,234	105,777	111,900	117,558	123,329	127,627	131,642	135,784	140,055	144,461	149,006
Kiama (A)	19,938	20,620	23,267	24,992	26,365	27,723	29,040	30,308	31,520	32,150	32,644	33,145	33,654	34,171	34,696
Kogarah (C)	54,382	58,235	58,902	62,052	66,583	71,594	76,824	81,940	86,653	89,906	92,893	95,980	99,169	102,464	105,869
Ku-ring-gai (A)	105,579	112,671	117,309	126,372	136,973	146,346	154,447	161,769	168,638	175,541	182,699	190,148	197,902	205,972	214,370
Lake Macquarie (C) - East	62,394	62,997	63,767	65,394	67,085	68,462	69,723	71,029	72,184	73,019	73,790	74,570	75,358	76,154	76,958
Lake Macquarie (C) - North	75,327	77,854	90,950	95,044	96,812	98,561	100,311	102,312	104,290	106,624	109,098	111,629	114,219	116,869	119,580
Lake Macquarie (C) - West	53,367	54,432	53,344	54,487	56,945	59,466	61,792	64,186	66,319	68,481	70,726	73,045	75,440	77,913	80,468
Lane Cove (A)	31,747	32,758	34,027	36,776	39,967	44,183	48,506	52,730	56,690	59,453	62,017	64,691	67,481	70,391	73,427
Leichhardt (A)	51,244	54,961	57,746	60,340	63,479	66,698	69,949	73,130	75,999	78,382	80,717	83,121	85,597	88,147	90,773
Liverpool (C) - East	99,899	108,715	111,844	116,338	122,736	130,459	136,892	143,012	149,199	155,688	162,478	169,564	176,960	184,677	192,732
Liverpool (C) - West	68,685	75,956	77,789	93,349	115,138	137,748	157,767	179,146	201,833	232,017	267,996	309,554	357,557	413,004	477,049
Maitland (C)	62,796	68,499	71,451	78,472	86,065	93,635	101,398	105,341	108,073	113,331	119,492	125,989	132,839	140,061	147,675
Manly (A)	38,877	41,653	42,761	44,530	47,138	50,008	52,997	55,980	58,754	60,950	63,071	65,266	67,538	69,888	72,321
Marrickville (A)	75,220	80,664	81,211	84,452	89,342	94,668	101,213	107,670	113,916	117,959	121,544	125,237	129,042	132,964	137,004
Mosman (A)	27,716	29,227	29,376	30,285	31,747	33,359	35,014	36,648	38,044	39,265	40,486	41,745	43,043	44,382	45,762
Newcastle (C) - Inner City	50,750	52,347	52,667	55,059	59,078	62,649	65,950	68,626	70,978	72,595	74,062	75,559	77,086	78,644	80,233
Newcastle (C) - Outer West	43,419	45,666	54,028	59,281	63,251	67,492	71,898	75,038	77,721	79,450	80,972	82,523	84,105	85,716	87,358
Newcastle (C) - Throsby	53,711	55,529	63,886	68,515	71,116	73,652	76,035	77,467	78,517	79,156	79,706	80,260	80,818	81,379	81,944
North Sydney (A)	61,254	66,049	73,195	80,001	86,763	92,937	98,865	104,395	109,552	113,999	118,419	123,011	127,780	132,735	137,881
Parramatta (C) - Inner	41,271	49,082	57,810	67,110	74,998	84,354	95,802	110,211	125,673	134,982	143,099	151,705	160,829	170,501	180,755
Parramatta (C) - North-East	43,616	47,050	46,984	50,364	56,007	61,332	66,184	69,917	73,456	76,676	79,919	83,299	86,821	90,493	94,319
Parramatta (C) - North-West	34,454	38,304	40,176	42,918	46,635	50,944	54,907	57,276	59,362	61,270	63,175	65,138	67,162	69,250	71,402
Parramatta (C) - South	32,097	36,182	36,934	39,261	43,096	47,154	50,893	53,288	55,429	57,215	58,948	60,735	62,575	64,472	66,425
Penrith (C) - East	96,090	99,087	100,325	109,565	121,752	131,360	141,039	152,727	165,354	174,747	183,651	193,008	202,842	213,177	224,039
Penrith (C) - West	80,876	83,850	83,905	90,024	98,014	106,730	115,567	123,057	130,206	137,252	144,574	152,286	160,409	168,966	177,979
Pittwater (A)	56,306	59,399	60,416	63,215	67,640	71,716	76,568	82,071	86,872	90,255	93,420	96,696	100,086	103,596	107,229
Port Stephens (A)	62,952	66,575	70,674	77,264	83,161	88,529	93,505	96,581	99,003	100,792	102,458	104,151	105,872	107,621	109,399

Randwick (C)	125,404	135,923	137,785	145,233	154,869	163,698	172,508	180,885	188,626	195,693	202,826	210,220	217,883	225,825	234,057
Rockdale (C)	95,512	102,928	105,386	113,461	121,303	127,846	134,277	140,266	145,906	150,679	155,363	160,192	165,172	170,306	175,600
Ryde (C)	100,188	106,947	113,831	122,266	132,919	145,029	157,738	169,252	180,631	190,856	201,213	212,131	223,642	235,778	248,572
Shellharbour (C)	62,761	65,712	66,185	69,766	74,423	79,015	83,402	87,588	91,616	94,224	96,528	98,888	101,306	103,783	106,321
Shoalhaven (C) - Pt A	32,013	34,004	34,636	35,934	37,746	39,368	40,690	41,730	42,383	43,249	44,206	45,184	46,184	47,206	48,250
Shoalhaven (C) - Pt B	59,572	61,310	63,511	65,638	67,394	69,176	70,735	71,911	72,668	75,067	77,985	81,016	84,166	87,438	90,837
Strathfield (A)	32,351	36,907	37,891	41,182	48,287	52,836	55,905	58,944	62,119	66,259	70,878	75,818	81,102	86,755	92,802
Sutherland Shire (A) - East	100,836	105,234	106,432	111,054	118,960	126,337	132,761	138,695	144,819	149,549	154,019	158,622	163,362	168,245	173,273
Sutherland Shire (A) - West	112,028	114,326	113,228	116,213	120,906	126,670	131,980	136,865	141,910	146,264	150,528	154,917	159,433	164,081	168,865
Sydney (C) - East	48,855	51,766	51,574	51,936	52,577	53,395	55,456	57,738	60,029	62,768	65,725	68,821	72,063	75,457	79,011
Sydney (C) - Inner	21,841	25,157	26,493	27,916	31,852	35,168	37,875	40,213	42,531	45,562	48,959	52,609	56,532	60,747	65,276
Sydney (C) - South	50,814	59,110	60,709	74,012	90,003	103,961	113,925	121,965	129,885	140,161	151,733	164,261	177,824	192,506	208,400
Sydney (C) - West	38,344	44,843	44,530	48,322	52,429	55,793	60,546	65,374	70,242	75,052	80,097	85,482	91,229	97,362	103,907
The Hills Shire (A) - Central	56,679	76,266	76,506	82,682	87,660	92,129	96,353	102,876	112,387	118,612	124,059	129,756	135,714	141,946	148,464
The Hills Shire (A) - North	41,997	58,182	68,527	81,302	99,090	118,495	136,797	152,628	165,744	169,779	171,697	173,636	175,598	177,581	179,587
The Hills Shire (A) - South	33,438	44,885	49,021	54,789	61,456	66,558	70,941	75,558	81,136	84,958	88,394	91,968	95,687	99,557	103,583
Warringah (A)	138,565	145,520	151,286	158,731	167,055	175,388	182,461	188,916	195,623	202,824	210,345	218,144	226,232	234,621	243,320
Waverley (A)	64,395	68,026	68,731	70,887	74,167	77,737	81,409	84,771	87,872	90,033	92,004	94,019	96,077	98,181	100,330
Willoughby (C)	65,872	71,251	77,171	82,036	86,923	91,890	96,509	101,099	105,162	108,982	112,883	116,923	121,108	125,443	129,933
Wingecarribee (A)	44,047	46,887	48,038	49,520	51,023	52,289	53,250	53,874	54,192	55,441	56,972	58,544	60,160	61,820	63,526
Wollondilly (A)	40,662	45,038	49,388	52,735	55,966	59,395	62,957	67,047	70,568	75,729	81,697	88,136	95,081	102,574	110,658
Wollongong (C) - Inner	98,698	102,999	104,822	108,372	112,171	115,356	118,163	120,672	122,911	124,431	125,796	127,177	128,572	129,983	131,410
Wollongong (C) Bal	94,892	100,397	98,320	100,784	105,001	109,399	113,466	117,047	120,196	123,423	126,762	130,191	133,713	137,330	141,044
Woollahra (A)	53,254	55,475	56,259	58,356	61,413	64,755	68,155	71,316	74,230	77,210	80,317	83,548	86,909	90,405	94,042
Wyong (A) - North-East	72,253	79,851	80,875	85,421	90,809	100,373	110,234	121,455	132,355	145,341	159,985	176,104	193,848	213,380	234,880
Wyong (A) - South and West	68,996	72,902	73,090	76,311	81,733	83,359	84,524	87,420	91,206	96,538	102,508	108,846	115,577	122,724	130,313
Total Sydney		5,578,292	5,718,744	6,113,277	6,599,212	7,085,069	7,556,139	8,018,080	8,476,314	8,883,309	9,296,489	9,734,728	10,200,044	10,694,666	11,221,057

TABLE 8 MEAN INCOME BY SLA, 2005-2075

	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075
Ashfield (A)	$94,487	$99,307	$104,016	$108,843	$113,110	$117,545	$123,594	$129,955	$136,680	$143,754	$151,185	$158,999	$167,219	$175,863	$184,953
Auburn (C)	$71,392	$75,033	$78,368	$81,712	$86,029	$90,573	$95,491	$100,677	$105,876	$111,344	$117,013	$122,971	$129,231	$135,810	$142,724
Bankstown (C) - North-East	$63,231	$66,457	$69,076	$71,590	$74,360	$77,237	$80,570	$84,047	$88,321	$92,812	$97,529	$102,486	$107,694	$113,167	$118,917
Bankstown (C) - North-West	$69,736	$73,294	$76,530	$79,768	$82,732	$85,806	$89,375	$93,094	$97,668	$102,468	$107,559	$112,903	$118,516	$124,409	$130,595
Bankstown (C) - South	$88,830	$93,361	$97,244	$101,049	$104,465	$107,996	$112,059	$116,274	$121,860	$127,714	$133,909	$140,403	$147,225	$154,377	$161,877
Blacktown (C) - North	$98,267	$103,279	$112,855	$124,509	$134,794	$145,928	$155,663	$166,048	$174,898	$184,219	$193,562	$203,379	$213,692	$224,528	$235,914
Blacktown (C) - South-East	$76,907	$80,830	$84,560	$88,347	$95,645	$103,545	$110,453	$117,822	$123,781	$130,041	$136,621	$143,534	$150,796	$158,425	$166,440
Blacktown (C) - South-West	$69,414	$72,955	$79,373	$87,095	$94,289	$102,077	$108,887	$116,151	$121,992	$128,126	$134,642	$141,491	$148,687	$156,248	$164,195
Blue Mountains (C)	$89,147	$93,694	$97,466	$101,117	$105,171	$109,387	$114,209	$119,243	$125,432	$131,941	$138,732	$145,871	$153,377	$161,269	$169,567
Botany Bay (C)	$85,421	$89,778	$93,901	$98,082	$102,605	$107,338	$112,024	$116,915	$123,069	$129,546	$136,272	$143,346	$150,787	$158,613	$166,845
Burwood (A)	$85,527	$89,890	$93,330	$96,594	$101,129	$105,877	$111,478	$117,375	$123,440	$129,817	$136,567	$143,667	$151,135	$158,992	$167,257
Camden (A)	$96,176	$101,082	$112,825	$127,825	$139,065	$151,295	$162,186	$173,861	$183,441	$193,549	$203,419	$213,793	$224,694	$236,152	$248,193
Campbelltown (C) - North	$77,669	$81,631	$86,222	$91,173	$99,191	$107,914	$115,683	$124,010	$130,367	$137,050	$143,865	$151,019	$158,529	$166,412	$174,688
Campbelltown (C) - South	$77,736	$81,701	$85,182	$88,622	$96,415	$104,894	$112,445	$120,540	$126,863	$133,517	$140,370	$147,575	$155,148	$163,110	$171,480
Canada Bay (A) - Concord	$105,681	$111,072	$114,374	$117,158	$122,772	$128,654	$135,521	$142,753	$150,037	$157,691	$165,743	$174,205	$183,098	$192,445	$202,268
Canada Bay (A) - Drummoyne	$118,475	$124,518	$129,081	$133,334	$140,002	$147,004	$155,123	$163,690	$171,916	$180,555	$189,881	$199,688	$210,000	$220,844	$232,249
Canterbury (C)	$70,465	$74,059	$77,298	$80,528	$83,547	$86,678	$90,331	$94,138	$98,833	$103,761	$108,992	$114,486	$120,258	$126,322	$132,690
Cessnock (C)	$74,486	$78,286	$82,288	$86,485	$90,897	$95,533	$100,407	$105,528	$110,911	$116,569	$122,515	$128,765	$135,333	$142,236	$149,492
Fairfield (C) - East	$57,964	$60,920	$63,295	$65,565	$68,063	$70,655	$73,657	$76,786	$80,713	$84,841	$89,114	$93,603	$98,325	$103,285	$108,496
Fairfield (C) - West	$76,601	$80,509	$85,771	$91,675	$97,668	$104,053	$107,938	$111,967	$117,590	$123,496	$129,650	$136,110	$142,894	$150,015	$157,492
Gosford (C) - East	$85,858	$90,238	$93,528	$96,588	$100,116	$103,774	$108,030	$112,460	$118,219	$124,274	$130,650	$137,354	$144,400	$151,808	$159,595
Gosford (C) - West	$75,653	$79,512	$82,463	$85,227	$88,240	$91,359	$94,916	$98,611	$103,521	$108,676	$114,175	$119,953	$126,022	$132,399	$139,098
Hawkesbury (C)	$87,023	$91,462	$95,793	$100,230	$104,564	$109,084	$114,180	$119,513	$125,484	$131,753	$138,402	$145,386	$152,722	$160,429	$168,525
Holroyd (C)	$77,811	$81,780	$85,813	$89,997	$93,576	$97,296	$101,595	$106,084	$111,294	$116,759	$122,614	$128,764	$135,222	$142,004	$149,126
Hornsby (A) -	$111,491	$117,179	$122,769	$128,510	$134,191	$140,124	$146,914	$154,033	$161,856	$170,075	$178,765	$187,898	$197,497	$207,587	$218,191

North															
Hornsby (A) - South	$107,228	$112,697	$118,414	$124,396	$129,298	$134,392	$140,365	$146,602	$154,035	$161,845	$170,133	$178,844	$188,000	$197,625	$207,743
Hunters Hill (A)	$134,545	$141,408	$147,840	$154,343	$161,206	$168,374	$176,622	$185,274	$194,634	$204,468	$214,897	$225,858	$237,382	$249,494	$262,224
Hurstville (C)	$85,262	$89,611	$93,303	$96,908	$100,572	$104,375	$108,767	$113,344	$119,088	$125,124	$131,518	$138,239	$145,303	$152,728	$160,532
Kiama (A)	$86,714	$91,137	$95,796	$100,682	$105,818	$111,216	$116,889	$122,852	$129,118	$135,705	$142,627	$149,902	$157,549	$165,585	$174,032
Kogarah (C)	$93,905	$98,695	$103,093	$107,509	$111,840	$116,346	$121,437	$126,750	$133,168	$139,911	$147,074	$154,605	$162,519	$170,839	$179,584
Ku-ring-gai (A)	$130,751	$137,421	$143,742	$150,157	$156,080	$162,237	$169,297	$176,665	$185,717	$195,233	$205,310	$215,909	$227,051	$238,770	$251,092
Lake Macquarie (C) - East	$80,916	$85,043	$89,390	$93,950	$98,742	$103,779	$109,073	$114,637	$120,485	$126,630	$133,090	$139,879	$147,014	$154,513	$162,395
Lake Macquarie (C) - North	$84,173	$88,467	$92,989	$97,732	$102,718	$107,957	$113,464	$119,252	$125,335	$131,728	$138,448	$145,510	$152,932	$160,734	$168,933
Lake Macquarie (C) - West	$74,123	$77,904	$81,886	$86,063	$90,453	$95,067	$99,917	$105,013	$110,370	$116,000	$121,917	$128,136	$134,673	$141,542	$148,762
Lane Cove (A)	$130,743	$137,413	$143,885	$150,504	$156,254	$162,223	$169,061	$176,186	$185,160	$194,590	$204,572	$215,066	$226,097	$237,695	$249,888
Leichhardt (A)	$135,598	$142,515	$149,026	$155,616	$162,296	$169,263	$177,466	$186,067	$195,612	$205,647	$216,226	$227,349	$239,043	$251,339	$264,267
Liverpool (C) - East	$74,198	$77,983	$83,054	$88,737	$94,657	$100,972	$107,708	$114,893	$120,775	$126,959	$133,405	$140,178	$147,295	$154,773	$162,631
Liverpool (C) - West	$85,894	$90,275	$99,791	$111,696	$119,147	$127,096	$135,574	$144,619	$152,527	$160,867	$169,079	$177,710	$186,781	$196,314	$206,334
Maitland (C)	$85,514	$89,876	$94,470	$99,289	$104,353	$109,676	$115,271	$121,151	$127,331	$133,826	$140,653	$147,827	$155,368	$163,293	$171,623
Manly (A)	$130,869	$137,545	$142,991	$148,229	$154,374	$160,774	$168,206	$175,982	$185,000	$194,480	$204,528	$215,094	$226,207	$237,894	$250,185
Marrickville (A)	$103,650	$108,937	$114,666	$120,725	$125,324	$130,097	$135,585	$141,304	$148,448	$155,952	$163,857	$172,162	$180,889	$190,058	$199,692
Mosman (A)	$143,837	$151,174	$156,757	$161,977	$168,897	$176,112	$184,309	$192,889	$202,889	$213,408	$224,484	$236,136	$248,391	$261,283	$274,844
Newcastle (C) - Inner City	$92,576	$97,298	$102,271	$107,488	$112,971	$118,734	$124,790	$131,156	$137,846	$144,878	$152,268	$160,035	$168,199	$176,778	$185,796
Newcastle (C) - Outer West	$76,716	$80,629	$84,750	$89,073	$93,617	$98,392	$103,411	$108,686	$114,230	$120,057	$126,182	$132,618	$139,383	$146,493	$153,965
Newcastle (C) - Throsby	$87,066	$91,507	$96,184	$101,091	$106,247	$111,667	$117,363	$123,350	$129,642	$136,255	$143,205	$150,510	$158,188	$166,257	$174,738
North Sydney (A)	$138,101	$145,146	$150,982	$156,629	$163,243	$170,137	$178,034	$186,296	$195,904	$206,007	$216,708	$227,965	$239,805	$252,259	$265,361
Parramatta (C) - Inner	$77,974	$81,951	$85,945	$90,073	$94,237	$98,593	$103,704	$109,079	$114,639	$120,482	$126,637	$133,107	$139,906	$147,053	$154,564
Parramatta (C) - North-East	$91,608	$96,281	$101,124	$106,179	$110,386	$114,760	$119,744	$124,944	$131,145	$137,653	$144,549	$151,790	$159,394	$167,379	$175,764
Parramatta (C) - North-West	$91,367	$96,028	$100,666	$105,447	$109,249	$113,187	$117,790	$122,580	$128,720	$135,168	$142,092	$149,370	$157,038	$165,099	$173,574
Parramatta (C) - South	$65,283	$68,613	$71,752	$74,931	$77,811	$80,802	$84,380	$88,117	$92,555	$97,216	$102,169	$107,374	$112,843	$118,590	$124,630
Penrith (C) - East	$80,589	$84,700	$91,019	$98,342	$104,902	$120,000	$133,505	$148,530	$156,212	$164,292	$172,657	$181,449	$190,687	$200,395	$210,598
Penrith (C) - West	$90,237	$94,840	$99,477	$104,276	$104,276	$108,547	$113,171	$117,992	$123,863	$130,025	$136,626	$143,563	$150,851	$158,508	$166,555
Pittwater (A)	$110,744	$116,393	$121,438	$126,454	$131,893	$137,565	$144,030	$150,798	$158,447	$166,484	$174,967	$183,883	$193,253	$203,100	$213,448
Port Stephens	$72,841	$76,556	$80,470	$84,574	$88,889	$93,423	$98,188	$103,197	$108,461	$113,994	$119,808	$125,920	$132,343	$139,094	$146,189

(A)															
Randwick (C)	$108,450	$113,982	$118,255	$122,276	$127,148	$132,213	$138,058	$144,161	$151,608	$159,439	$167,645	$176,273	$185,344	$194,882	$204,911
Rockdale (C)	$82,691	$86,910	$93,099	$100,193	$105,581	$111,259	$118,705	$126,649	$133,040	$139,755	$146,964	$154,545	$162,515	$170,895	$179,708
Ryde (C)	$99,590	$104,670	$109,371	$114,102	$119,052	$124,217	$130,162	$136,391	$143,227	$150,405	$158,020	$166,021	$174,424	$183,254	$192,530
Shellharbour (C)	$75,763	$79,628	$83,698	$87,967	$92,455	$97,171	$102,127	$107,337	$112,812	$118,567	$124,615	$130,971	$137,652	$144,674	$152,054
Shoalhaven (C) - Pt A	$67,534	$70,979	$74,607	$78,413	$82,413	$86,617	$91,035	$95,679	$100,559	$105,689	$111,080	$116,746	$122,701	$128,960	$135,539
Shoalhaven (C) - Pt B	$59,411	$62,442	$65,633	$68,981	$72,500	$76,198	$80,085	$84,170	$88,464	$92,977	$97,719	$102,704	$107,943	$113,449	$119,236
Strathfield (A)	$93,309	$98,069	$102,145	$106,138	$110,812	$115,692	$121,474	$127,544	$134,069	$140,929	$148,148	$155,736	$163,711	$172,095	$180,908
Sutherland Shire (A) - West	$106,581	$112,017	$117,440	$123,034	$127,678	$132,498	$137,850	$143,417	$150,437	$157,800	$165,598	$173,781	$182,371	$191,385	$200,845
Sydney (C) - Inner	$98,034	$103,035	$107,343	$111,572	$116,054	$120,716	$126,006	$131,528	$138,218	$145,248	$152,697	$160,528	$168,761	$177,415	$186,514
Sydney (C) - East	$130,544	$137,203	$142,269	$147,006	$153,082	$159,410	$166,638	$174,194	$182,972	$192,192	$202,073	$212,462	$223,385	$234,870	$246,945
Sydney (C) - South	$112,302	$118,030	$123,227	$128,423	$133,881	$139,572	$145,703	$152,104	$159,781	$167,846	$176,568	$185,744	$195,393	$205,544	$216,223
Sydney (C) - West	$116,103	$122,025	$130,262	$139,580	$148,293	$157,551	$165,075	$172,957	$181,768	$191,028	$200,807	$211,086	$221,889	$233,245	$245,183
The Hills Shire (A) - Central	$111,319	$116,997	$121,843	$126,582	$132,147	$137,956	$144,096	$150,509	$158,229	$166,344	$174,944	$183,988	$193,497	$203,498	$214,016
The Hills Shire (A) - North	$113,690	$119,489	$129,358	$141,064	$150,475	$160,514	$171,222	$182,644	$191,972	$201,776	$212,024	$222,792	$234,105	$245,992	$258,484
The Hills Shire (A) - South	$109,038	$114,600	$127,429	$143,686	$153,272	$163,497	$174,404	$186,039	$195,773	$206,016	$216,526	$227,573	$239,181	$251,381	$264,204
Warringah (A)	$108,429	$113,960	$119,572	$125,392	$133,758	$142,681	$152,199	$162,353	$170,793	$179,671	$189,067	$198,954	$209,359	$220,308	$231,830
Warrumbungle Shire (A)	$55,578	$58,413	$61,066	$63,747	$66,338	$69,034	$72,060	$75,219	$79,031	$83,037	$87,260	$91,697	$96,360	$101,260	$106,409
Waverley (A)	$124,817	$131,184	$137,488	$143,974	$148,991	$154,183	$160,229	$166,512	$174,945	$183,806	$193,159	$202,988	$213,316	$224,169	$235,574
Willoughby (C)	$121,551	$127,751	$132,902	$137,891	$143,354	$149,034	$155,607	$162,470	$170,803	$179,563	$188,840	$198,597	$208,855	$219,644	$230,989
Wingecarribee (A)	$78,798	$82,817	$87,051	$91,491	$96,158	$101,063	$106,218	$111,637	$117,331	$123,316	$129,607	$136,218	$143,166	$150,469	$158,145
Wollondilly (A)	$89,826	$94,408	$99,371	$104,620	$109,389	$114,375	$120,107	$126,127	$132,640	$139,489	$146,579	$154,030	$161,859	$170,086	$178,731
Wollongong (C) - Inner	$84,595	$88,910	$93,455	$98,222	$103,232	$108,498	$114,032	$119,849	$125,963	$132,388	$139,141	$146,239	$153,698	$161,538	$169,779
Wollongong (C) Bal	$78,844	$82,866	$87,102	$91,545	$96,215	$101,123	$106,281	$111,702	$117,400	$123,389	$129,683	$136,298	$143,251	$150,558	$158,238
Woollahra (A)	$142,409	$149,673	$155,854	$161,893	$168,265	$174,889	$182,428	$190,292	$199,884	$209,960	$220,831	$232,264	$244,287	$256,932	$270,233
Wyong (A) - North-East	$66,425	$69,814	$73,934	$78,435	$83,256	$88,372	$93,803	$99,568	$104,892	$110,501	$116,136	$122,058	$128,282	$134,823	$141,697
Wyong (A) - South and West	$72,078	$75,755	$78,538	$81,135	$86,121	$91,414	$97,032	$102,996	$108,200	$113,668	$119,424	$125,471	$131,823	$138,496	$145,508

Source: SGS modelling. 2015

TABLE 9 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2010

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	8	0	290	28	686	244	1853	969	264	80	180	749	819	300	1304	1222	2710	150	457	305	12618
Auburn (C)	47	15	8611	1294	4184	6767	5295	1950	4478	1330	4599	768	2896	1536	3244	2829	3150	1553	2227	2012	58786
Bankstown (C) - North-East	11	3	4900	182	1367	1351	5108	1590	3444	1412	756	536	999	869	1971	2953	4435	244	1351	1074	34556
Bankstown (C) - North-West	20	0	5036	532	1450	1564	1994	787	2290	234	311	202	778	416	711	1857	1767	198	724	708	21579
Bankstown (C) - South	30	13	6087	115	2243	2022	1815	1186	1054	78	238	197	780	520	359	2182	1271	149	892	624	21857
The Hills Shire (A) - Central	27	22	4243	233	3342	3241	10120	2624	497	587	2343	804	4164	1125	1319	2750	5183	694	1789	1222	46329
The Hills Shire (A) - North	999	153	863	68	2049	1025	3315	1661	509	154	428	478	1368	581	90	2428	1751	282	855	485	19541
The Hills Shire (A) - South	106	7	646	12	891	545	1327	412	275	80	186	132	2870	345	167	2904	1191	93	831	305	13324
Blacktown (C) - North	228	16	2930	206	2066	1377	2114	1113	1047	82	224	263	905	546	803	3016	1741	241	860	573	20353
Blacktown (C) - South-East	31	25	10257	2020	4980	6047	7085	2706	5776	460	802	779	1680	1819	2651	3624	5538	416	2886	1960	61542
Blacktown (C) - South-West	115	21	3158	812	1888	2332	5309	2057	4820	101	268	361	561	829	1213	3412	3115	345	956	842	32515
Blue Mountains (C)	172	6	534	137	1385	389	2715	2428	747	261	335	354	1391	588	1331	2520	3547	495	886	400	20622
Botany Bay (C)	14	24	5622	285	2568	4413	4059	3025	24996	530	630	1090	1907	1953	2003	724	1581	260	1213	1461	58360
Burwood (A)	0	3	298	30	618	832	2718	1092	2075	544	580	442	1256	619	1096	2684	3445	127	605	519	19582
Camden (A)	392	20	1668	288	2428	925	3205	1439	1128	129	396	398	980	461	679	2190	2278	413	978	495	20889
Campbelltown (C) - North	43	52	7280	211	1959	1714	1942	1030	2280	129	220	471	614	616	1034	2564	1775	108	979	720	25741
Campbelltown (C) - South	57	168	722	117	883	416	4787	2550	814	305	595	412	956	773	1714	3668	5240	329	938	580	26023
Canada Bay (A) - Concord	3	7	2247	201	1552	1960	1893	1091	399	942	3563	413	1829	546	235	961	4780	298	962	592	24476
Canada Bay (A) - Drummoyne	7	0	286	61	621	335	1452	949	284	106	236	314	1124	249	382	867	1195	220	688	262	9636
Canterbury (C)	20	3	2906	39	2634	2094	4149	2215	2077	243	489	478	1235	890	1740	2616	4047	344	1383	1006	30608
Cessnock (C)	423	736	2060	76	1491	334	2479	2656	555	81	181	278	549	546	924	1588	2009	279	844	416	18505
Fairfield (C) - East	35	14	3307	78	1469	1312	3990	2903	1232	169	410	443	1021	733	1589	3203	3443	278	1379	1071	28080
Fairfield (C) - West	230	28	8506	298	2516	3633	3147	1422	2783	164	458	345	664	1010	888	2343	2325	231	1147	1251	33389
Gosford (C) - East	104	25	487	104	1726	526	4126	2404	470	305	537	442	1342	618	617	2240	2715	342	888	427	20443
Gosford (C) - West	838	204	4606	471	2534	1346	5029	2815	1406	699	836	706	2029	1382	3305	3375	9557	619	1818	1015	44591
Hawkesbury (C)	1309	22	3070	192	2491	866	3109	2057	981	443	314	381	1049	630	3165	2554	2775	547	1297	716	27970
Holroyd (C)	66	20	8291	184	2596	3424	3781	1615	4185	172	456	418	1069	680	1077	2232	2669	166	1341	1089	35530

Hornsby (A) - North	281	11	974	103	1356	828	1746	910	1045	121	250	204	1248	384	216	2363	1886	216	641	343	15126
Hornsby (A) - South	33	18	2949	200	1802	1458	6668	2882	1088	390	1207	715	2991	1089	1340	5917	7069	568	1783	881	41048
Hunters Hill (A)	0	3	89	8	300	69	347	403	78	39	137	130	420	134	287	868	1213	30	210	135	4901
Hurstville (C)	35	0	1839	102	1863	1715	3373	1728	1105	216	1621	477	1609	872	1265	2211	3486	299	1242	715	25773
Kiama (A)	325	3	184	42	546	140	834	1111	257	64	136	138	390	191	352	564	653	259	267	131	6586
Kogarah (C)	11	16	449	438	739	284	1034	1345	599	164	1634	353	1056	367	1689	1840	7196	247	566	496	20523
Ku-ring-gai (A)	73	19	829	87	1880	1531	3121	1806	714	650	1083	884	4562	976	1077	5787	7214	445	1283	888	34907
Lake Macquarie (C) - East	23	150	1201	88	1742	449	2689	1448	404	48	251	220	723	487	453	1761	2690	174	747	301	16051
Lake Macquarie (C) - North	49	938	3770	178	2604	1224	6245	3024	1651	352	1563	579	1636	956	2212	3120	4558	464	1782	708	37612
Lake Macquarie (C) - West	138	847	1266	630	1147	288	1802	1007	575	71	217	200	706	475	291	1765	2927	172	581	328	15433
Lane Cove (A)	18	0	1451	31	814	1378	1441	791	206	465	575	250	2493	885	419	1020	2457	207	400	446	15748
Leichhardt (A)	49	3	1152	33	1551	873	3113	1848	701	647	455	534	3012	1219	1441	1835	3465	584	1074	616	24204
Liverpool (C) - East	35	24	7571	359	2644	2791	5719	2281	2986	415	807	844	1756	2482	8373	3817	9023	499	1635	1585	55647
Liverpool (C) - West	676	50	1784	451	1678	1060	1842	891	1639	169	117	176	423	476	274	2467	1193	154	521	593	16634
Maitland (C)	255	594	2374	433	2389	653	4245	2048	1207	180	574	616	1608	1104	1517	2717	3771	259	1675	620	28837
Manly (A)	29	9	275	60	855	351	1556	1935	169	278	547	471	1467	383	674	1332	2329	304	530	321	13876
Marrickville (A)	16	12	3900	57	1809	2298	3415	1902	2045	590	414	403	2103	741	1356	2624	2623	698	1395	820	29220
Mosman (A)	33	9	172	8	568	172	1206	927	278	146	340	396	1239	251	657	955	1090	689	437	274	9846
Newcastle (C) - Inner City	38	427	4619	740	2512	1388	3135	3289	4230	1066	3099	864	5812	1790	4660	2787	5293	364	1619	907	48641
Newcastle (C) - Outer West	146	344	2805	1667	2159	1381	2458	1327	1008	192	289	308	842	556	614	5138	2633	296	950	499	25610
Newcastle (C) - Throsby	40	41	2249	225	1773	1157	7937	3283	1245	309	1145	482	2397	1067	1876	3193	12286	645	1539	733	43623
North Sydney (A)	83	328	4066	492	4483	3847	4637	4878	2106	6547	11598	2481	37411	5637	3528	5636	6132	1644	3067	3110	111712
Parramatta (C) - Inner	54	89	5949	1925	3587	3512	6836	3672	3106	1191	10049	1308	5318	3560	15695	4221	17674	621	2961	2490	93818
Parramatta (C) - North-East	26	4	2427	3	670	653	711	568	269	76	425	197	743	325	209	685	1428	96	417	296	10229
Parramatta (C) - North-West	4	13	1373	0	654	556	1691	552	593	51	115	59	412	198	92	688	1819	63	321	246	9499
Parramatta (C) - South	3	9	1194	10	593	660	772	370	1458	60	88	82	398	194	444	1315	509	403	249	281	9093
Penrith (C) - East	462	44	4948	671	2514	1789	2756	1865	2320	136	409	547	720	842	1959	4932	5463	350	1213	936	34878
Penrith (C) - West	77	148	3336	461	2561	1189	6448	3096	1627	336	645	633	1694	880	3836	2774	4176	616	1524	921	36978
Pittwater (A)	68	9	1841	85	2492	1316	2767	1899	437	351	537	548	2364	714	687	1566	2867	577	1065	651	22840
Port Stephens (A)	374	198	4844	192	2066	591	4173	2959	1436	226	395	606	1359	725	5462	1787	2517	444	1175	688	32216

Randwick (C)	46	3	1197	113	2468	895	2814	3600	3126	386	676	761	2524	1461	3710	10559	11411	1261	1434	1121	49567
Rockdale (C)	24	16	1717	87	1794	745	5134	2968	9047	242	501	767	1588	2148	6043	2251	2843	315	1215	1109	40554
Ryde (C)	48	60	6947	426	4410	11796	7033	3510	1040	9077	1089	1036	11831	2513	2698	8171	10730	541	2603	2212	87770
Shellharbour (C)	91	164	671	121	1362	473	3108	1645	621	67	284	260	520	427	1281	2308	2712	252	820	336	17525
Shoalhaven (C) - Pt A	172	21	1965	255	1007	404	2736	1204	806	235	342	273	895	530	3450	1684	3634	254	729	350	20947
Shoalhaven (C) - Pt B	657	22	652	181	1453	280	2306	2586	443	118	223	422	729	519	437	1546	1958	415	549	309	15804
Strathfield (A)	73	19	2878	734	1883	4111	2911	1070	5314	298	919	391	1265	638	660	2105	1073	372	858	817	28389
Sutherland Shire (A) - East	48	52	4424	285	3371	2049	7949	3731	1116	338	1043	864	2673	1066	862	2993	6093	683	1878	924	42443
Sutherland Shire (A) - West	25	3	1446	159	2350	806	3636	1989	909	157	680	425	3452	732	2139	3720	3569	445	1497	521	28661
Sydney (C) - East	27	42	1544	114	1470	1456	3502	5742	827	4210	1052	936	9302	2623	8733	3858	8920	2341	2006	1484	60190
Sydney (C) - Inner	197	1059	3298	2755	6783	3247	14290	21124	7581	16394	88956	7264	66752	17104	22938	8220	7672	4267	5876	7077	312853
Sydney (C) - South	28	19	5926	586	2540	6749	6106	2666	7220	3646	708	982	4948	1593	3688	2071	3340	1151	2939	1715	58621
Sydney (C) - West	7	16	797	210	2575	1639	2976	3069	3342	6483	1737	679	8347	1696	3370	13281	6826	4885	1355	1420	64710
Warringah (A)	116	43	4804	352	4029	6271	8871	3516	1436	1094	1272	1001	5370	1772	1704	5606	6313	884	2651	1447	58553
Willoughby (C)	49	124	3045	455	4371	3269	6843	2503	1458	4890	2269	1366	7582	1977	2299	2943	10203	659	2175	1560	60041
Waverley (A)	20	18	417	66	1097	605	4380	2518	470	495	810	543	2447	1285	1015	2468	3070	828	1045	647	24244
Wingecarribee (A)	841	105	2017	148	1339	537	2826	2028	749	233	341	436	1209	591	658	1823	2609	289	767	474	20018
Wollondilly (A)	620	1527	1507	230	1558	337	997	596	635	63	117	147	580	288	423	1076	725	233	411	347	12419
Wollongong (C) - Inner	57	631	3533	368	2518	1086	4963	4432	2201	847	3200	1024	3562	1692	4680	7737	9240	713	1939	1042	55466
Wollongong (C) Bal	148	1419	6299	657	2968	944	4421	2302	2165	156	402	422	1205	1160	897	2635	4372	411	1699	760	35443
Woollahra (A)	40	13	356	36	1273	549	2863	1974	193	360	824	1053	2083	758	1365	2561	2299	622	969	610	20802
Wyong (A) - North-East	163	246	866	551	1215	339	3052	1634	850	76	264	290	581	515	561	1978	3533	316	633	441	18103
Wyong (A) - South and West	147	71	3672	339	2076	1037	4828	3061	1094	346	731	590	1324	1105	2354	2543	3658	391	1188	615	31170
No fixed address	668	390	3661	948	45651	2774	4092	1600	9704	1832	958	568	4961	12322	2663	4783	7130	2211	4495	3868	115280
Total GMA	13098	12051	234427	28228	208532	139039	305272	185861	169798	77410	170690	50858	271479	107658	177190	242114	336805	46547	105776	75297	2958129

Source: SGS modelling. 2015

TABLE 10 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2015

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	8	0	327	26	722	260	1900	1027	228	96	186	770	820	297	1300	1204	2750	135	467	319	12842
Auburn (C)	54	17	9356	1319	4130	7094	5575	2129	4480	1554	4361	896	3129	1668	3759	2943	3597	1714	2465	1833	62075
Bankstown (C) - North-East	10	6	5555	188	1397	1489	5209	1596	3417	1578	762	564	956	804	1991	2861	4585	256	1438	1039	35699
Bankstown (C) - North-West	18	0	5689	770	1477	1682	2037	800	2292	260	316	219	765	403	947	1841	1877	207	773	677	23051
Bankstown (C) - South	28	22	6742	118	2293	2228	1851	1190	1046	87	240	208	746	481	362	2110	1313	157	950	603	22776
The Hills Shire (A) - Central	28	15	4762	214	3745	3687	11519	2777	552	864	2432	922	4289	1301	1510	2684	5447	738	1972	1255	50712
The Hills Shire (A) - North	1016	213	1014	136	2253	1085	3698	2014	576	231	489	595	1587	653	203	2454	2041	375	944	508	22085
The Hills Shire (A) - South	109	8	731	11	948	603	1392	445	269	100	183	148	2830	359	180	2820	1247	98	920	297	13697
Blacktown (C) - North	261	23	3271	194	2187	1464	2309	1252	1038	71	259	319	901	562	753	3510	2053	209	992	516	22142
Blacktown (C) - South-East	38	55	11490	1934	5274	6400	7580	2987	5686	483	867	827	1624	1822	2846	3592	5839	418	3195	1837	64795
Blacktown (C) - South-West	115	33	4033	945	2063	2659	5381	2202	5355	99	297	486	606	924	1277	3375	3538	372	1127	818	35705
Blue Mountains (C)	203	6	607	151	1347	406	2826	2657	730	254	335	375	1436	620	1363	2433	3758	505	947	474	21432
Botany Bay (C)	18	24	5465	261	2719	4599	4093	3296	24087	616	717	1237	2106	1950	2220	829	1846	304	1367	1315	59069
Burwood (A)	0	4	339	28	651	886	2787	1157	1790	657	598	454	1259	613	1093	2643	3495	114	618	543	19729
Camden (A)	403	31	1913	264	2539	1087	3902	1741	1397	197	489	488	1437	589	818	2386	2509	461	1109	527	24289
Campbelltown (C) - North	40	47	8256	163	2096	1939	2085	1106	2358	126	226	503	615	608	1031	2611	1886	112	1087	715	27610
Campbelltown (C) - South	54	154	818	90	945	471	5139	2738	841	298	612	440	957	762	1709	3736	5567	341	1042	576	27289
Canada Bay (A) - Concord	4	8	2268	125	1583	1881	1979	1131	353	644	3658	420	1759	537	234	955	4845	275	991	575	24227
Canada Bay (A) - Drummoyne	9	0	296	38	633	320	1518	984	251	72	242	319	1080	244	381	862	1211	203	708	255	9626
Canterbury (C)	22	4	3392	53	2682	2269	4339	2239	2016	305	498	511	1230	846	1781	2585	4464	326	1455	1087	32104
Cessnock (C)	464	655	2362	97	1539	373	2563	2831	586	74	178	260	591	566	943	1513	2109	239	885	426	19252
Fairfield (C) - East	33	18	3620	103	1472	1412	4127	2989	1245	171	400	456	973	763	1670	3106	3826	283	1465	1024	29157
Fairfield (C) - West	226	37	9551	394	2941	4365	3261	1461	3497	164	445	368	709	1091	924	2240	2555	237	1536	1199	37201
Gosford (C) - East	113	26	527	92	1795	584	4211	2523	458	281	551	467	1324	618	632	2145	2790	339	948	439	20865
Gosford (C) - West	914	212	4954	418	2636	1494	5133	2954	1371	646	859	746	2001	1383	3387	3232	9824	613	1941	1045	45761
Hawkesbury (C)	1354	34	3447	207	2634	912	3242	2173	1015	429	333	420	1113	679	3146	2552	2898	560	1342	731	29219
Holroyd (C)	64	26	9312	309	2736	3727	3913	1728	4315	191	468	484	1094	690	1164	2282	2961	164	1482	1041	38152

Hornsby (A) - North	287	7	1115	115	1492	897	1787	976	983	133	266	231	1233	404	277	2265	2011	199	691	355	15725
Hornsby (A) - South	46	13	3359	228	1958	1608	6839	3112	1004	629	1317	804	3019	1215	1565	5759	7484	534	1901	945	43338
Hunters Hill (A)	0	4	96	12	324	73	359	422	76	40	140	148	431	136	300	838	1294	30	233	153	5109
Hurstville (C)	36	0	2054	105	1946	1859	3519	1776	1072	217	1716	527	1712	819	1256	2130	3547	335	1281	719	26629
Kiama (A)	321	3	186	44	571	140	890	1150	266	69	142	147	396	181	344	544	664	245	268	129	6700
Kogarah (C)	11	13	494	449	768	302	1079	1393	580	179	1996	381	1092	347	1694	1800	7697	269	603	509	21657
Ku-ring-gai (A)	78	23	1036	98	2137	1674	3359	2035	691	871	1115	890	4638	1012	1039	5646	7595	453	1352	1033	36774
Lake Macquarie (C) - East	26	136	1335	103	1840	471	2690	1424	391	47	253	233	669	473	444	1656	2699	172	806	295	16165
Lake Macquarie (C) - North	53	907	4172	180	2740	1265	6235	2991	1614	345	1580	619	1536	933	2184	2938	4581	461	1919	699	37950
Lake Macquarie (C) - West	123	827	1319	535	1189	275	1772	1041	571	74	218	224	739	472	309	1672	2966	174	619	332	15449
Lane Cove (A)	25	0	1670	35	819	1401	1516	823	212	587	618	249	2430	950	425	1004	2609	202	449	497	16521
Leichhardt (A)	57	4	1185	46	1682	963	3144	1991	686	769	503	558	2905	1185	1283	1823	3620	568	1123	684	24778
Liverpool (C) - East	37	23	8127	379	2783	2785	6360	2540	3021	637	988	961	2204	2511	8490	4002	9612	567	1866	1428	59321
Liverpool (C) - West	706	36	1835	460	1762	1149	2482	1144	2064	225	145	231	488	514	336	2971	1507	194	659	550	19460
Maitland (C)	277	671	2756	392	2479	694	4167	2060	1144	178	565	568	1474	974	1453	2636	3888	258	1592	581	28808
Manly (A)	33	9	349	81	942	389	1547	1947	161	273	554	504	1536	370	636	1295	2439	275	572	385	14298
Marrickville (A)	24	11	4126	58	1920	2532	4081	2046	1807	658	496	462	2278	746	1352	2901	3087	672	1629	845	31729
Mosman (A)	38	11	198	9	605	174	1278	975	254	176	336	402	1239	251	579	904	1116	700	449	352	10047
Newcastle (C) - Inner City	58	335	4549	669	2556	1399	3422	3566	3958	1275	3214	948	6037	1740	4853	2754	5484	434	1764	896	49911
Newcastle (C) - Outer West	220	270	2781	1506	2197	1352	2467	1391	923	209	291	304	805	502	629	4928	2688	290	989	470	25213
Newcastle (C) - Throsby	60	32	2240	203	1804	1133	8009	3481	1182	375	1192	516	2492	1005	1922	3104	12584	631	1602	691	44258
North Sydney (A)	100	360	4298	559	4690	3898	4907	5115	1996	8027	11660	2503	36976	5751	3153	5384	6335	1645	3259	3808	114425
Parramatta (C) - Inner	60	95	6664	1947	3815	3839	7216	3933	3009	1407	10329	1503	5943	3482	16032	4212	18476	781	3313	2311	98366
Parramatta (C) - North-East	33	5	2712	8	671	703	741	648	264	142	427	225	762	353	227	694	1516	103	459	312	11006
Parramatta (C) - North-West	5	13	1573	0	725	618	1763	577	566	56	118	64	431	188	92	655	1889	66	351	224	9975
Parramatta (C) - South	3	12	1449	16	601	697	791	394	1474	66	90	93	404	201	484	1383	587	390	266	265	9668
Penrith (C) - East	489	42	5179	784	2634	1867	2834	2000	2571	129	352	564	870	812	1947	5032	6001	354	1438	783	36684
Penrith (C) - West	85	173	3721	486	2639	1249	6868	3280	1666	348	699	675	1874	926	3926	2660	4560	666	1657	886	39045
Pittwater (A)	66	9	1943	72	2493	1435	2863	1969	424	369	580	571	2276	674	667	1544	2957	569	1137	723	23341
Port Stephens (A)	400	195	5140	175	2177	623	4328	3126	1288	218	375	644	1304	768	4987	1804	2622	496	1223	657	32548

Randwick (C)	50	3	1389	154	2734	967	2781	3711	3088	452	641	768	2568	1502	3463	10127	11644	1212	1504	1122	49881
Rockdale (C)	26	12	1895	94	1840	775	5319	3152	11186	299	624	853	1677	2112	6633	2265	3079	348	1337	1094	44620
Ryde (C)	79	70	7435	620	4768	12411	7580	3753	1018	9279	1118	1175	12122	2551	2822	7889	11448	552	2882	2507	92079
Shellharbour (C)	90	169	681	127	1423	471	3317	1704	645	73	297	276	528	405	1253	2226	2757	239	823	332	17836
Shoalhaven (C) - Pt A	183	32	2124	230	984	385	2743	1211	760	236	323	275	887	539	3293	1577	3639	248	751	354	20775
Shoalhaven (C) - Pt B	699	34	716	164	1420	267	2312	2601	418	119	211	424	722	528	417	1447	1961	405	566	312	15741
Strathfield (A)	75	22	3210	699	1970	4399	2993	1122	4986	359	958	402	1272	627	661	2073	1090	335	879	856	28987
Sutherland Shire (A) - East	58	63	5146	277	3517	2122	8300	3888	1086	306	1105	896	2625	943	952	2969	6447	624	1999	985	44308
Sutherland Shire (A) - West	25	5	1615	155	2426	836	3831	2244	921	144	694	447	3348	741	2476	3736	3754	404	1657	543	30001
Sydney (C) - East	28	43	1526	106	1538	1573	3505	5872	777	4305	1077	956	9277	2585	8594	3544	9173	2306	2035	1548	60370
Sydney (C) - Inner	184	1045	3354	2551	7042	3503	14948	22400	7225	16828	95727	7670	70644	17428	23009	7695	7974	4675	6080	7303	327286
Sydney (C) - South	26	19	6079	549	2640	7287	6779	3091	6794	3972	896	1195	5735	1795	3818	2080	3629	1379	3195	1769	62726
Sydney (C) - West	6	16	827	194	2674	1769	3128	3283	3139	6605	1855	772	8470	1752	3378	12137	7034	4834	1385	1465	64723
Warringah (A)	125	46	5485	408	4221	6518	9371	3752	1463	1183	1329	1099	5210	1717	1774	5425	6619	911	2832	1553	61040
Willoughby (C)	66	125	3507	517	4398	3324	7199	2605	1504	6168	2437	1356	7390	2123	2331	2898	10833	642	2443	1738	63603
Waverley (A)	23	26	483	78	1219	675	4516	2712	435	520	854	548	2511	1248	1091	2367	3444	819	1113	749	25431
Wingecarribee (A)	921	114	2162	143	1343	529	2722	2012	722	242	340	451	1158	521	658	1694	2680	291	774	451	19928
Wollondilly (A)	609	1550	1621	232	1621	398	1108	647	668	81	133	158	652	285	479	1090	809	202	458	341	13141
Wollongong (C) - Inner	59	552	3838	330	2519	1298	4980	4307	2162	841	3076	1052	3306	1693	4719	7420	9341	709	2016	1038	55257
Wollongong (C) Bal	177	1407	6787	615	3020	917	4549	2332	1956	151	442	433	1227	1160	912	2627	4499	424	1681	757	36073
Woollahra (A)	47	18	402	42	1415	611	2953	2126	179	378	869	1063	2137	737	1468	2456	2579	615	1032	706	21833
Wyong (A) - North-East	161	240	961	507	1280	345	3308	1795	834	90	310	345	742	489	556	1947	3700	419	698	462	19190
Wyong (A) - South and West	145	70	4110	313	2187	1058	4738	3173	1074	319	717	599	1263	1005	2247	2478	3778	383	1215	618	31488
No fixed address	715	373	4032	960	47801	2958	4294	1692	9628	1988	1012	608	5106	12435	2700	4689	7499	2270	4832	3947	119538
Total GMA	13942	11968	257144	28469	218398	148235	320155	196637	169835	84213	180322	54475	278709	108647	180207	237296	354358	47733	113827	76740	3081309

Source: SGS modelling. 2015

TABLE 11 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2020

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	8	0	354	27	806	296	2122	1150	243	105	206	865	858	326	1399	1320	3075	134	495	344	14130
Auburn (C)	54	18	9654	1446	4378	7208	6002	2432	4524	1622	4701	958	3494	1867	4312	3179	4386	1798	2674	1796	66503
Bankstown (C) - North-East	10	7	6047	198	1468	1524	5569	1658	3457	1609	776	585	946	805	2043	2998	5032	259	1492	1031	37514
Bankstown (C) - North-West	17	0	5857	882	1549	1708	2172	836	2329	268	327	229	773	411	1083	1946	2078	209	806	666	24147
Bankstown (C) - South	27	29	6875	124	2410	2280	1980	1237	1059	88	245	215	737	482	371	2208	1441	159	986	599	23552
The Hills Shire (A) - Central	28	16	5361	236	4314	4242	13986	3306	749	1318	2899	1283	6891	1882	2082	3188	6536	1087	2452	1431	63284
The Hills Shire (A) - North	1033	260	1179	252	2670	1280	4677	2573	845	380	626	786	2080	799	412	2854	2573	538	1241	623	27680
The Hills Shire (A) - South	109	8	755	12	1012	616	1508	472	271	108	193	158	2939	377	202	3012	1381	101	978	300	14510
Blacktown (C) - North	274	79	3485	267	2516	1733	3465	1844	1238	122	398	495	1374	719	902	4449	2585	344	1259	598	28147
Blacktown (C) - South-East	39	79	12223	1980	5682	6807	8579	3271	6409	489	919	864	1594	1869	3065	3767	6534	410	3444	1815	69839
Blacktown (C) - South-West	117	39	4566	1019	2356	3246	6237	2561	6719	101	389	625	980	1161	1494	3607	3972	361	1542	844	41938
Blue Mountains (C)	224	6	642	158	1372	409	3022	2802	745	259	343	386	1490	654	1417	2532	4105	510	992	510	22579
Botany Bay (C)	18	26	5067	280	2880	4671	4556	3685	24092	697	755	1361	2292	2081	2513	906	2234	322	1491	1297	61223
Burwood (A)	0	4	352	29	697	968	2988	1244	1830	684	636	490	1264	646	1129	2782	3752	108	628	561	20793
Camden (A)	425	37	2133	279	2813	1268	5077	2243	1650	319	672	661	2337	813	1058	2758	3012	588	1319	582	30043
Campbelltown (C) - North	39	53	8858	158	2233	2097	2518	1334	2526	127	272	571	771	667	1086	2797	2184	149	1220	730	30390
Campbelltown (C) - South	53	172	881	87	1006	509	5643	3022	901	300	633	466	963	788	1801	3945	6333	339	1131	588	29560
Canada Bay (A) - Concord	5	10	2345	109	1664	2007	2158	1216	359	598	3887	449	1763	574	245	1035	5245	274	1053	585	25579
Canada Bay (A) - Drummoyne	10	0	293	33	664	341	1656	1057	255	67	257	341	1082	261	398	934	1311	202	753	259	10176
Canterbury (C)	24	4	3430	59	2827	2346	4664	2337	2039	334	512	534	1245	846	1876	2725	4965	308	1501	1128	33703
Cessnock (C)	499	652	2509	120	1669	404	2750	3055	643	76	177	273	652	597	994	1577	2237	236	942	440	20504
Fairfield (C) - East	34	20	3698	114	1532	1451	4523	3225	1281	176	403	465	969	798	1808	3308	4270	286	1535	1014	30909
Fairfield (C) - West	237	43	10236	433	3400	4961	3597	1578	4419	169	449	402	1055	1379	991	2380	2836	240	1951	1192	41948
Gosford (C) - East	119	27	543	92	1889	589	4312	2667	454	280	565	477	1342	639	670	2174	2847	337	996	450	21470
Gosford (C) - West	958	218	5097	417	2775	1506	5256	3123	1359	642	881	763	2029	1431	3587	3277	10023	610	2039	1071	47059
Hawkesbury (C)	1409	40	3718	229	2819	914	3543	2327	1070	438	347	446	1145	743	3262	2724	3194	555	1420	754	31097
Holroyd (C)	61	27	9538	398	2901	3828	4190	1848	4500	197	496	523	1130	712	1295	2448	3313	165	1586	1033	40188

Hornsby (A) - North	292	6	1184	122	1615	936	1936	1044	997	139	282	247	1267	428	325	2449	2262	190	732	362	16815
Hornsby (A) - South	48	13	3629	241	2069	1645	7279	3289	1004	701	1341	854	3128	1294	1749	6067	8202	514	1995	965	46025
Hunters Hill (A)	0	4	102	14	356	75	384	447	76	42	141	161	455	143	330	884	1433	29	250	164	5491
Hurstville (C)	38	0	2079	110	2052	1904	3747	1863	1081	215	1777	550	1769	821	1315	2240	3868	336	1315	731	27809
Kiama (A)	328	3	195	46	603	145	957	1236	281	69	149	155	412	188	362	558	705	244	280	131	7047
Kogarah (C)	12	15	502	468	808	302	1154	1455	582	189	2141	400	1118	350	1766	1893	8500	273	627	523	23078
Ku-ring-gai (A)	81	24	1160	104	2301	1728	3526	2178	698	971	1123	918	4711	1048	1087	5962	8340	444	1393	1080	38877
Lake Macquarie (C) - East	28	133	1396	116	1951	450	2691	1481	391	49	268	239	669	480	465	1708	2849	173	856	291	16683
Lake Macquarie (C) - North	56	917	4404	190	2908	1210	6238	3119	1646	355	1667	635	1547	954	2296	3027	4831	463	2035	695	39193
Lake Macquarie (C) - West	125	840	1384	525	1268	263	1774	1108	596	79	218	232	783	500	338	1711	3114	178	651	340	16026
Lane Cove (A)	28	0	1757	37	869	1393	1607	870	211	634	625	257	2476	993	433	1051	2869	200	474	513	17298
Leichhardt (A)	70	4	1180	51	1799	1011	3338	2126	675	820	533	587	2898	1240	1305	1953	3910	565	1159	717	25941
Liverpool (C) - East	38	24	8401	403	2959	3181	7315	2837	3824	816	1123	1048	2568	2724	8905	4473	10893	625	2034	1407	65599
Liverpool (C) - West	751	35	1881	559	1956	1346	3408	1464	2814	324	188	313	798	632	423	3534	1938	241	778	553	23938
Maitland (C)	290	735	2988	414	2629	708	4357	2159	1160	172	560	580	1469	982	1504	2767	4146	259	1656	578	30113
Manly (A)	39	10	373	91	1010	406	1606	2044	155	273	572	529	1732	374	643	1382	2229	263	598	414	14743
Marrickville (A)	25	12	4044	59	2114	2653	4650	2212	1773	706	534	497	2418	763	1422	3111	3434	680	1751	847	33707
Mosman (A)	42	12	211	10	652	174	1361	1025	241	186	345	416	1258	255	574	954	1221	711	461	391	10501
Newcastle (C) - Inner City	70	331	4503	676	2708	1376	3921	3957	4047	1472	3406	1066	6767	1853	5226	2925	5686	530	1930	927	53378
Newcastle (C) - Outer West	269	266	2766	1523	2327	1279	2462	1473	921	217	298	307	814	492	665	5062	2739	286	1027	460	25654
Newcastle (C) - Throsby	74	32	2245	206	1911	1072	8043	3733	1228	438	1272	570	2764	1034	2032	3236	12870	623	1664	676	45722
North Sydney (A)	111	407	4714	592	5028	3900	5218	5385	1921	8545	11941	2586	37611	5886	3138	5668	6940	1657	3380	4130	118758
Parramatta (C) - Inner	57	104	6961	2052	4076	3927	7891	4216	3029	1519	11140	1632	6565	3611	17664	4554	20219	893	3553	2295	105957
Parramatta (C) - North-East	35	5	2880	11	700	716	795	688	267	164	432	240	793	372	258	762	1685	105	494	318	11719
Parramatta (C) - North-West	5	14	1612	0	774	625	1907	608	566	58	126	66	450	190	101	690	2058	69	367	222	10508
Parramatta (C) - South	3	13	1519	20	626	703	839	419	1507	68	95	98	416	208	541	1495	668	386	279	258	10160
Penrith (C) - East	507	43	5943	1216	3258	3035	3358	2397	4437	127	408	690	1172	989	2045	5343	6729	356	1908	827	44788
Penrith (C) - West	87	189	3860	518	2749	1281	7509	3509	1771	356	733	706	2030	999	4158	2804	5120	813	1769	889	41849
Pittwater (A)	63	10	2046	68	2595	1530	3045	2070	420	384	605	599	2313	689	695	1654	3235	583	1202	759	24567
Port Stephens (A)	418	192	5362	181	2277	644	4596	3283	1282	223	357	684	1321	803	5008	1927	2848	526	1294	675	33901

Randwick (C)	53	4	1511	173	2982	990	2882	3874	3041	484	633	769	2672	1590	3583	10654	12715	1175	1562	1170	52517
Rockdale (C)	27	13	1910	95	1935	760	5869	3411	11784	474	747	990	1983	2270	7467	2413	3459	479	1409	1112	48607
Ryde (C)	97	81	7925	737	5234	12765	8174	3997	1009	9726	1120	1282	12815	2684	3104	8323	12682	537	3095	2677	98062
Shellharbour (C)	92	180	697	135	1502	489	3566	1831	681	72	312	291	549	421	1320	2285	2925	237	861	337	18783
Shoalhaven (C) - Pt A	190	37	2198	229	1013	354	2751	1221	763	238	305	277	885	551	3301	1625	3748	247	753	361	21045
Shoalhaven (C) - Pt B	725	38	746	162	1462	246	2318	2622	419	120	199	428	720	539	418	1492	2019	404	568	318	15962
Strathfield (A)	78	25	3364	708	2101	4768	3211	1200	5213	373	1022	433	1278	657	682	2182	1170	320	895	881	30561
Sutherland Shire (A) - East	59	72	5468	288	3772	2158	9071	4144	1093	308	1138	908	2674	916	1051	3144	7139	605	2134	1003	47145
Sutherland Shire (A) - West	24	6	1647	161	2553	844	4114	2481	941	137	713	453	3396	762	2838	3969	4133	380	1764	537	31855
Sydney (C) - East	28	48	1417	104	1653	1629	3705	6103	748	4506	1129	993	9524	2646	8877	3665	9981	2310	2092	1626	62783
Sydney (C) - Inner	164	1143	3251	2503	7549	3626	16543	24048	7064	17840	104367	8255	76300	18397	24243	8179	8828	5599	6413	7654	351967
Sydney (C) - South	23	20	5743	541	2834	7544	7498	3475	6608	4478	1124	1453	6846	2210	4241	2397	4224	1708	3373	1849	68191
Sydney (C) - West	5	17	805	191	2867	1830	3415	3525	3025	6929	2002	862	8811	1853	3536	12558	7673	4831	1435	1535	67705
Warringah (A)	128	50	5702	439	4419	6794	10086	4003	1490	1225	1375	1163	5213	1731	1902	5769	8169	905	2972	1568	65103
Willoughby (C)	75	135	3674	547	4667	3304	7629	2755	1498	6655	2464	1401	7531	2218	2379	3032	11916	638	2580	1792	66891
Waverley (A)	25	33	511	84	1332	706	4793	2849	406	546	876	547	2576	1259	1177	2473	3782	832	1151	803	26760
Wingecarribee (A)	969	116	2217	146	1400	497	2714	2009	727	252	330	469	1152	506	663	1727	2761	292	782	451	20180
Wollondilly (A)	615	1613	1709	246	1756	429	1237	721	702	93	141	167	705	300	529	1148	925	198	496	345	14075
Wollongong (C) - Inner	61	564	3883	311	2568	1347	5135	4383	2166	786	3195	1077	3269	1748	4983	7576	9598	713	2080	1044	56488
Wollongong (C) Bal	190	1521	6932	625	3118	902	4891	2492	1999	176	505	473	1396	1237	1007	2740	4758	462	1783	739	37946
Woollahra (A)	51	23	415	46	1546	640	3133	2234	167	397	891	1060	2192	743	1584	2566	2832	625	1066	757	22968
Wyong (A) - North-East	164	237	1011	540	1415	521	3554	1966	991	107	351	385	942	513	600	2014	3889	491	842	488	21021
Wyong (A) - South and West	148	69	4358	314	2324	1062	4841	3366	1108	317	738	610	1281	1022	2363	2543	3939	384	1264	629	32676
No fixed address	747	387	4242	1022	51350	3119	4691	1827	10186	2127	1090	657	5492	13241	2886	4981	8220	2410	5197	4069	127942
Total GMA	14558	12699	268319	30410	234601	15618	34948	21233	17939	90244	194134	58934	29888	11563	19300	25212	38848	50626	12240	79122	330142

Source: SGS modelling. 2015

TABLE 12 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2025

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	8	0	327	26	722	260	1900	1027	228	96	186	770	820	297	1300	1204	2750	135	467	319	12842
Auburn (C)	54	17	9356	1319	4130	7094	5575	2129	4480	1554	4361	896	3129	1668	3759	2943	3597	1714	2465	1833	62075
Bankstown (C) - North-East	10	6	5555	188	1397	1489	5209	1596	3417	1578	762	564	956	804	1991	2861	4585	256	1438	1039	35699
Bankstown (C) - North-West	18	0	5689	770	1477	1682	2037	800	2292	260	316	219	765	403	947	1841	1877	207	773	677	23051
Bankstown (C) - South	28	22	6742	118	2293	2228	1851	1190	1046	87	240	208	746	481	362	2110	1313	157	950	603	22776
The Hills Shire (A) - Central	28	15	4762	214	3745	3687	11519	2777	552	864	2432	922	4289	1301	1510	2684	5447	738	1972	1255	50712
The Hills Shire (A) - North	1016	213	1014	136	2253	1085	3698	2014	576	231	489	595	1587	653	203	2454	2041	375	944	508	22085
The Hills Shire (A) - South	109	8	731	11	948	603	1392	445	269	100	183	148	2830	359	180	2820	1247	98	920	297	13697
Blacktown (C) - North	261	23	3271	194	2187	1464	2309	1252	1038	71	259	319	901	562	753	3510	2053	209	992	516	22142
Blacktown (C) - South-East	38	55	11490	1934	5274	6400	7580	2987	5686	483	867	827	1624	1822	2846	3592	5839	418	3195	1837	64795
Blacktown (C) - South-West	115	33	4033	945	2063	2659	5381	2202	5355	99	297	486	606	924	1277	3375	3538	372	1127	818	35705
Blue Mountains (C)	203	6	607	151	1347	406	2826	2657	730	254	335	375	1436	620	1363	2433	3758	505	947	474	21432
Botany Bay (C)	18	24	5465	261	2719	4599	4093	3296	24087	616	717	1237	2106	1950	2220	829	1846	304	1367	1315	59069
Burwood (A)	0	4	339	28	651	886	2787	1157	1790	657	598	454	1259	613	1093	2643	3495	114	618	543	19729
Camden (A)	403	31	1913	264	2539	1087	3902	1741	1397	197	489	488	1437	589	818	2386	2509	461	1109	527	24289
Campbelltown (C) - North	40	47	8256	163	2096	1939	2085	1106	2358	126	226	503	615	608	1031	2611	1886	112	1087	715	27610
Campbelltown (C) - South	54	154	818	90	945	471	5139	2738	841	298	612	440	957	762	1709	3736	5567	341	1042	576	27289
Canada Bay (A) - Concord	4	8	2268	125	1583	1881	1979	1131	353	644	3658	420	1759	537	234	955	4845	275	991	575	24227
Canada Bay (A) - Drummoyne	9	0	296	38	633	320	1518	984	251	72	242	319	1080	244	381	862	1211	203	708	255	9626
Canterbury (C)	22	4	3392	53	2682	2269	4339	2239	2016	305	498	511	1230	846	1781	2585	4464	326	1455	1087	32104
Cessnock (C)	464	655	2362	97	1539	373	2563	2831	586	74	178	260	591	566	943	1513	2109	239	885	426	19252
Fairfield (C) - East	33	18	3620	103	1472	1412	4127	2989	1245	171	400	456	973	763	1670	3106	3826	283	1465	1024	29157
Fairfield (C) - West	226	37	9551	394	2941	4365	3261	1461	3497	164	445	368	709	1091	924	2240	2555	237	1536	1199	37201
Gosford (C) - East	113	26	527	92	1795	584	4211	2523	458	281	551	467	1324	618	632	2145	2790	339	948	439	20865
Gosford (C) - West	914	212	4954	418	2636	1494	5133	2954	1371	646	859	746	2001	1383	3387	3232	9824	613	1941	1045	45761
Hawkesbury (C)	1354	34	3447	207	2634	912	3242	2173	1015	429	333	420	1113	679	3146	2552	2898	560	1342	731	29219
Holroyd (C)	64	26	9312	309	2736	3727	3913	1728	4315	191	468	484	1094	690	1164	2282	2961	164	1482	1041	38152

Hornsby (A) - North	287	7	1115	115	1492	897	1787	976	983	133	266	231	1233	404	277	2265	2011	199	691	355	15725
Hornsby (A) - South	46	13	3359	228	1958	1608	6839	3112	1004	629	1317	804	3019	1215	1565	5759	7484	534	1901	945	43338
Hunters Hill (A)	0	4	96	12	324	73	359	422	76	40	140	148	431	136	300	838	1294	30	233	153	5109
Hurstville (C)	36	0	2054	105	1946	1859	3519	1776	1072	217	1716	527	1712	819	1256	2130	3547	335	1281	719	26629
Kiama (A)	321	3	186	44	571	140	890	1150	266	69	142	147	396	181	344	544	664	245	268	129	6700
Kogarah (C)	11	13	494	449	768	302	1079	1393	580	179	1996	381	1092	347	1694	1800	7697	269	603	509	21657
Ku-ring-gai (A)	78	23	1036	98	2137	1674	3359	2035	691	871	1115	890	4638	1012	1039	5646	7595	453	1352	1033	36774
Lake Macquarie (C) - East	26	136	1335	103	1840	471	2690	1424	391	47	253	233	669	473	444	1656	2699	172	806	295	16165
Lake Macquarie (C) - North	53	907	4172	180	2740	1265	6235	2991	1614	345	1580	619	1536	933	2184	2938	4581	461	1919	699	37950
Lake Macquarie (C) - West	123	827	1319	535	1189	275	1772	1041	571	74	218	224	739	472	309	1672	2966	174	619	332	15449
Lane Cove (A)	25	0	1670	35	819	1401	1516	823	212	587	618	249	2430	950	425	1004	2609	202	449	497	16521
Leichhardt (A)	57	4	1185	46	1682	963	3144	1991	686	769	503	558	2905	1185	1283	1823	3620	568	1123	684	24778
Liverpool (C) - East	37	23	8127	379	2783	2785	6360	2540	3021	637	988	961	2204	2511	8490	4002	9612	567	1866	1428	59321
Liverpool (C) - West	706	36	1835	460	1762	1149	2482	1144	2064	225	145	231	488	514	336	2971	1507	194	659	550	19460
Maitland (C)	277	671	2756	392	2479	694	4167	2060	1144	178	565	568	1474	974	1453	2636	3888	258	1592	581	28808
Manly (A)	33	9	349	81	942	389	1547	1947	161	273	554	504	1536	370	636	1295	2439	275	572	385	14298
Marrickville (A)	24	11	4126	58	1920	2532	4081	2046	1807	658	496	462	2278	746	1352	2901	3087	672	1629	845	31729
Mosman (A)	38	11	198	9	605	174	1278	975	254	176	336	402	1239	251	579	904	1116	700	449	352	10047
Newcastle (C) - Inner City	58	335	4549	669	2556	1399	3422	3566	3958	1275	3214	948	6037	1740	4853	2754	5484	434	1764	896	49911
Newcastle (C) - Outer West	220	270	2781	1506	2197	1352	2467	1391	923	209	291	304	805	502	629	4928	2688	290	989	470	25213
Newcastle (C) - Throsby	60	32	2240	203	1804	1133	8009	3481	1182	375	1192	516	2492	1005	1922	3104	12584	631	1602	691	44258
North Sydney (A)	100	360	4298	559	4690	3898	4907	5115	1996	8027	11660	2503	36976	5751	3153	5384	6335	1645	3259	3808	114425
Parramatta (C) - Inner	60	95	6664	1947	3815	3839	7216	3933	3009	1407	10329	1503	5943	3482	16032	4212	18476	781	3313	2311	98366
Parramatta (C) - North-East	33	5	2712	8	671	703	741	648	264	142	427	225	762	353	227	694	1516	103	459	312	11006
Parramatta (C) - North-West	5	13	1573	0	725	618	1763	577	566	56	118	64	431	188	92	655	1889	66	351	224	9975
Parramatta (C) - South	3	12	1449	16	601	697	791	394	1474	66	90	93	404	201	484	1383	587	390	266	265	9668
Penrith (C) - East	489	42	5179	784	2634	1867	2834	2000	2571	129	352	564	870	812	1947	5032	6001	354	1438	783	36684
Penrith (C) - West	85	173	3721	486	2639	1249	6868	3280	1666	348	699	675	1874	926	3926	2660	4560	666	1657	886	39045
Pittwater (A)	66	9	1943	72	2493	1435	2863	1969	424	369	580	571	2276	674	667	1544	2957	569	1137	723	23341
Port Stephens (A)	400	195	5140	175	2177	623	4328	3126	1288	218	375	644	1304	768	4987	1804	2622	496	1223	657	32548

Randwick (C)	50	3	1389	154	2734	967	2781	3711	3088	452	641	768	2568	1502	3463	10127	11644	1212	1504	1122	49881
Rockdale (C)	26	12	1895	94	1840	775	5319	3152	11186	299	624	853	1677	2112	6633	2265	3079	348	1337	1094	44620
Ryde (C)	79	70	7435	620	4768	12411	7580	3753	1018	9279	1118	1175	12122	2551	2822	7889	11448	552	2882	2507	92079
Shellharbour (C)	90	169	681	127	1423	471	3317	1704	645	73	297	276	528	405	1253	2226	2757	239	823	332	17836
Shoalhaven (C) - Pt A	183	32	2124	230	984	385	2743	1211	760	236	323	275	887	539	3293	1577	3639	248	751	354	20775
Shoalhaven (C) - Pt B	699	34	716	164	1420	267	2312	2601	418	119	211	424	722	528	417	1447	1961	405	566	312	15741
Strathfield (A)	75	22	3210	699	1970	4399	2993	1122	4986	359	958	402	1272	627	661	2073	1090	335	879	856	28987
Sutherland Shire (A) - East	58	63	5146	277	3517	2122	8300	3888	1086	306	1105	896	2625	943	952	2969	6447	624	1999	985	44308
Sutherland Shire (A) - West	25	5	1615	155	2426	836	3831	2244	921	144	694	447	3348	741	2476	3736	3754	404	1657	543	30001
Sydney (C) - East	28	43	1526	106	1538	1573	3505	5872	777	4305	1077	956	9277	2585	8594	3544	9173	2306	2035	1548	60370
Sydney (C) - Inner	184	1045	3354	2551	7042	3503	14948	22400	7225	16828	95727	7670	70644	17428	23009	7695	7974	4675	6080	7303	327286
Sydney (C) - South	26	19	6079	549	2640	7287	6779	3091	6794	3972	896	1195	5735	1795	3818	2080	3629	1379	3195	1769	62726
Sydney (C) - West	6	16	827	194	2674	1769	3128	3283	3139	6605	1855	772	8470	1752	3378	12137	7034	4834	1385	1465	64723
Warringah (A)	125	46	5485	408	4221	6518	9371	3752	1463	1183	1329	1099	5210	1717	1774	5425	6619	911	2832	1553	61040
Willoughby (C)	66	125	3507	517	4398	3324	7199	2605	1504	6168	2437	1356	7390	2123	2331	2898	10833	642	2443	1738	63603
Waverley (A)	23	26	483	78	1219	675	4516	2712	435	520	854	548	2511	1248	1091	2367	3444	819	1113	749	25431
Wingecarribee (A)	921	114	2162	143	1343	529	2722	2012	722	242	340	451	1158	521	658	1694	2680	291	774	451	19928
Wollondilly (A)	609	1550	1621	232	1621	398	1108	647	668	81	133	158	652	285	479	1090	809	202	458	341	13141
Wollongong (C) - Inner	59	552	3838	330	2519	1298	4980	4307	2162	841	3076	1052	3306	1693	4719	7420	9341	709	2016	1038	55257
Wollongong (C) Bal	177	1407	6787	615	3020	917	4549	2332	1956	151	442	433	1227	1160	912	2627	4499	424	1681	757	36073
Woollahra (A)	47	18	402	42	1415	611	2953	2126	179	378	869	1063	2137	737	1468	2456	2579	615	1032	706	21833
Wyong (A) - North-East	161	240	961	507	1280	345	3308	1795	834	90	310	345	742	489	556	1947	3700	419	698	462	19190
Wyong (A) - South and West	145	70	4110	313	2187	1058	4738	3173	1074	319	717	599	1263	1005	2247	2478	3778	383	1215	618	31488
No fixed address	715	373	4032	960	47801	2958	4294	1692	9628	1988	1012	608	5106	12435	2700	4689	7499	2270	4832	3947	119538
Total GMA	13942	11968	257144	28469	218398	14823	320155	19663	16983	84213	18032	54475	27870	10864	18020	23729	35435	47733	11382	76740	308109

Source: SGS modelling. 2015

TABLE 13 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2025

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	9	0	360	29	862	325	2271	1235	266	104	223	939	872	348	1460	1407	3289	134	506	354	14993
Auburn (C)	54	20	10146	1689	4910	7597	6878	2855	4878	1699	5521	1036	4081	2169	5055	3577	5381	1968	2969	1885	74369
Bankstown (C) - North-East	10	8	6699	220	1616	1596	6129	1815	3744	1665	840	630	1002	859	2196	3352	5713	277	1607	1080	41057
Bankstown (C) - North-West	18	0	6064	964	1703	1786	2399	915	2529	280	358	246	832	440	1222	2179	2362	224	874	694	26089
Bankstown (C) - South	28	34	7077	138	2652	2387	2179	1354	1146	91	265	232	781	515	399	2469	1636	170	1062	627	25242
The Hills Shire (A) - Central	29	18	6002	281	4969	4750	16328	4001	983	1772	3541	1621	8825	2550	2662	3918	7831	1389	2905	1578	75953
The Hills Shire (A) - North	1100	300	1302	300	3086	1412	5989	3334	1004	627	804	990	2961	1077	649	3419	3271	722	1597	799	34742
The Hills Shire (A) - South	112	9	787	13	1120	642	1685	513	295	115	220	173	3256	411	237	3411	1572	111	1073	319	16073
Blacktown (C) - North	293	210	3776	441	3068	2251	4836	2690	1812	269	666	781	2260	1008	1179	5620	3261	577	1743	784	37524
Blacktown (C) - South-East	40	89	13205	2182	6377	7350	9508	3712	7412	512	1019	935	1669	2004	3412	4301	7553	428	3840	1906	77454
Blacktown (C) - South-West	124	41	4991	1108	2756	4134	7137	3083	8057	108	355	777	1834	1553	1724	4072	4459	360	1871	909	49454
Blue Mountains (C)	248	6	687	171	1475	427	3337	3050	818	278	374	410	1627	714	1536	2811	4605	549	1080	551	24754
Botany Bay (C)	16	30	5096	327	3176	5063	5165	4157	25859	798	817	1531	2590	2331	2925	1012	2734	356	1653	1374	67010
Burwood (A)	0	5	371	31	777	1108	3331	1392	2088	709	719	554	1339	718	1228	3088	4181	113	669	602	23022
Camden (A)	451	38	2309	309	3108	1402	6432	2930	1859	459	913	871	3456	1031	1309	3167	3544	729	1541	624	36482
Campbelltown (C) - North	41	62	9708	173	2462	2313	2910	1566	2876	135	308	635	868	734	1206	3121	2579	169	1379	783	34027
Campbelltown (C) - South	55	202	971	95	1110	561	6401	3491	1026	317	693	510	1026	855	1999	4390	7459	356	1271	631	33420
Canada Bay (A) - Concord	5	11	2552	112	1832	2307	2439	1368	404	633	4389	504	1902	649	269	1183	5896	298	1174	629	28558
Canada Bay (A) - Drummoyne	10	0	301	34	731	392	1871	1190	288	71	291	383	1168	296	438	1067	1474	220	840	279	11343
Canterbury (C)	26	5	3458	63	3125	2499	5061	2567	2220	360	557	577	1335	896	2068	3048	5615	314	1612	1202	36609
Cessnock (C)	551	721	2667	158	1893	469	3055	3420	758	81	184	304	746	649	1128	1751	2439	256	1070	473	22773
Fairfield (C) - East	37	21	3837	126	1678	1536	5063	3663	1406	189	436	494	1034	891	2048	3781	4838	307	1672	1062	34118
Fairfield (C) - West	262	47	10913	465	4298	6069	4418	2104	5198	181	600	549	1697	1909	1105	2720	3197	335	2244	1251	49562
Gosford (C) - East	128	28	569	100	2068	603	4638	2935	483	296	612	504	1446	701	742	2346	3056	359	1088	479	23182
Gosford (C) - West	1032	227	5351	455	3037	1542	5654	3436	1444	680	954	805	2186	1568	3972	3535	10758	650	2228	1141	50656
Hawkesbury (C)	1529	42	4069	263	3133	948	4008	2601	1198	474	381	486	1228	837	3557	3046	3633	585	1576	813	34409
Holroyd (C)	61	28	9826	477	3206	4061	4678	2035	5007	208	559	579	1236	763	1525	2748	3751	178	1762	1091	43781

Hornsby (A) - North	309	7	1271	134	1799	1005	2182	1163	1098	148	313	270	1385	469	378	2783	2615	199	804	384	18716
Hornsby (A) - South	48	13	4010	261	2252	1729	8041	3620	1094	710	1418	925	3440	1400	1980	6833	9236	538	2175	1013	50736
Hunters Hill (A)	0	5	112	16	404	81	427	495	81	46	149	180	511	157	378	995	1629	30	277	178	6150
Hurstville (C)	41	0	2122	121	2253	2004	4079	2046	1173	221	1932	589	1905	872	1451	2518	4382	349	1414	777	30249
Kiama (A)	354	4	213	51	660	159	1053	1386	315	69	165	169	452	207	404	602	781	264	309	139	7753
Kogarah (C)	13	17	520	515	888	311	1262	1589	628	205	2317	434	1202	373	1934	2121	9623	290	677	559	25480
Ku-ring-gai (A)	87	24	1285	113	2525	1830	3786	2376	758	1046	1194	995	5049	1123	1208	6713	9425	462	1494	1136	42633
Lake Macquarie (C) - East	29	136	1475	132	2144	440	2865	1630	421	52	302	252	723	511	514	1855	3185	186	941	302	18095
Lake Macquarie (C) - North	59	955	4714	212	3205	1187	6646	3438	1802	383	1877	669	1676	1024	2547	3281	5393	499	2235	726	42529
Lake Macquarie (C) - West	134	877	1503	569	1411	263	1898	1234	667	87	232	243	869	554	384	1838	3451	195	712	363	17485
Lane Cove (A)	32	0	1860	41	971	1445	1754	958	223	672	659	280	2693	1065	462	1168	3241	215	513	538	18791
Leichhardt (A)	88	5	1224	55	1985	1098	3699	2350	715	874	589	644	3079	1375	1436	2204	4350	606	1248	766	28390
Liverpool (C) - East	39	26	8893	450	3271	3615	8401	3250	4651	963	1280	1159	2953	3185	9782	5250	12714	704	2255	1490	74332
Liverpool (C) - West	830	38	1979	653	2563	1736	4289	1767	3676	428	239	379	1102	805	517	4164	2413	268	859	589	29295
Maitland (C)	312	843	3244	479	2903	746	4788	2382	1274	173	585	634	1583	1067	1706	3083	4648	281	1867	612	33209
Manly (A)	48	12	393	100	1109	434	1742	2250	160	286	626	575	1902	398	692	1576	2401	275	647	444	16072
Marrickville (A)	25	14	4072	64	2363	2831	5108	2429	1901	770	579	538	2622	811	1570	3435	3803	749	1889	882	36454
Mosman (A)	47	14	227	11	729	183	1490	1118	248	196	379	451	1354	270	617	1081	1385	770	496	426	11492
Newcastle (C) - Inner City	78	353	4620	745	3005	1368	4393	4435	4440	1631	3775	1186	7758	2005	5804	3182	6082	602	2128	994	58585
Newcastle (C) - Outer West	298	285	2871	1679	2583	1257	2613	1624	1003	230	326	324	882	514	734	5443	2912	303	1114	478	27473
Newcastle (C) - Throsby	82	34	2336	227	2121	1053	8558	4121	1344	475	1414	628	3276	1108	2245	3487	13691	660	1805	702	49366
North Sydney (A)	125	466	5361	644	5619	4081	5709	5887	1996	9015	13001	2808	40676	6265	3368	6396	7865	1787	3642	4450	129162
Parramatta (C) - Inner	55	114	7350	2302	4509	4116	8858	4631	3284	1635	12803	1790	7429	3914	20875	5171	22682	1013	3911	2431	118873
Parramatta (C) - North-East	36	6	3115	11	770	751	882	740	290	163	466	260	875	400	309	881	1920	114	551	334	12874
Parramatta (C) - North-West	5	16	1662	0	846	644	2125	661	612	61	145	71	493	203	119	773	2304	75	397	237	11448
Parramatta (C) - South	3	13	1572	22	684	732	933	458	1643	72	106	104	454	224	637	1679	761	412	305	266	11081
Penrith (C) - East	524	45	6363	1496	3747	4186	4206	3118	6592	375	687	1089	2712	1733	2259	5924	7683	581	2566	853	56738
Penrith (C) - West	92	203	4040	580	2975	1361	8424	3906	2004	379	801	764	2270	1114	4597	3166	5866	1005	1949	942	46440
Pittwater (A)	63	12	2225	70	2836	1687	3353	2305	447	413	659	655	2518	747	767	1886	3662	644	1322	813	27081
Port Stephens (A)	452	204	5706	204	2466	688	5059	3581	1400	242	360	754	1434	864	5571	2168	3199	583	1450	737	37124

Randwick (C)	57	4	1666	190	3340	1055	3124	4231	3190	521	673	802	2937	1750	3971	11999	14406	1230	1691	1281	58120
Rockdale (C)	29	15	1957	99	2130	776	6609	3805	12451	709	887	1171	2421	2570	8661	2713	3968	634	1530	1188	54322
Ryde (C)	108	94	8780	839	5943	13857	9062	4414	1073	10646	1186	1428	14377	2947	3562	9365	14415	554	3423	2903	10897 5
Shellharbour (C)	99	196	740	148	1644	534	3923	2053	762	72	346	317	604	463	1472	2465	3242	256	950	358	20642
Shoalhaven (C) - Pt A	204	38	2318	247	1101	339	2909	1282	829	250	305	292	934	581	3485	1751	3995	265	784	386	22295
Shoalhaven (C) - Pt B	776	40	791	175	1589	235	2452	2754	455	126	200	451	760	569	441	1608	2152	433	591	340	16937
Strathfield (A)	84	29	3597	772	2336	5406	3577	1337	5953	386	1156	490	1354	728	739	2423	1304	334	955	940	33901
Sutherland Shire (A) - East	60	82	5826	323	4220	2284	10076	4552	1181	332	1227	954	2902	957	1194	3534	8115	627	2341	1053	51838
Sutherland Shire (A) - West	25	6	1692	180	2808	886	4555	2810	1024	139	775	476	3682	817	3309	4462	4687	391	1932	550	35205
Sydney (C) - East	28	55	1364	110	1856	1724	4107	6655	776	4920	1253	1081	10377	2843	9675	4098	11236	2504	2265	1773	68701
Sydney (C) - Inner	150	1297	3254	2655	8481	3835	18579	26437	7346	19557	11630 2	9071	83814	19881	26468	9190	9982	6445	7003	8353	38810 0
Sydney (C) - South	21	23	5576	575	3183	7979	8476	4028	6938	5276	1412	1799	8431	2774	4873	2882	5005	2215	3721	2013	77200
Sydney (C) - West	5	19	806	202	3220	1936	3875	3854	3137	7609	2269	986	9859	2040	3893	14051	8675	5253	1613	1676	74977
Warringah (A)	135	56	5977	482	4798	7404	11186	4413	1613	1303	1496	1265	5566	1839	2125	6559	9702	953	3239	1627	71739
Willoughby (C)	84	150	3878	595	5214	3428	8331	3032	1578	7061	2599	1527	8191	2380	2538	3371	13461	683	2791	1881	72775
Waverley (A)	27	39	546	93	1494	755	5270	3095	410	594	943	568	2783	1337	1312	2765	4198	907	1234	869	29239
Wingecarribee (A)	1046	118	2320	160	1530	484	2886	2096	789	271	335	508	1223	525	696	1843	2924	312	825	478	21367
Wollondilly (A)	655	1721	1853	277	1987	467	1412	838	779	105	154	183	785	332	595	1277	1079	214	555	367	15634
Wollongong (C) - Inner	64	613	3958	315	2741	1397	5494	4725	2326	753	3572	1151	3481	1886	5522	8135	10238	767	2240	1100	60479
Wollongong (C) Bal	205	1701	7131	694	3357	935	5350	2740	2211	188	570	513	1533	1353	1137	2952	5197	507	1975	754	41004
Woollahra (A)	56	28	435	51	1734	684	3446	2426	169	432	959	1101	2368	789	1765	2869	3144	682	1144	820	25100
Wyong (A) - North-East	177	242	1079	603	1597	700	3884	2195	1194	124	396	421	1114	576	681	2200	4276	540	985	531	23513
Wyong (A) - South and West	158	70	4670	341	2562	1106	5248	3730	1226	336	813	648	1392	1128	2646	2765	4322	413	1383	671	35629
No fixed address	806	426	4522	1141	57299	3395	5255	2046	11352	2339	1217	734	6167	14784	3232	5590	9266	2691	5763	4356	14238 1
Total GMA	15636	14004	28417 3	33955	26198 6	17015 3	39150 7	23790 5	19976 0	99180	21702 3	65814	33558 8	12908 4	21648 6	28306 2	43838 1	56602	13579 1	84749	36708 36

Source: SGS modelling. 2015

TABLE 14 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2030

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	9	0	368	30	921	358	2415	1323	293	104	242	1013	899	374	1519	1503	3488	136	520	362	15878
Auburn (C)	52	20	10205	1863	5270	7721	7485	3093	5097	1716	6189	1076	4572	2406	5657	3846	6233	2080	3170	1894	79647
Bankstown (C) - North-East	10	9	7088	233	1708	1613	6418	1908	3926	1665	874	653	1034	886	2263	3587	6157	287	1668	1083	43068
Bankstown (C) - North-West	18	0	6022	1005	1797	1803	2529	961	2658	283	379	254	872	455	1325	2334	2548	232	912	692	27081
Bankstown (C) - South	28	37	6993	146	2802	2413	2282	1423	1202	91	275	240	805	531	411	2642	1763	177	1102	628	25993
The Hills Shire (A) - Central	29	19	6332	313	5422	5022	17660	4456	1129	2018	4028	1874	9622	2999	3071	4447	8785	1589	3224	1627	83666
The Hills Shire (A) - North	1126	329	1510	458	3501	1913	7349	4191	1432	882	1028	1225	3950	1360	951	3942	3884	997	1982	1062	43072
The Hills Shire (A) - South	112	10	788	14	1189	647	1799	536	309	118	240	181	3494	431	264	3688	1696	117	1131	324	17087
Blacktown (C) - North	300	321	3917	620	3536	2659	5939	3443	2354	461	925	1052	3212	1293	1429	6436	3804	785	2171	976	45634
Blacktown (C) - South-East	40	97	13644	2290	6868	7580	10208	4048	8103	517	1084	973	1704	2075	3621	4657	8284	435	4097	1918	82243
Blacktown (C) - South-West	128	43	5247	1161	3020	4487	7773	3392	8806	112	352	831	2119	1704	1881	4389	4819	355	1993	944	53554
Blue Mountains (C)	263	6	705	177	1519	431	3514	3194	868	287	392	419	1722	751	1592	2986	4912	572	1130	567	26006
Botany Bay (C)	14	32	5009	361	3363	5306	5550	4448	26620	869	850	1645	2824	2505	3225	1082	3071	381	1754	1393	70301
Burwood (A)	0	5	378	32	830	1220	3542	1491	2301	709	780	598	1380	772	1277	3301	4434	115	687	616	24468
Camden (A)	480	40	2464	338	3404	1524	7907	3705	2071	637	1180	1116	4616	1265	1578	3609	4120	851	1762	657	43324
Campbelltown (C) - North	41	69	10175	180	2605	2443	3127	1721	3146	137	321	665	891	766	1277	3324	2878	171	1487	802	36226
Campbelltown (C) - South	55	226	1025	99	1174	593	6935	3874	1123	324	727	536	1062	895	2117	4681	8341	364	1375	646	36173
Canada Bay (A) - Concord	5	13	2667	111	1936	2550	2622	1472	441	645	4751	542	1998	707	282	1295	6302	313	1254	645	30553
Canada Bay (A) - Drummoyne	11	0	300	34	773	433	2012	1281	313	72	314	411	1227	322	459	1168	1576	231	898	286	12123
Canterbury (C)	27	6	3365	65	3314	2566	5219	2706	2339	372	583	600	1393	919	2178	3265	6031	313	1669	1224	38153
Cessnock (C)	581	753	2693	184	2061	508	3271	3676	851	95	195	335	847	691	1235	1852	2535	278	1157	484	24281
Fairfield (C) - East	38	21	3818	132	1765	1568	5389	3989	1491	195	453	506	1073	971	2214	4139	5208	320	1753	1067	36111
Fairfield (C) - West	279	50	11099	479	4616	6398	4796	2373	5552	188	656	597	1964	2130	1177	2988	3438	372	2332	1260	52745
Gosford (C) - East	132	28	569	104	2167	594	4776	3094	497	301	637	510	1511	732	782	2416	3142	370	1145	487	23996
Gosford (C) - West	1065	230	5366	473	3182	1519	5822	3622	1486	692	992	815	2284	1637	4190	3642	11063	670	2345	1159	52254
Hawkesbury (C)	1591	44	4245	286	3334	951	4310	2786	1292	493	402	508	1281	904	3705	3252	3922	599	1678	835	36418
Holroyd (C)	59	27	9707	531	3395	4148	4998	2144	5357	212	606	612	1314	790	1722	2949	4027	186	1874	1104	45763

Hornsby (A) - North	315	7	1308	139	1920	1037	2337	1242	1168	152	333	284	1468	495	415	3003	2862	203	849	390	19929
Hornsby (A) - South	47	13	4251	271	2358	1755	8479	3833	1152	698	1449	964	3673	1461	2131	7363	9885	547	2281	1019	53632
Hunters Hill (A)	0	5	118	17	438	85	452	524	83	48	152	191	556	166	412	1070	1757	30	294	184	6586
Hurstville (C)	43	0	2084	127	2376	2034	4233	2158	1232	220	2018	607	1994	897	1529	2708	4713	352	1465	789	31579
Kiama (A)	365	4	223	53	690	166	1099	1482	338	65	175	176	480	219	428	624	824	275	326	141	8153
Kogarah (C)	13	19	518	541	937	310	1314	1668	658	213	2412	453	1257	385	2025	2273	10346	300	704	571	26917
Ku-ring-gai (A)	90	24	1358	118	2661	1868	3895	2489	797	1083	1224	1037	5261	1163	1281	7226	10118	468	1545	1145	44851
Lake Macquarie (C) - East	29	134	1490	143	2256	414	2932	1718	438	54	325	255	756	523	542	1903	3365	193	992	300	18761
Lake Macquarie (C) - North	59	957	4811	226	3380	1119	6804	3629	1905	397	2019	676	1758	1055	2689	3362	5692	520	2354	726	44137
Lake Macquarie (C) - West	136	881	1554	588	1500	252	1951	1314	717	92	238	245	931	587	414	1868	3621	205	747	370	18212
Lane Cove (A)	34	0	1887	42	1039	1450	1830	1011	228	686	671	293	2842	1104	474	1244	3478	223	534	541	19611
Leichhardt (A)	103	5	1231	57	2102	1157	3912	2491	740	896	625	678	3183	1473	1510	2388	4608	630	1294	783	29866
Liverpool (C) - East	40	28	9013	478	3469	3850	9205	3591	5201	1092	1411	1246	3318	3630	10297	5897	14095	772	2418	1510	80559
Liverpool (C) - West	1106	49	2503	941	3518	2625	6404	2579	5414	639	537	636	1679	1264	749	5852	3659	347	1126	754	42382
Maitland (C)	322	908	3344	522	3065	755	5012	2515	1349	168	583	665	1655	1116	1852	3250	4943	290	2016	618	34950
Manly (A)	56	12	400	105	1165	450	1807	2375	162	290	659	601	1978	410	713	1715	2569	280	674	455	16875
Marrickville (A)	23	15	3971	66	2513	2906	5321	2543	1963	804	603	558	2746	834	1654	3640	4009	796	1957	881	37804
Mosman (A)	51	15	233	11	780	186	1557	1171	250	199	399	469	1417	277	635	1170	1492	807	514	442	12075
Newcastle (C) - Inner City	82	362	4545	781	3189	1297	4506	4687	4659	1665	3956	1206	8141	2027	6098	3239	6115	617	2211	994	60378
Newcastle (C) - Outer West	313	291	2857	1759	2740	1187	2665	1714	1054	235	342	328	926	518	772	5539	2925	311	1160	475	28115
Newcastle (C) - Throsby	86	35	2326	238	2250	995	8758	4345	1407	481	1505	663	3549	1144	2361	3547	13754	678	1880	698	50699
North Sydney (A)	134	511	5813	669	6014	4122	5965	6178	2020	9162	13602	2929	42717	6450	3467	6899	8463	1865	3782	4575	135336
Parramatta (C) - Inner	52	121	7427	2455	4782	4165	9496	4880	3446	1704	14113	1895	8158	4098	23656	5624	24128	1123	4144	2464	127930
Parramatta (C) - North-East	36	7	3221	11	812	762	935	766	305	157	485	271	939	415	353	970	2076	119	588	337	13564
Parramatta (C) - North-West	4	17	1646	0	889	643	2260	690	641	61	159	74	526	209	135	829	2444	80	414	241	11960
Parramatta (C) - South	3	13	1561	23	719	737	995	480	1732	74	115	108	483	232	719	1803	822	427	320	263	11627
Penrith (C) - East	537	47	6477	1640	4290	5268	4923	3806	8162	766	943	1527	4097	2647	2385	6426	8681	718	2948	888	67177
Penrith (C) - West	94	211	4046	617	3079	1391	8958	4154	2171	381	833	784	2422	1186	4832	3409	6353	1188	2056	954	49116
Pittwater (A)	61	12	2312	70	2968	1788	3522	2467	461	428	690	688	2658	781	808	2052	3937	685	1395	831	28613
Port Stephens (A)	468	206	5780	217	2562	707	5304	3747	1476	250	349	795	1507	896	5949	2305	3394	615	1558	764	38849

Randwick (C)	59	4	1761	199	3582	1086	3239	4440	3240	538	691	803	3126	1854	4201	12922	15498	1251	1763	1335	61593
Rockdale (C)	30	17	1935	100	2251	768	7167	4091	12716	1009	1014	1327	2886	2827	9539	2916	4332	851	1598	1212	58583
Ryde (C)	115	103	9324	906	6445	14504	9583	4675	1108	11176	1211	1521	15663	3114	3880	10072	15551	557	3632	3001	116141
Shellharbour (C)	102	206	748	154	1720	558	4096	2195	819	68	366	331	641	490	1561	2552	3420	267	1004	363	21661
Shoalhaven (C) - Pt A	208	38	2336	254	1115	313	2913	1289	823	254	293	291	933	585	3503	1764	4073	265	783	390	22423
Shoalhaven (C) - Pt B	792	40	802	181	1610	217	2454	2769	452	127	191	450	759	573	443	1620	2194	433	590	344	17041
Strathfield (A)	87	32	3703	804	2490	5904	3800	1428	6471	387	1253	529	1396	779	767	2589	1384	339	982	959	36081
Sutherland Shire (A) - East	59	88	5943	344	4520	2330	10613	4782	1235	343	1269	965	3059	969	1289	3799	8749	628	2458	1059	54501
Sutherland Shire (A) - West	25	7	1670	192	2964	898	4808	3039	1077	136	807	481	3877	846	3652	4798	5047	393	2034	541	37289
Sydney (C) - East	28	60	1275	112	1996	1754	4338	6970	779	5147	1333	1130	10967	2950	10086	4386	12016	2633	2363	1841	72164
Sydney (C) - Inner	133	1406	3142	2698	9124	3900	19572	27629	7380	20463	123221	9475	88138	20597	27508	9803	10659	6725	7301	8680	407554
Sydney (C) - South	19	25	5246	586	3422	8116	9075	4441	7057	5857	1632	2069	9416	3035	5179	3166	5460	2653	3947	2087	82488
Sydney (C) - West	4	21	779	206	3464	1969	4096	4022	3153	7974	2415	1034	10459	2121	4056	15034	9282	5518	1695	1741	79045
Warringah (A)	136	60	6027	505	4995	7773	11823	4663	1692	1332	1565	1321	5782	1890	2262	7120	10782	975	3394	1619	75717
Willoughby (C)	89	162	3935	619	5579	3439	8690	3200	1615	7211	2646	1598	8643	2467	2600	3590	14445	709	2907	1891	76036
Waverley (A)	29	45	561	98	1603	776	5531	3233	405	619	977	566	2920	1374	1395	2959	4439	956	1276	898	30658
Wingecarribee (A)	1075	115	2317	167	1557	452	2901	2095	783	279	326	517	1227	522	695	1841	2964	311	833	481	21461
Wollondilly (A)	671	1769	1919	296	2147	487	1535	934	834	113	162	193	844	353	638	1360	1196	225	597	373	16645
Wollongong (C) - Inner	66	639	3866	307	2806	1397	5604	4889	2417	691	3813	1182	3599	1960	5828	8391	10401	798	2320	1107	62080
Wollongong (C) Bal	213	1818	7006	731	3463	935	5526	2860	2341	181	601	523	1566	1410	1206	3042	5393	524	2082	739	42158
Woollahra (A)	59	32	439	53	1861	703	3616	2535	167	450	994	1098	2485	811	1876	3070	3324	718	1183	846	26320
Wyong (A) - North-East	182	240	1097	665	1748	937	4072	2360	1425	147	434	449	1327	624	744	2303	4497	576	1160	561	25548
Wyong (A) - South and West	163	70	4767	353	2699	1106	5440	3956	1304	342	858	659	1466	1185	2819	2868	4528	430	1457	683	37151
No fixed address	832	446	4605	1212	60898	3533	5583	2184	12057	2455	1294	781	6589	15720	3446	5971	9907	2866	6093	4453	150927
Total GMA	16371	14783	289216	36389	279991	178303	418548	255275	213733	104657	231746	703788	360508	137990	231861	304559	471135	60559	144273	870526	390732

Source: SGS modelling. 2015

TABLE 15 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2035

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	9	0	378	31	979	395	2564	1417	324	105	262	1094	929	403	1576	1602	3695	138	535	370	16806
Auburn (C)	50	21	10255	2043	5630	7870	8095	3320	5357	1741	6818	1122	5003	2568	6313	4113	7193	2188	3373	1906	84980
Bankstown (C) - North-East	10	10	7487	246	1800	1636	6717	2010	4139	1674	910	680	1069	918	2328	3822	6612	296	1730	1086	45180
Bankstown (C) - North-West	18	0	5987	1048	1892	1827	2664	1013	2808	288	400	264	916	473	1437	2489	2738	239	951	691	28144
Bankstown (C) - South	28	40	6922	155	2953	2447	2388	1500	1267	92	287	250	832	550	423	2815	1893	182	1144	630	26799
The Hills Shire (A) - Central	29	21	6677	347	5853	5286	18986	4750	1194	2165	4525	2054	10192	3233	3427	4867	9683	1789	3521	1675	90277
The Hills Shire (A) - North	1154	359	1611	524	3908	2197	8739	5178	1707	1128	1260	1416	5442	1762	1217	4349	4448	1166	2227	1229	51020
The Hills Shire (A) - South	113	10	790	15	1258	655	1919	561	327	121	261	191	3740	453	293	3963	1821	123	1191	329	18133
Blacktown (C) - North	308	349	3979	771	3970	3047	6974	4095	2774	606	1108	1335	4136	1506	1635	7173	4306	979	2496	1120	52669
Blacktown (C) - South-East	40	105	14082	2405	7375	7826	11040	4427	8860	524	1152	1018	1746	2158	3819	4994	9051	442	4352	1931	87349
Blacktown (C) - South-West	131	44	5485	1216	3267	4692	8461	3687	9533	116	368	865	2142	1784	2032	4689	5199	350	2092	976	57130
Blue Mountains (C)	277	6	725	183	1559	437	3694	3354	924	297	410	430	1820	791	1643	3157	5229	594	1180	583	27294
Botany Bay (C)	12	35	4949	396	3551	5552	5949	4712	27277	942	885	1768	2982	2688	3514	1152	3411	406	1854	1412	73449
Burwood (A)	0	6	388	34	883	1346	3760	1597	2546	714	844	645	1426	832	1325	3518	4696	116	707	629	26011
Camden (A)	510	42	2605	368	3707	1654	9040	4325	2306	722	1338	1260	5478	1517	1850	4058	4744	959	1982	688	49156
Campbelltown (C) - North	41	77	10629	187	2748	2574	3361	1898	3440	140	334	699	917	801	1345	3526	3202	174	1603	820	38514
Campbelltown (C) - South	55	251	1082	103	1239	624	7514	4312	1227	331	763	566	1102	939	2229	4970	9296	371	1486	661	39121
Canada Bay (A) - Concord	5	14	2795	111	2041	2822	2811	1584	483	660	5130	582	2097	772	295	1410	6720	328	1334	660	32653
Canada Bay (A) - Drummoyne	11	0	302	34	814	479	2158	1377	343	74	340	442	1288	352	480	1272	1680	242	955	293	12937
Canterbury (C)	29	6	3291	68	3504	2643	5388	2859	2477	385	610	626	1454	949	2282	3482	6458	313	1728	1244	39795
Cessnock (C)	610	785	2737	232	2317	592	3577	4028	1025	142	241	401	1073	770	1360	1951	2598	336	1264	495	26535
Fairfield (C) - East	40	22	3803	139	1852	1604	5785	4350	1587	202	471	523	1117	1065	2381	4484	5590	332	1834	1072	38253
Fairfield (C) - West	297	53	11174	495	4768	6528	5117	2557	5886	194	676	609	2012	2272	1247	3246	3688	383	2399	1271	54869
Gosford (C) - East	136	29	569	109	2260	586	4967	3266	514	308	662	519	1579	772	821	2527	3279	381	1198	495	24977
Gosford (C) - West	1099	233	5376	492	3319	1500	6055	3824	1538	706	1031	829	2387	1726	4396	3809	11542	690	2453	1177	54183
Hawkesbury (C)	1653	45	4409	310	3531	959	4619	2984	1396	513	424	533	1338	975	3840	3457	4219	613	1780	857	38454
Holroyd (C)	58	27	9598	601	3599	4281	5343	2270	5788	216	657	656	1400	822	1936	3148	4305	193	2001	1125	48025

Hornsby (A) - North	322	8	1348	146	2041	1072	2495	1328	1247	157	354	299	1554	524	452	3222	3114	207	893	396	21176
Hornsby (A) - South	46	13	4509	282	2466	1787	8933	4065	1220	693	1486	1009	3923	1530	2277	7891	10552	558	2387	1026	56654
Hunters Hill (A)	0	6	124	18	472	89	479	557	87	51	156	204	606	176	445	1145	1889	31	310	189	7034
Hurstville (C)	44	0	2053	134	2500	2071	4395	2280	1300	221	2108	629	2088	927	1603	2897	5053	356	1517	800	32978
Kiama (A)	377	4	232	55	718	173	1144	1582	364	61	185	185	508	231	451	643	869	286	344	143	8555
Kogarah (C)	14	21	518	567	986	311	1369	1755	692	222	2512	474	1314	399	2112	2425	11088	309	732	581	28403
Ku-ring-gai (A)	93	24	1430	123	2797	1912	4013	2615	842	1123	1257	1085	5488	1209	1349	7737	10830	475	1598	1153	47154
Lake Macquarie (C) - East	30	133	1504	154	2366	390	2995	1813	458	56	348	259	790	536	567	1969	3561	200	1042	298	19468
Lake Macquarie (C) - North	59	962	4897	240	3551	1058	6951	3835	2020	411	2160	686	1843	1089	2821	3475	6018	540	2470	726	45812
Lake Macquarie (C) - West	138	887	1603	609	1586	242	2000	1399	771	97	244	248	993	621	442	1918	3808	216	781	377	18982
Lane Cove (A)	36	0	1913	44	1107	1461	1909	1069	235	704	686	308	2996	1149	484	1320	3722	231	556	544	20473
Leichhardt (A)	119	6	1248	59	2220	1229	4135	2645	776	921	663	716	3297	1584	1580	2576	4875	653	1341	799	31440
Liverpool (C) - East	40	29	9129	506	3667	4251	9999	3887	6154	1151	1472	1293	3474	4075	10708	6468	15473	798	2529	1529	86634
Liverpool (C) - West	1357	59	2908	1154	4345	3423	8655	3334	7090	934	778	834	2627	1661	1081	7558	5001	573	1636	886	55893
Maitland (C)	331	973	3427	566	3220	767	5131	2660	1433	165	577	699	1730	1170	1970	3355	5092	302	2163	624	36355
Manly (A)	63	13	410	110	1219	467	1875	2511	165	295	692	630	2058	424	734	1854	2744	285	701	466	17717
Marrickville (A)	22	17	3904	69	2664	2992	5545	2666	2034	839	628	583	2875	862	1733	3847	4222	845	2027	881	39254
Mosman (A)	54	17	239	11	831	189	1628	1230	254	202	419	491	1482	286	653	1259	1601	842	533	457	12680
Newcastle (C) - Inner City	86	370	4480	818	3368	1233	4570	4932	4904	1693	4128	1221	8446	2047	6365	3321	6150	626	2289	991	62037
Newcastle (C) - Outer West	328	298	2848	1844	2894	1124	2715	1812	1113	240	358	334	971	525	808	5692	2943	319	1207	473	28843
Newcastle (C) - Throsby	90	36	2316	249	2376	942	8923	4586	1479	489	1575	678	3696	1162	2469	3641	13837	695	1954	696	51890
North Sydney (A)	143	559	6287	696	6408	4180	6231	6501	2064	9351	14223	3069	44859	6672	3560	7400	9076	1940	3925	4693	141837
Parramatta (C) - Inner	49	128	7496	2616	5064	4240	10188	5166	3637	1791	15531	2023	8993	4315	26694	6089	25562	1247	4392	2497	137714
Parramatta (C) - North-East	36	7	3319	11	855	775	991	797	323	154	507	283	1009	433	401	1058	2234	123	626	340	14282
Parramatta (C) - North-West	4	18	1632	0	932	646	2404	722	675	62	175	76	561	216	152	884	2582	84	430	245	12500
Parramatta (C) - South	3	13	1552	24	753	745	1060	505	1835	75	124	112	514	242	808	1925	884	441	336	261	12211
Penrith (C) - East	554	49	6832	1795	4907	6259	5651	4261	8932	1078	1262	2025	5069	3429	2800	7093	9488	1059	3400	1017	76959
Penrith (C) - West	95	219	4051	655	3171	1425	9508	4426	2349	382	863	805	2580	1265	5042	3650	6846	1419	2164	966	51882
Pittwater (A)	59	13	2398	70	3093	1897	3696	2640	480	443	722	724	2803	819	847	2217	4219	725	1469	848	30183
Port Stephens (A)	484	208	5835	231	2654	726	5437	3929	1562	259	337	841	1583	933	6234	2392	3492	651	1665	789	40242

Randwick (C)	62	4	1862	209	3824	1120	3360	4672	3309	557	710	807	3322	1966	4421	13840	16617	1274	1835	1386	65157
Rockdale (C)	31	18	1923	102	2372	766	7775	4417	13041	1385	1188	1535	3506	3127	10417	3138	4731	1086	1666	1234	63458
Ryde (C)	121	113	9891	975	6944	15166	10117	4958	1152	11741	1240	1624	17069	3296	4187	10777	16715	561	3841	3093	12358 1
Shellharbour (C)	105	216	754	161	1790	582	4261	2343	882	65	386	346	678	518	1645	2631	3608	278	1057	368	22674
Shoalhaven (C) - Pt A	212	38	2357	263	1143	289	2862	1297	828	258	280	295	933	595	3499	1782	4008	267	780	394	22377
Shoalhaven (C) - Pt B	809	40	813	187	1649	200	2412	2786	455	129	183	456	760	582	443	1636	2159	435	588	347	17069
Strathfield (A)	90	36	3825	838	2643	6463	4032	1525	7040	389	1355	571	1443	837	793	2760	1466	344	1011	977	38436
Sutherland Shire (A) - East	58	95	6058	365	4820	2382	11162	5035	1297	356	1311	981	3225	988	1380	4064	9400	632	2576	1065	57250
Sutherland Shire (A) - West	24	7	1651	204	3121	912	5066	3283	1136	134	839	489	4084	880	3985	5133	5415	395	2136	534	39428
Sydney (C) - East	28	65	1206	114	2136	1790	4573	7312	788	5386	1414	1186	11579	3072	10475	4673	12809	2761	2461	1905	75734
Sydney (C) - Inner	117	1520	3050	2753	9766	3978	20537	28886	7457	21407	13023 2	9928	92563	21407	28486	10408	11344	6953	7594	8986	42737 3
Sydney (C) - South	17	27	4980	599	3661	8278	9649	4739	7161	6337	1788	2242	10183	3236	5450	3414	5917	2895	4161	2157	86891
Sydney (C) - West	4	23	757	210	3708	2008	4297	4205	3186	8348	2552	1076	11013	2201	4200	16011	9890	5778	1763	1803	83034
Warringah (A)	137	64	6098	530	5181	8179	12473	4936	1783	1368	1637	1386	6015	1953	2393	7679	11517	997	3551	1615	79491
Willoughby (C)	94	174	4002	644	5943	3466	9064	3384	1668	7390	2703	1680	9114	2567	2659	3809	15455	734	3024	1902	79477
Waverley (A)	30	50	578	103	1712	799	5799	3389	406	646	1014	567	3063	1418	1473	3151	4688	1004	1320	924	32136
Wingecarribee (A)	1104	114	2311	174	1602	422	2861	2097	788	288	315	534	1233	524	691	1847	2903	312	838	483	21443
Wollondilly (A)	687	1825	1985	315	2305	508	1667	1044	895	122	170	203	904	376	679	1442	1322	234	642	380	17703
Wollongong (C) - Inner	67	668	3782	302	2867	1403	5712	5073	2525	635	4055	1221	3725	2043	6115	8623	10568	828	2399	1114	63726
Wollongong (C) Bal	220	1940	6882	768	3561	939	5679	2978	2482	171	627	531	1579	1467	1266	3119	5591	535	2182	727	43245
Woollahra (A)	62	35	446	56	1988	724	3791	2657	167	470	1031	1100	2607	837	1982	3270	3511	754	1223	871	27582
Wyong (A) - North-East	187	239	1112	778	1939	1300	4306	2540	1743	175	476	481	1603	683	809	2445	4786	614	1427	595	28238
Wyong (A) - South and West	168	70	4853	366	2829	1107	5691	4198	1391	349	902	673	1542	1255	2982	3018	4800	446	1526	693	38860
No fixed address	858	466	4687	1283	64451	3672	5909	2322	12759	2570	1370	827	7005	16644	3657	6347	10538	3039	6420	4542	15936 7
Total GMA	17094	15525	29439 1	38817	29776 3	18659 2	44576 0	27284 0	22787 9	11010 3	24647 0	74941	38509 6	14683 4	24717 4	32598 2	50388 0	64518	15280 7	89211	41436 78

Source: SGS modelling. 2015

TABLE 16 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2040

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	9	0	389	32	1040	438	2730	1518	360	106	283	1188	962	436	1633	1705	3907	143	552	377	17809
Auburn (C)	49	22	10306	2229	6001	8075	8696	3562	5660	1779	7466	1182	5349	2715	7051	4390	8271	2336	3585	1916	90641
Bankstown (C) - North-East	10	11	7889	260	1896	1672	7054	2123	4385	1696	947	717	1107	956	2394	4066	7076	311	1799	1088	47456
Bankstown (C) - North-West	18	0	5965	1093	1992	1865	2808	1069	2981	294	423	278	964	494	1562	2649	2932	252	994	691	29321
Bankstown (C) - South	28	44	6873	164	3110	2500	2508	1584	1342	93	298	263	862	573	435	2994	2027	192	1189	632	27712
The Hills Shire (A) - Central	29	22	6959	382	6247	5505	20304	5002	1235	2235	4938	2149	10598	3372	3646	5195	10473	1890	3720	1712	95613
The Hills Shire (A) - North	1182	389	1658	612	4183	2349	9683	5649	1868	1271	1465	1539	6332	2034	1447	4705	4926	1288	2330	1265	56174
The Hills Shire (A) - South	113	11	794	16	1331	668	2037	589	347	125	283	203	3995	477	324	4249	1947	131	1255	334	19228
Blacktown (C) - North	316	352	4028	938	4503	3519	7895	4683	3171	722	1269	1530	4976	1678	1810	7884	4759	1091	2759	1285	59168
Blacktown (C) - South-East	40	113	14524	2526	7914	8122	11984	4854	9700	536	1221	1075	1793	2252	4016	5324	9854	459	4624	1943	92873
Blacktown (C) - South-West	135	46	5714	1274	3528	4909	9234	4016	10323	121	384	905	2167	1870	2184	4982	5597	352	2196	1005	60941
Blue Mountains (C)	291	6	747	190	1597	445	3895	3532	987	309	429	446	1921	836	1693	3331	5553	628	1235	597	28670
Botany Bay (C)	11	37	4917	431	3747	5829	6296	4982	28005	1020	921	1915	3122	2886	3803	1225	3781	439	1960	1429	76758
Burwood (A)	0	6	400	35	938	1493	4004	1710	2827	725	910	701	1476	900	1373	3744	4965	121	729	641	27698
Camden (A)	542	44	2739	399	4005	1778	9850	4771	2547	758	1412	1327	5992	1636	1998	4392	5284	1045	2183	717	53419
Campbelltown (C) - North	41	84	11075	195	2896	2719	3628	2100	3764	144	347	741	944	840	1412	3737	3551	179	1732	836	40966
Campbelltown (C) - South	56	276	1143	108	1305	660	8172	4813	1343	340	799	603	1144	988	2341	5272	10326	386	1609	674	42356
Canada Bay (A) - Concord	6	15	2928	112	2150	3137	3018	1703	532	679	5525	630	2200	844	308	1528	7147	349	1418	674	34904
Canada Bay (A) - Drummoyne	11	0	306	34	858	533	2317	1481	378	76	366	478	1352	385	501	1379	1787	258	1016	299	13815
Canterbury (C)	30	7	3236	70	3701	2741	5590	3027	2635	400	638	661	1518	986	2386	3707	6895	320	1793	1262	41601
Cessnock (C)	639	818	2744	247	2464	613	3701	4307	1102	157	249	434	1159	816	1442	1985	2628	361	1342	505	27712
Fairfield (C) - East	42	23	3795	146	1945	1651	6180	4751	1696	210	490	546	1163	1177	2556	4845	5979	351	1921	1077	40544
Fairfield (C) - West	317	57	11214	511	4926	6687	5437	2760	6167	202	696	627	2040	2440	1315	3515	3944	399	2471	1280	57006
Gosford (C) - East	141	29	570	113	2358	584	5178	3458	536	317	688	533	1652	818	860	2658	3416	400	1254	502	26065
Gosford (C) - West	1133	237	5393	513	3463	1492	6312	4049	1603	727	1072	852	2497	1830	4606	4006	12027	724	2568	1195	56297
Hawkesbury (C)	1714	47	4570	334	3732	975	4955	3197	1511	537	446	564	1398	1051	3973	3670	4522	640	1888	876	40601
Holroyd (C)	57	27	9506	636	3775	4370	5663	2389	6151	222	712	689	1494	857	2177	3355	4581	205	2100	1129	50095

Hornsby (A) - North	329	8	1396	153	2166	1113	2665	1419	1336	162	375	317	1643	555	489	3449	3372	215	941	402	22504
Hornsby (A) - South	45	13	4788	294	2580	1832	9424	4318	1297	696	1526	1067	4189	1607	2422	8437	11234	580	2503	1033	59885
Hunters Hill (A)	0	6	130	20	507	93	508	592	91	54	160	220	661	187	477	1223	2023	32	328	194	7506
Hurstville (C)	46	0	2032	140	2629	2123	4584	2414	1380	224	2199	660	2186	962	1677	3093	5400	367	1576	809	34502
Kiama (A)	388	4	241	58	747	181	1193	1689	393	58	194	196	538	245	475	662	920	302	362	145	8992
Kogarah (C)	14	23	520	595	1037	315	1432	1851	732	232	2613	502	1374	416	2200	2583	11845	325	762	591	29964
Ku-ring-gai (A)	96	24	1503	128	2940	1968	4157	2754	893	1170	1292	1148	5726	1262	1417	8267	11556	492	1657	1161	49612
Lake Macquarie (C) - East	30	132	1520	166	2481	370	3045	1919	483	58	372	265	827	552	593	2025	3735	211	1096	297	20178
Lake Macquarie (C) - North	60	967	4984	254	3731	1007	7071	4063	2154	428	2303	704	1933	1128	2953	3571	6308	571	2598	727	47515
Lake Macquarie (C) - West	141	893	1651	632	1677	233	2040	1493	833	103	251	254	1058	657	470	1960	3973	230	819	383	19750
Lane Cove (A)	37	0	1942	46	1177	1484	1999	1132	245	725	701	327	3156	1200	496	1399	3970	243	580	547	21407
Leichhardt (A)	134	6	1276	61	2342	1317	4385	2811	821	953	703	763	3419	1709	1650	2770	5149	689	1393	813	33167
Liverpool (C) - East	41	30	9249	536	3873	4473	10788	4192	6693	1193	1513	1339	3568	4573	11097	7045	16882	823	2632	1547	92090
Liverpool (C) - West	1586	67	3220	1319	5009	4045	10998	4099	9106	1112	883	946	3881	1989	1301	9101	6402	706	1963	991	68727
Maitland (C)	341	1038	3503	612	3381	784	5242	2819	1531	164	570	743	1810	1231	2082	3414	5245	320	2319	630	37779
Manly (A)	70	14	424	115	1272	489	1955	2660	170	302	725	668	2142	440	756	1998	2923	296	731	475	18625
Marrickville (A)	20	18	3869	72	2819	3101	5795	2800	2113	880	655	615	3010	896	1812	4063	4439	910	2104	882	40872
Mosman (A)	58	18	245	12	884	193	1707	1295	261	207	440	519	1551	297	671	1351	1713	893	553	471	13340
Newcastle (C) - Inner City	90	378	4433	858	3555	1180	4618	5199	5191	1731	4306	1247	8769	2076	6634	3389	6133	644	2377	988	63795
Newcastle (C) - Outer West	343	304	2847	1933	3054	1071	2754	1920	1181	247	375	343	1018	534	843	5819	2935	334	1258	472	29585
Newcastle (C) - Throsby	94	36	2311	261	2508	897	9050	4853	1563	501	1641	693	3829	1180	2577	3720	13798	727	2038	694	52972
North Sydney (A)	151	609	6855	725	6816	4269	6532	6856	2128	9606	14855	3250	47084	6934	3657	7919	9702	2053	4082	4800	148884
Parramatta (C) - Inner	47	135	7561	2783	5363	4349	10859	5464	3856	1875	17028	2158	9807	4550	30044	6532	26942	1347	4644	2526	147869
Parramatta (C) - North-East	36	8	3413	11	900	793	1049	831	343	153	531	300	1086	453	455	1150	2395	131	666	342	15043
Parramatta (C) - North-West	4	19	1621	0	977	654	2544	757	715	64	191	80	600	224	171	942	2716	90	449	249	13066
Parramatta (C) - South	3	13	1545	26	790	759	1124	532	1953	77	133	117	548	253	908	2052	947	464	352	259	12856
Penrith (C) - East	567	51	6965	1861	5294	6628	6388	4742	9275	1435	1692	2355	7292	4106	3285	7772	10162	1280	3924	1273	86346
Penrith (C) - West	96	227	4066	695	3262	1468	10053	4691	2548	387	895	836	2712	1336	5250	3905	7353	1516	2266	977	54539
Pittwater (A)	58	14	2487	70	3218	2023	3891	2826	503	462	755	771	2954	862	886	2388	4506	778	1548	864	31862
Port Stephens (A)	500	211	5888	246	2753	750	5561	4134	1662	269	326	898	1664	976	6505	2444	3592	701	1778	812	41670

Randwick (C)	64	4	1968	219	4074	1160	3502	4928	3397	580	731	819	3523	2088	4640	14793	17759	1322	1914	1433	68919
Rockdale (C)	32	20	1920	104	2499	771	8383	4745	13428	1738	1335	1730	4049	3428	11279	3353	5122	1301	1741	1254	68233
Ryde (C)	127	122	10489	1046	7457	15914	10706	5264	1206	12385	1272	1748	18598	3494	4493	11510	17904	577	4062	3177	131552
Shellharbour (C)	109	225	759	168	1862	610	4444	2503	952	61	407	367	718	549	1730	2708	3819	294	1114	372	23771
Shoalhaven (C) - Pt A	217	38	2379	272	1177	269	2816	1308	802	264	268	304	936	611	3489	1800	3973	275	781	397	22372
Shoalhaven (C) - Pt B	827	40	825	193	1699	186	2373	2809	440	133	175	470	762	598	441	1652	2140	449	589	350	17150
Strathfield (A)	93	39	3962	873	2802	7118	4290	1630	7696	395	1462	620	1493	902	820	2937	1550	357	1044	992	41075
Sutherland Shire (A) - East	57	101	6180	387	5131	2451	11771	5312	1369	370	1353	1009	3398	1015	1470	4338	10064	649	2702	1071	60198
Sutherland Shire (A) - West	24	7	1637	216	3285	934	5353	3543	1204	134	870	502	4299	919	4318	5480	5791	406	2245	528	41697
Sydney (C) - East	27	70	1153	117	2281	1838	4832	7684	800	5657	1496	1257	12212	3211	10866	4971	13614	2944	2569	1963	79564
Sydney (C) - Inner	103	1633	2976	2818	10429	4084	21606	30248	7573	22472	137301	10500	97132	22328	29469	11036	12037	7283	7913	9265	448207
Sydney (C) - South	15	29	4773	614	3908	8498	10139	4934	7281	6627	1862	2337	10608	3348	5633	3593	6255	3011	4335	2221	90019
Sydney (C) - West	3	24	740	215	3960	2062	4520	4403	3238	8769	2690	1130	11584	2293	4345	17027	10507	6156	1837	1859	87359
Warringah (A)	138	67	6197	556	5368	8659	13192	5233	1889	1412	1709	1470	6260	2027	2523	8258	12150	1039	3720	1612	83478
Willoughby (C)	99	186	4092	671	6320	3520	9491	3585	1734	7620	2765	1783	9600	2682	2720	4037	16487	773	3153	1912	83232
Waverley (A)	32	56	598	108	1825	828	6099	3563	412	676	1051	574	3213	1471	1552	3352	4945	1070	1369	948	33741
Wingecarribee (A)	1134	113	2306	182	1656	397	2824	2106	763	300	305	559	1241	533	686	1853	2865	321	846	485	21475
Wollondilly (A)	704	1880	2048	334	2467	532	1814	1169	963	131	179	216	965	400	719	1527	1458	248	692	385	18833
Wollongong (C) - Inner	69	697	3712	300	2934	1421	5851	5285	2656	587	4302	1277	3862	2138	6405	8849	10776	875	2491	1121	65608
Wollongong (C) Bal	227	2063	6773	806	3665	951	5856	3110	2642	161	652	545	1593	1533	1326	3194	5817	556	2290	717	44476
Woollahra (A)	65	39	454	59	2119	750	3987	2793	169	492	1069	1113	2734	868	2087	3478	3703	804	1269	894	28948
Wyong (A) - North-East	193	240	1126	905	2126	1636	4493	2693	2040	182	498	497	1775	726	854	2584	5055	639	1684	608	30554
Wyong (A) - South and West	173	70	4940	381	2965	1114	5962	4465	1488	359	948	695	1622	1337	3148	3190	5074	471	1599	704	40703
No fixed address	886	486	4772	1355	68031	3814	6238	2463	13470	2687	1446	873	7424	17575	3870	6725	11173	3216	6749	4629	167882
Total GMA	17802	16241	299647	41183	315384	194811	473083	290585	242219	115520	261024	79472	409812	155612	262381	347180	536462	68554	161231	91187	437938

Source: SGS modelling. 2015

TABLE 17 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2045

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	9	0	401	32	1076	455	2833	1576	373	110	293	1240	1003	452	1704	1781	4067	149	568	391	18514
Auburn (C)	52	23	10582	2274	6220	8388	9054	3712	5872	1847	7796	1227	5602	2833	7357	4596	8605	2454	3721	1993	94206
Bankstown (C) - North-East	10	12	8173	270	1959	1739	7320	2201	4526	1753	986	739	1158	994	2490	4246	7387	323	1860	1130	49276
Bankstown (C) - North-West	18	0	6108	1117	2053	1937	2916	1106	3097	294	440	286	1005	514	1631	2770	3059	261	1029	717	30359
Bankstown (C) - South	30	46	7043	166	3212	2596	2602	1642	1392	93	310	272	898	596	454	3129	2115	199	1235	655	28684
The Hills Shire (A) - Central	31	23	7162	393	6547	5728	21197	5219	1278	2303	5136	2231	11059	3510	3826	5448	10917	1972	3839	1782	99602
The Hills Shire (A) - North	1233	407	1695	635	4289	2432	10151	5910	1944	1325	1532	1597	6646	2128	1518	4930	5165	1348	2422	1315	58624
The Hills Shire (A) - South	119	11	820	17	1365	692	2120	610	359	128	294	206	4176	495	337	4446	2039	136	1299	348	20016
Blacktown (C) - North	330	370	4171	979	4679	3677	8262	4896	3323	761	1336	1598	5237	1764	1890	8256	4981	1150	2877	1336	61873
Blacktown (C) - South-East	43	118	15020	2590	8233	8458	12477	5042	10144	548	1273	1106	1857	2349	4200	5561	10280	476	4811	2025	96611
Blacktown (C) - South-West	141	48	5878	1315	3666	5103	9606	4170	10694	122	400	933	2241	1951	2288	5207	5828	363	2265	1047	63265
Blue Mountains (C)	304	7	765	195	1661	464	4056	3671	1030	316	449	461	2005	870	1764	3494	5768	652	1277	622	29828
Botany Bay (C)	11	37	5077	444	3872	6048	6538	5169	29064	1057	956	1975	3275	3017	3974	1277	3935	457	2040	1485	79710
Burwood (A)	0	7	411	35	969	1543	4170	1780	2928	746	944	730	1542	933	1436	3912	5180	124	752	665	28807
Camden (A)	565	46	2841	416	4154	1863	10360	4988	2667	808	1494	1402	6362	1729	2115	4625	5598	1109	2289	745	56177
Campbelltown (C) - North	44	91	11477	206	3034	2837	3775	2179	3973	148	362	785	982	876	1469	3905	3754	189	1816	872	42771
Campbelltown (C) - South	58	286	1175	113	1365	687	8496	5002	1408	352	831	642	1188	1028	2449	5514	10924	409	1687	703	44317
Canada Bay (A) - Concord	6	15	3032	117	2219	3255	3130	1768	550	703	5749	656	2296	874	319	1599	7483	361	1471	702	36305
Canada Bay (A) - Drummoyne	12	0	311	0	887	553	2405	1539	391	79	380	500	1411	400	523	1440	1860	268	1047	310	14316
Canterbury (C)	31	7	3322	70	3829	2842	5790	3136	2724	410	663	677	1583	1021	2498	3872	7199	331	1847	1307	43157
Cessnock (C)	669	857	2822	253	2549	638	3864	4481	1150	165	260	455	1217	855	1508	2080	2746	378	1396	527	28868
Fairfield (C) - East	49	23	3881	153	2014	1718	6454	4938	1775	217	511	576	1216	1226	2675	5067	6324	370	2011	1120	42318
Fairfield (C) - West	330	60	11518	536	5104	6968	5671	2867	6453	207	724	662	2123	2539	1370	3674	4170	421	2609	1331	59338
Gosford (C) - East	145	30	584	115	2425	603	5402	3604	555	327	715	549	1721	852	898	2776	3559	416	1302	523	27101
Gosford (C) - West	1189	247	5549	517	3572	1552	6556	4203	1666	749	1105	874	2607	1904	4811	4186	12564	751	2662	1244	58506
Hawkesbury (C)	1789	49	4700	346	3825	1010	5159	3310	1568	553	464	577	1462	1090	4133	3828	4729	661	1954	912	42119
Holroyd (C)	60	28	9751	650	3890	4528	5894	2479	6377	228	737	709	1554	888	2225	3490	4758	197	2167	1173	51784

Hornsby (A) - North	343	8	1440	158	2221	1155	2774	1473	1387	166	390	322	1717	574	509	3607	3529	222	974	418	23387
Hornsby (A) - South	47	14	4947	303	2645	1901	9799	4481	1340	714	1589	1091	4375	1666	2525	8805	11715	600	2592	1075	62225
Hunters Hill (A)	0	7	134	20	526	96	527	611	93	55	167	224	688	192	498	1279	2111	33	337	202	7801
Hurstville (C)	46	0	2071	144	2717	2210	4759	2510	1426	233	2275	680	2283	1004	1750	3230	5632	381	1622	841	35816
Kiama (A)	408	5	249	58	773	189	1239	1753	407	60	202	201	561	254	496	692	958	313	375	150	9343
Kogarah (C)	15	23	534	613	1072	328	1485	1922	756	240	2712	517	1434	432	2293	2698	12365	338	784	614	31171
Ku-ring-gai (A)	101	25	1556	132	3046	2045	4296	2833	928	1215	1340	1177	5977	1305	1475	8644	12050	509	1703	1210	51566
Lake Macquarie (C) - East	31	136	1551	173	2549	382	3154	1985	491	64	386	273	861	574	622	2108	3881	219	1136	307	20884
Lake Macquarie (C) - North	63	999	5129	261	3835	1040	7323	4200	2203	426	2405	725	2011	1175	3082	3717	6556	592	2687	753	49183
Lake Macquarie (C) - West	147	922	1685	651	1722	240	2113	1544	851	98	261	261	1102	683	494	2040	4127	239	849	397	20425
Lane Cove (A)	40	0	1988	47	1218	1537	2078	1177	254	754	725	333	3302	1246	517	1463	4142	252	597	570	22242
Leichhardt (A)	140	6	1304	61	2422	1367	4562	2920	850	987	730	796	3568	1773	1722	2894	5360	714	1438	843	34455
Liverpool (C) - East	44	32	9505	564	4014	4658	11207	4342	6992	1239	1568	1407	3716	4756	11546	7366	17882	863	2775	1607	96083
Liverpool (C) - West	1657	69	3306	1383	5196	4390	11515	4281	9749	1175	928	1007	4091	2090	1355	9516	6769	742	2125	1030	72375
Maitland (C)	356	1085	3619	631	3509	813	5457	2927	1597	169	594	770	1896	1285	2171	3571	5473	332	2405	656	39316
Manly (A)	75	15	435	119	1318	506	2031	2749	174	310	758	685	2229	454	780	2089	3047	307	752	493	19327
Marrickville (A)	21	19	3943	72	2913	3224	6015	2912	2190	914	679	643	3140	929	1891	4241	4624	942	2174	915	42402
Mosman (A)	60	18	251	12	917	200	1775	1338	271	216	460	532	1614	306	701	1413	1787	926	569	488	13855
Newcastle (C) - Inner City	95	391	4557	880	3656	1220	4767	5367	5324	1758	4472	1283	9168	2151	6869	3541	6370	664	2453	1024	66009
Newcastle (C) - Outer West	359	314	2900	1990	3138	1103	2853	1986	1216	249	389	353	1060	556	886	6058	3048	347	1302	489	30597
Newcastle (C) - Throsby	101	38	2362	269	2576	923	9376	5020	1596	499	1704	712	3985	1227	2709	3873	14333	755	2113	718	54887
North Sydney (A)	160	635	7043	771	7068	4401	6789	7116	2178	9989	15417	3318	49193	7175	3783	8268	10146	2125	4181	5017	154776
Parramatta (C) - Inner	49	139	7788	2854	5553	4507	11291	5653	4011	1933	17764	2205	10230	4728	31429	6809	27991	1398	4815	2629	153774
Parramatta (C) - North-East	37	8	3517	11	930	824	1092	863	357	158	551	308	1134	470	469	1199	2488	136	694	356	15602
Parramatta (C) - North-West	4	19	1660	0	1008	679	2641	787	741	66	200	83	627	233	170	979	2822	92	462	259	13531
Parramatta (C) - South	3	13	1587	26	814	789	1171	553	2034	80	138	119	572	262	950	2147	982	487	363	269	13357
Penrith (C) - East	592	53	7151	1913	5500	6848	6669	4938	9712	1500	1764	2451	7644	4292	3423	8146	10646	1331	4075	1323	89971
Penrith (C) - West	101	237	4169	711	3405	1527	10471	4863	2662	396	915	862	2829	1388	5488	4081	7704	1573	2342	1017	56740
Pittwater (A)	61	15	2558	71	3330	2095	4025	2948	515	475	784	793	3081	892	929	2496	4704	805	1599	899	33074
Port Stephens (A)	522	221	6094	254	2850	783	5789	4292	1734	278	338	931	1733	1020	6787	2548	3748	727	1846	848	43342

Randwick (C)	68	4	2018	226	4213	1206	3633	5104	3565	602	758	845	3689	2166	4837	15490	18578	1364	1978	1488	71831
Rockdale (C)	33	21	1959	106	2584	792	8698	4919	13899	1789	1379	1783	4204	3556	11770	3491	5337	1348	1798	1304	70769
Ryde (C)	135	128	10811	1077	7721	16529	11119	5460	1238	12780	1321	1805	19422	3626	4704	12027	18670	598	4200	3306	13667 6
Shellharbour (C)	114	235	783	173	1927	633	4628	2597	986	64	423	376	748	570	1805	2829	3975	304	1153	387	24712
Shoalhaven (C) - Pt A	227	40	2456	279	1218	278	2928	1355	831	273	278	310	977	633	3640	1880	4157	284	807	413	23263
Shoalhaven (C) - Pt B	868	42	847	199	1758	193	2467	2915	455	137	182	483	795	620	460	1727	2227	465	609	364	17813
Strathfield (A)	98	40	4073	911	2905	7393	4452	1696	7973	410	1519	648	1552	935	856	3072	1616	370	1083	1030	42633
Sutherland Shire (A) - East	60	106	6342	401	5309	2547	12261	5522	1418	380	1399	1040	3546	1048	1535	4527	10497	676	2803	1113	62529
Sutherland Shire (A) - West	26	8	1671	223	3395	962	5563	3683	1250	139	903	517	4494	948	4507	5731	6039	421	2320	549	43346
Sydney (C) - East	28	73	1164	117	2360	1898	5008	7943	826	5870	1540	1290	12722	3329	11287	5181	14176	3040	2659	2044	82557
Sydney (C) - Inner	108	1705	3054	2879	10838	4221	22476	31384	7789	23338	14260 8	10747	10095 9	23212	30273	11465	12459	7549	8180	9651	46489 7
Sydney (C) - South	15	31	4848	627	4044	8840	10586	5128	7534	6848	1931	2418	11068	3466	5836	3761	6508	3133	4506	2311	93438
Sydney (C) - West	4	25	759	225	4129	2129	4685	4558	3356	9106	2789	1159	12070	2376	4469	17833	10940	6387	1897	1937	90831
Warringah (A)	144	71	6350	573	5548	9004	13764	5426	1955	1468	1774	1507	6529	2098	2627	8622	12666	1074	3843	1677	86719
Willoughby (C)	104	195	4194	692	6532	3661	9902	3717	1795	7923	2868	1829	10013	2776	2832	4215	17188	799	3257	1990	86482
Waverley (A)	33	59	613	111	1887	861	6364	3694	426	703	1090	589	3351	1523	1615	3500	5155	1106	1414	987	35080
Wingecarribee (A)	1184	117	2365	191	1718	413	2952	2187	800	309	318	591	1299	555	715	1938	3031	338	886	504	22410
Wollondilly (A)	734	1951	2104	351	2559	554	1897	1215	1010	133	186	229	1011	417	749	1598	1542	262	725	401	19628
Wollongong (C) - Inner	72	725	3795	308	3022	1440	6041	5415	2744	606	4478	1316	3947	2226	6683	9244	11244	906	2578	1160	67950
Wollongong (C) Bal	237	2148	6968	827	3775	971	6046	3170	2737	165	677	561	1630	1585	1382	3337	6067	576	2370	741	45971
Woollahra (A)	69	41	468	59	2197	778	4150	2893	174	506	1109	1149	2849	901	2174	3602	3769	836	1305	929	29958
Wyong (A) - North-East	200	249	1190	937	2212	1736	4687	2815	2146	188	525	522	1879	768	891	2715	5285	663	1760	633	32003
Wyong (A) - South and West	179	72	5129	390	3063	1155	6227	4627	1553	370	986	715	1687	1394	3289	3314	5265	489	1647	733	42284
No fixed address	927	506	4909	1398	70452	3964	6492	2556	14018	2786	1503	905	7742	18274	4031	7027	11675	3346	7008	4815	17433 4
Total GMA	18620	16904	30816 9	42384	32647 6	20245 0	49232 3	30152 4	25179 7	11965 8	27128 6	82062	42743 1	16178 0	27315 2	36275 4	56004 7	71225	16718 1	94863	45520 85

Source: SGS modelling. 2015

TABLE 18 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2050

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	9	0	414	32	1115	473	2947	1635	389	115	304	1285	1044	468	1774	1860	4245	154	589	407	19261
Auburn (C)	54	23	10895	2345	6442	8710	9416	3850	6107	1914	8093	1272	5834	2944	7657	4797	8980	2551	3862	2071	97818
Bankstown (C) - North-East	10	12	8444	279	2028	1806	7614	2283	4707	1816	1024	767	1206	1033	2592	4432	7710	336	1930	1175	51203
Bankstown (C) - North-West	19	0	6281	1152	2126	2011	3033	1147	3221	294	456	297	1046	535	1698	2890	3192	271	1069	745	31484
Bankstown (C) - South	31	48	7227	170	3327	2695	2706	1704	1447	93	322	282	935	619	472	3266	2207	207	1281	681	29721
The Hills Shire (A) - Central	33	24	7378	404	6780	5948	22045	5415	1330	2386	5332	2313	11517	3649	3983	5686	11394	2049	3983	1852	103502
The Hills Shire (A) - North	1290	422	1735	656	4442	2527	10558	6133	2021	1373	1591	1655	6921	2211	1580	5146	5390	1401	2514	1365	60932
The Hills Shire (A) - South	124	12	846	17	1413	720	2204	632	372	135	304	213	4349	516	351	4639	2128	141	1347	362	20827
Blacktown (C) - North	346	386	4292	1010	4846	3818	8593	5080	3456	788	1388	1657	5454	1833	1968	8616	5198	1196	2986	1388	64300
Blacktown (C) - South-East	45	123	15498	2676	8528	8783	12978	5231	10549	566	1321	1146	1935	2440	4372	5804	10728	495	4994	2106	100318
Blacktown (C) - South-West	148	50	6050	1359	3799	5299	9990	4326	11119	126	415	967	2333	2028	2382	5434	6082	378	2351	1089	65724
Blue Mountains (C)	318	7	786	201	1720	481	4218	3808	1072	328	467	479	2088	905	1835	3647	6019	678	1326	647	31028
Botany Bay (C)	12	37	5241	460	4010	6279	6800	5363	30224	1095	993	2047	3410	3135	4136	1332	4108	475	2118	1544	82818
Burwood (A)	0	7	425	35	1004	1602	4337	1846	3049	773	980	755	1605	971	1495	4083	5407	129	780	691	29975
Camden (A)	591	48	2906	430	4301	1934	10775	5175	2774	838	1551	1453	6627	1797	2201	4828	5841	1153	2376	775	58373
Campbelltown (C) - North	46	95	11820	213	3142	2945	3926	2260	4132	151	376	813	1024	910	1528	4076	3917	196	1884	906	44363
Campbelltown (C) - South	60	298	1209	116	1414	713	8836	5189	1465	365	863	665	1238	1068	2549	5755	11400	425	1751	731	46112
Canada Bay (A) - Concord	7	15	3141	121	2298	3378	3255	1836	571	728	5969	680	2391	908	331	1668	7809	376	1527	729	37738
Canada Bay (A) - Drummoyne	13	0	320	0	919	576	2500	1597	407	82	394	518	1470	416	544	1503	1941	278	1088	323	14888
Canterbury (C)	32	7	3415	70	3965	2951	6021	3254	2832	423	688	700	1649	1061	2600	4041	7513	344	1918	1359	44843
Cessnock (C)	700	892	2908	261	2640	662	4018	4648	1195	171	270	472	1268	888	1569	2171	2865	394	1448	549	29989
Fairfield (C) - East	59	24	3975	159	2087	1783	6712	5124	1847	224	530	598	1266	1274	2784	5288	6599	384	2087	1164	43969
Fairfield (C) - West	346	62	11835	553	5286	7235	5898	2976	6709	213	752	687	2212	2637	1427	3834	4352	438	2708	1384	61541
Gosford (C) - East	151	31	600	119	2512	626	5618	3739	577	338	743	569	1792	884	935	2898	3715	432	1351	543	28173
Gosford (C) - West	1245	256	5718	532	3699	1611	6819	4361	1733	775	1147	905	2714	1978	5008	4369	13112	781	2763	1294	60820
Hawkesbury (C)	1872	52	4829	358	3961	1049	5365	3433	1631	574	481	597	1523	1134	4303	3995	4936	687	2028	948	43755
Holroyd (C)	63	30	10026	671	4030	4702	6130	2573	6631	236	766	736	1618	923	2315	3643	4965	207	2249	1219	53732

Hornsby (A) - North	359	9	1485	163	2300	1200	2884	1529	1443	172	405	332	1788	596	529	3765	3682	231	1011	435	24319
Hornsby (A) - South	49	15	5113	313	2739	1975	10191	4648	1392	739	1650	1132	4557	1731	2628	9190	12226	624	2691	1117	64720
Hunters Hill (A)	0	7	139	20	546	100	547	633	97	57	173	232	717	201	518	1335	2203	34	348	210	8116
Hurstville (C)	46	0	2125	148	2814	2295	4950	2604	1483	241	2362	705	2378	1043	1822	3371	5877	396	1684	875	37220
Kiama (A)	426	5	257	58	800	198	1288	1819	423	63	210	209	584	263	517	721	1000	325	389	156	9711
Kogarah (C)	15	23	550	634	1110	341	1544	1994	786	247	2815	537	1493	448	2387	2817	12904	352	813	638	32447
Ku-ring-gai (A)	106	26	1607	136	3155	2123	4468	2940	965	1258	1390	1222	6225	1355	1534	9021	12576	528	1767	1258	53662
Lake Macquarie (C) - East	32	142	1595	181	2641	397	3280	2059	510	80	401	283	896	596	648	2199	4050	228	1179	319	21718
Lake Macquarie (C) - North	66	1039	5287	269	3973	1080	7616	4358	2295	439	2497	751	2094	1221	3207	3879	6842	616	2791	784	51103
Lake Macquarie (C) - West	153	959	1739	674	1784	250	2197	1602	884	98	271	272	1147	710	514	2129	4307	248	881	412	21229
Lane Cove (A)	43	0	2042	49	1261	1596	2161	1221	263	782	753	346	3439	1296	538	1526	4323	262	621	593	23116
Leichhardt (A)	144	6	1341	61	2508	1419	4745	3030	884	1022	758	825	3715	1843	1792	3021	5593	742	1492	877	35819
Liverpool (C) - East	46	33	9774	583	4157	4836	11654	4505	7271	1284	1628	1459	3870	4942	12019	7688	18661	898	2880	1670	99860
Liverpool (C) - West	1736	71	3398	1428	5381	4558	11975	4443	10137	1218	964	1044	4259	2172	1411	9933	7064	772	2206	1071	75241
Maitland (C)	372	1129	3724	652	3633	844	5675	3038	1660	175	617	798	1975	1336	2260	3726	5711	345	2496	682	40850
Manly (A)	81	15	448	125	1364	524	2113	2852	181	322	787	710	2323	471	813	2181	3180	319	781	513	20103
Marrickville (A)	22	19	4045	72	3018	3348	6257	3021	2277	946	705	666	3270	966	1969	4426	4825	979	2257	951	44038
Mosman (A)	64	18	259	12	951	208	1845	1387	290	223	477	553	1681	318	730	1475	1865	962	589	507	14416
Newcastle (C) - Inner City	100	407	4708	909	3786	1267	4957	5569	5535	1822	4642	1330	9548	2235	7149	3697	6648	690	2546	1064	68610
Newcastle (C) - Outer West	376	327	2975	2055	3252	1146	2967	2061	1264	262	404	366	1104	577	923	6323	3182	361	1352	507	31784
Newcastle (C) - Throsby	110	39	2431	277	2668	958	9751	5208	1658	519	1769	738	4149	1275	2820	4042	14958	785	2194	746	57096
North Sydney (A)	167	661	7256	804	7320	4570	7060	7383	2265	10348	16006	3435	51229	7456	3939	8630	10588	2212	4339	5215	160882
Parramatta (C) - Inner	51	145	8044	2948	5750	4680	11743	5864	4171	2003	18442	2286	10653	4913	32715	7106	29212	1453	4998	2733	159910
Parramatta (C) - North-East	37	8	3631	11	963	856	1136	895	372	163	572	320	1181	488	489	1251	2596	142	720	371	16200
Parramatta (C) - North-West	4	19	1709	0	1045	704	2745	816	771	69	209	87	653	242	176	1022	2944	104	479	269	14063
Parramatta (C) - South	3	13	1638	26	843	820	1218	574	2114	83	143	123	595	272	989	2240	1024	507	376	280	13881
Penrith (C) - East	619	56	7358	1978	5695	7109	6936	5123	10100	1556	1832	2539	7961	4461	3562	8502	11110	1383	4230	1376	93487
Penrith (C) - West	105	246	4292	735	3527	1586	10889	5045	2768	411	950	893	2945	1443	5713	4259	8040	1636	2430	1057	58970
Pittwater (A)	64	15	2630	73	3449	2175	4186	3059	536	491	813	823	3209	927	967	2606	4909	837	1660	934	34362
Port Stephens (A)	546	230	6281	263	2951	812	6021	4452	1802	288	352	966	1805	1060	7064	2659	3911	757	1915	881	45016

Randwick (C)	71	4	2076	234	4364	1253	3778	5296	3706	624	787	877	3842	2251	5034	16166	19388	1419	2053	1546	74769
Rockdale (C)	34	21	2015	110	2675	821	9047	5104	14451	1851	1431	1849	4378	3696	12253	3644	5571	1403	1867	1356	73578
Ryde (C)	141	133	11153	1111	7996	17164	11564	5664	1286	13239	1372	1872	20225	3767	4897	12551	19484	621	4360	3437	14203 8
Shellharbour (C)	120	244	806	178	1995	658	4813	2695	1026	67	439	391	779	591	1879	2953	4148	316	1197	402	25698
Shoalhaven (C) - Pt A	237	41	2531	288	1261	288	3046	1406	865	283	289	321	1018	658	3789	1962	4339	296	837	429	24184
Shoalhaven (C) - Pt B	910	43	869	207	1821	201	2566	3024	474	142	188	501	828	644	479	1802	2324	484	632	378	18515
Strathfield (A)	102	42	4208	942	3008	7676	4629	1761	8291	424	1578	672	1617	972	891	3207	1687	384	1124	1071	44285
Sutherland Shire (A) - East	63	109	6517	414	5498	2644	12752	5729	1476	394	1453	1078	3693	1088	1598	4724	10954	703	2910	1157	64955
Sutherland Shire (A) - West	27	8	1717	231	3517	999	5785	3821	1300	144	937	535	4680	984	4692	5981	6302	437	2408	571	45077
Sydney (C) - East	29	76	1192	117	2444	1969	5209	8241	859	6082	1599	1338	13249	3459	11748	5407	14794	3162	2760	2126	85862
Sydney (C) - Inner	113	1774	3155	2974	11227	4382	23377	32561	8099	24179	14804 7	11143	10513 7	24120	31512	11967	13002	7850	8490	10032	48314 0
Sydney (C) - South	16	32	4970	647	4188	9179	11010	5321	7834	7096	2005	2508	11526	3601	6073	3925	6793	3257	4678	2402	97061
Sydney (C) - West	4	27	782	231	4276	2211	4872	4728	3489	9433	2897	1202	12569	2468	4651	18611	11417	6642	1970	2013	94493
Warringah (A)	150	74	6531	592	5746	9350	14315	5629	2033	1520	1841	1562	6799	2180	2734	8998	13218	1116	3989	1744	90121
Willoughby (C)	108	204	4313	715	6765	3802	10299	3856	1866	8204	2977	1895	10427	2885	2948	4399	17937	831	3381	2069	89879
Waverley (A)	35	61	630	115	1954	894	6618	3832	443	728	1132	610	3489	1582	1681	3653	5379	1150	1468	1026	36481
Wingecarribee (A)	1240	122	2431	197	1780	429	3070	2270	832	320	330	612	1353	576	744	2022	3163	352	919	524	23286
Wollondilly (A)	767	2030	2170	362	2650	575	1973	1260	1050	137	193	238	1052	433	780	1669	1609	273	753	417	20391
Wollongong (C) - Inner	76	755	3906	317	3129	1495	6284	5618	2855	628	4649	1364	4110	2314	6957	9648	11734	943	2676	1206	70664
Wollongong (C) Bal	248	2235	7204	857	3910	1009	6288	3289	2846	170	702	582	1698	1646	1438	3483	6332	599	2461	771	47769
Woollahra (A)	72	43	481	59	2275	807	4317	3001	181	524	1151	1192	2967	935	2263	3760	3933	869	1356	966	31152
Wyong (A) - North-East	211	259	1225	968	2291	1803	4876	2920	2232	196	546	541	1957	799	928	2833	5516	689	1827	657	33274
Wyong (A) - South and West	187	75	5300	401	3174	1199	6476	4801	1615	382	1023	741	1757	1448	3424	3458	5495	510	1709	762	43937
No fixed address	970	526	5053	1443	72968	4116	6752	2652	14576	2887	1560	938	8063	18988	4196	7334	12184	3480	7273	5005	18096 6
Total GMA	19499	17581	31733 0	43771	33813 1	21021 4	51203 0	31283 4	26184 9	12396 0	28164 2	85072	44512 1	16810 6	28431 9	37859 6	58446 8	74071	17352 1	98612	47307 27

Source: SGS modelling. 2015

TABLE 19 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2055

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	9	0	428	32	1156	492	3065	1696	406	120	315	1332	1087	486	1847	1942	4431	160	612	423	20038
Auburn (C)	57	24	11217	2419	6671	9044	9793	3994	6351	1984	8402	1318	6076	3059	7969	5008	9371	2652	4008	2153	101571
Bankstown (C) - North-East	10	12	8725	289	2099	1876	7919	2368	4894	1882	1063	795	1256	1073	2698	4626	8047	350	2003	1221	53205
Bankstown (C) - North-West	19	0	6458	1189	2203	2088	3155	1190	3350	294	473	308	1089	556	1768	3015	3332	281	1110	775	32653
Bankstown (C) - South	32	50	7416	175	3446	2798	2814	1769	1505	93	335	292	973	643	491	3409	2304	215	1328	707	30796
The Hills Shire (A) - Central	35	25	7600	416	7022	6176	22928	5618	1384	2472	5536	2398	11994	3793	4147	5934	11890	2130	4133	1925	107556
The Hills Shire (A) - North	1349	437	1777	678	4600	2626	10982	6365	2100	1422	1653	1716	7207	2298	1644	5371	5624	1457	2610	1418	63331
The Hills Shire (A) - South	130	12	874	18	1464	748	2292	656	386	142	315	221	4529	537	366	4841	2222	147	1397	377	21671
Blacktown (C) - North	362	403	4417	1042	5018	3965	8938	5270	3594	816	1441	1718	5679	1904	2049	8992	5426	1244	3100	1443	66822
Blacktown (C) - South-East	48	128	15992	2766	8832	9121	13498	5428	10970	586	1372	1187	2015	2535	4550	6058	11195	514	5183	2190	104168
Blacktown (C) - South-West	156	52	6227	1404	3936	5502	10390	4488	11562	130	430	1002	2430	2107	2480	5671	6347	393	2440	1133	68279
Blue Mountains (C)	333	7	808	208	1781	500	4387	3950	1115	341	485	497	2174	940	1910	3806	6282	705	1376	672	32276
Botany Bay (C)	12	37	5410	475	4153	6519	7072	5565	31429	1134	1031	2123	3551	3257	4304	1388	4288	493	2199	1605	86047
Burwood (A)	0	7	440	35	1039	1664	4510	1916	3176	801	1017	782	1672	1009	1556	4261	5644	134	809	718	31191
Camden (A)	617	50	2973	444	4454	2007	11207	5370	2885	869	1610	1506	6902	1868	2291	5039	6095	1200	2466	806	60656
Campbelltown (C) - North	49	98	12173	221	3255	3057	4084	2345	4297	155	391	843	1067	946	1591	4254	4087	205	1956	942	46014
Campbelltown (C) - South	62	310	1245	119	1465	741	9190	5384	1523	379	896	690	1290	1109	2654	6007	11897	442	1817	761	47981
Canada Bay (A) - Concord	7	15	3254	126	2379	3506	3384	1905	594	753	6197	705	2490	943	344	1740	8150	392	1586	757	39228
Canada Bay (A) - Drummoyne	14	0	329	0	952	599	2599	1658	423	85	409	536	1531	434	567	1569	2025	288	1130	336	15482
Canterbury (C)	34	7	3511	70	4107	3065	6261	3376	2944	437	714	724	1717	1102	2707	4217	7840	358	1992	1412	46595
Cessnock (C)	733	928	2996	269	2734	687	4179	4822	1243	177	279	490	1321	923	1633	2266	2990	410	1503	571	31153
Fairfield (C) - East	70	25	4072	165	2161	1851	6981	5316	1921	232	551	619	1319	1323	2897	5519	6887	400	2166	1210	45686
Fairfield (C) - West	362	64	12160	571	5474	7512	6134	3088	6976	219	780	712	2304	2738	1485	4000	4542	455	2811	1439	63828
Gosford (C) - East	158	33	617	122	2601	649	5842	3881	599	350	771	589	1866	918	973	3025	3877	449	1402	565	29287
Gosford (C) - West	1304	267	5892	548	3830	1672	7092	4525	1802	803	1190	938	2825	2056	5213	4559	13684	813	2869	1345	63225
Hawkesbury (C)	1959	54	4961	370	4102	1089	5580	3561	1697	595	499	619	1586	1179	4479	4169	5152	714	2105	986	45456

Holroyd (C)	67	31	10308	693	4175	4883	6376	2669	6895	243	796	764	1686	959	2409	3802	5182	217	2334	1267	55755
Hornsby (A) - North	375	9	1532	169	2382	1246	3000	1586	1502	179	420	343	1863	619	549	3929	3843	240	1049	452	25287
Hornsby (A) - South	52	15	5285	324	2837	2051	10599	4821	1447	765	1713	1175	4745	1799	2734	9592	12759	648	2793	1161	67315
Hunters Hill (A)	0	7	144	20	566	103	568	656	100	59	180	240	748	209	539	1393	2299	35	361	218	8444
Hurstville (C)	46	0	2180	153	2914	2382	5149	2702	1543	250	2453	730	2476	1084	1896	3518	6133	412	1748	910	38681
Kiama (A)	445	5	266	58	828	207	1339	1887	440	66	217	217	609	273	539	753	1044	337	404	162	10095
Kogarah (C)	15	23	566	656	1150	354	1606	2069	817	255	2923	557	1554	465	2485	2941	13467	366	844	663	33776
Ku-ring-gai (A)	111	27	1660	140	3268	2204	4646	3052	1003	1303	1443	1269	6483	1407	1596	9415	13124	549	1834	1308	55843
Lake Macquarie (C) - East	34	148	1640	190	2736	412	3411	2135	529	100	417	294	934	620	674	2295	4227	238	1224	332	22588
Lake Macquarie (C) - North	69	1081	5448	278	4116	1121	7922	4522	2389	452	2593	779	2180	1268	3338	4048	7140	641	2898	815	53099
Lake Macquarie (C) - West	160	997	1794	697	1848	259	2285	1663	920	98	281	283	1194	738	536	2222	4494	257	913	427	22066
Lane Cove (A)	46	0	2098	51	1306	1658	2247	1267	274	811	781	360	3581	1347	560	1593	4512	273	645	616	24024
Leichhardt (A)	148	6	1379	61	2598	1473	4936	3143	919	1059	787	857	3869	1915	1865	3153	5837	771	1548	911	37237
Liverpool (C) - East	49	35	10051	603	4306	5021	12120	4674	7561	1331	1690	1513	4030	5134	12511	8023	19475	934	2989	1736	103788
Liverpool (C) - West	1819	74	3493	1473	5572	4733	12454	4611	10541	1263	1001	1083	4435	2258	1468	10369	7371	804	2289	1113	78222
Maitland (C)	388	1175	3833	675	3762	877	5902	3153	1726	181	641	827	2057	1388	2352	3889	5960	359	2591	709	42444
Manly (A)	86	16	461	131	1413	543	2198	2959	189	333	817	736	2419	489	847	2277	3319	332	811	533	20911
Marrickville (A)	24	19	4148	72	3126	3477	6508	3133	2368	980	731	691	3406	1005	2050	4618	5034	1018	2342	988	45737
Mosman (A)	68	18	267	12	986	216	1918	1438	310	232	495	575	1751	331	760	1540	1947	1000	611	526	15000
Newcastle (C) - Inner City	105	424	4864	939	3922	1315	5155	5778	5755	1890	4819	1379	9944	2322	7441	3859	6938	717	2643	1107	71314
Newcastle (C) - Outer West	394	341	3052	2122	3370	1190	3086	2139	1314	276	420	379	1150	600	961	6599	3321	376	1403	527	33019
Newcastle (C) - Throsby	119	41	2503	286	2763	994	10142	5403	1723	541	1837	764	4321	1324	2935	4219	15611	816	2278	775	59395
North Sydney (A)	175	689	7476	839	7581	4745	7341	7660	2356	10720	16618	3555	53348	7748	4100	9007	11050	2301	4502	5421	167231
Parramatta (C) - Inner	53	151	8309	3046	5954	4859	12214	6083	4338	2075	19145	2370	11093	5105	34054	7415	30486	1512	5188	2841	166292
Parramatta (C) - North-East	37	8	3750	11	996	888	1181	928	387	169	594	331	1230	508	509	1305	2709	148	746	386	16822
Parramatta (C) - North-West	4	19	1759	0	1083	730	2852	847	801	71	218	91	680	251	182	1066	3072	117	497	279	14618
Parramatta (C) - South	3	13	1691	26	873	852	1268	596	2198	86	149	127	620	283	1029	2338	1068	527	390	292	14426
Penrith (C) - East	647	58	7572	2046	5898	7381	7214	5314	10504	1614	1902	2632	8290	4636	3707	8873	11594	1436	4392	1431	97142
Penrith (C) - West	110	256	4418	760	3653	1647	11325	5234	2877	427	986	926	3066	1500	5947	4444	8390	1701	2523	1099	61289
Pittwater (A)	67	16	2704	74	3573	2257	4353	3174	557	509	844	853	3342	963	1006	2721	5122	871	1723	971	35701
Port Stephens	572	239	6473	272	3057	842	6263	4618	1873	299	365	1002	1880	1102	7352	2775	4081	787	1986	915	46755

(A)																					
Randwick (C)	75	5	2137	242	4521	1302	3930	5495	3854	647	817	909	4001	2339	5240	16871	20233	1475	2130	1607	77829
Rockdale (C)	35	22	2072	115	2770	852	9409	5297	15025	1916	1486	1918	4559	3841	12756	3803	5815	1460	1938	1410	76498
Ryde (C)	148	137	11506	1147	8282	17823	12027	5876	1335	13715	1425	1941	21062	3914	5097	13098	20333	646	4526	3573	14761 1
Shellharbour (C)	126	254	830	184	2067	684	5006	2796	1067	70	456	405	810	614	1957	3082	4329	328	1243	417	26724
Shoalhaven (C) - Pt A	248	43	2609	297	1306	298	3168	1459	900	293	300	332	1060	684	3944	2048	4529	308	869	445	25141
Shoalhaven (C) - Pt B	953	45	891	214	1885	208	2669	3137	493	147	195	520	863	668	499	1880	2425	504	655	393	19244
Strathfield (A)	106	43	4347	974	3116	7971	4814	1828	8621	438	1639	697	1684	1010	927	3348	1760	400	1166	1114	46002
Sutherland Shire (A) - East	67	113	6697	429	5694	2745	13263	5944	1536	408	1508	1117	3846	1130	1663	4931	11431	731	3020	1202	67475
Sutherland Shire (A) - West	29	8	1763	240	3643	1037	6017	3964	1353	150	973	555	4874	1022	4885	6242	6576	454	2498	594	46876
Sydney (C) - East	30	79	1221	117	2532	2044	5418	8551	894	6300	1660	1388	13798	3594	12228	5643	15439	3289	2865	2210	89300
Sydney (C) - Inner	118	1846	3258	3073	11629	4550	24313	33783	8421	25050	15369 4	11552	10948 8	25063	32800	12491	13569	8162	8813	10429	50210 1
Sydney (C) - South	17	34	5095	669	4338	9532	11451	5520	8146	7353	2081	2600	12003	3741	6320	4097	7090	3385	4856	2497	10082 6
Sydney (C) - West	4	28	806	238	4429	2296	5067	4905	3629	9773	3008	1247	13089	2564	4840	19423	11915	6906	2046	2092	98304
Warringah (A)	157	77	6716	612	5952	9710	14888	5840	2113	1574	1911	1618	7080	2265	2846	9391	13794	1161	4140	1813	93657
Willoughby (C)	113	213	4435	739	7007	3948	10712	4001	1940	8495	3091	1964	10858	2997	3068	4591	18718	864	3509	2150	93411
Waverley (A)	36	64	648	119	2024	928	6884	3976	460	754	1175	632	3633	1644	1750	3812	5614	1195	1523	1066	37939
Wingecarribee (A)	1299	127	2498	203	1843	445	3193	2355	865	332	342	635	1409	598	776	2111	3300	365	954	545	24196
Wollondilly (A)	802	2112	2237	374	2744	597	2052	1308	1091	141	200	247	1095	450	813	1742	1679	284	782	434	21184
Wollongong (C) - Inner	79	785	4020	327	3241	1551	6536	5830	2971	651	4826	1414	4281	2404	7243	10069	12246	981	2778	1253	73487
Wollongong (C) Bal	260	2325	7449	887	4050	1047	6539	3412	2960	176	729	604	1768	1711	1496	3636	6608	624	2555	801	49637
Woollahra (A)	75	45	495	59	2356	838	4491	3113	189	542	1195	1236	3090	971	2356	3924	4105	903	1408	1004	32395
Wyong (A) - North-East	223	269	1261	999	2372	1874	5072	3029	2322	204	567	560	2038	831	965	2957	5757	716	1897	683	34595
Wyong (A) - South and West	196	78	5477	414	3288	1245	6735	4982	1680	395	1061	768	1829	1505	3565	3609	5734	531	1773	792	45655
No fixed address	1015	547	5202	1490	75574	4274	7023	2751	15157	2991	1620	971	8396	19731	4369	7654	12715	3619	7549	5203	18785 1
Total GMA	20422	18287	32676 5	45205	35020 1	21827 6	53252 5	32456 8	27230 3	12842 2	29239 3	88193	46354 3	17467 9	29594 3	39512 9	60995 3	77031	18010 2	10251 0	49164 49

Source: SGS modelling. 2015

TABLE 20 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2060

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	9	0	442	32	1198	512	3188	1759	423	125	326	1381	1131	504	1922	2028	4625	166	635	440	20846
Auburn (C)	60	25	11549	2494	6908	9392	10186	4143	6604	2056	8723	1367	6328	3179	8295	5227	9780	2757	4160	2238	105468
Bankstown (C) - North-East	10	12	9015	299	2173	1949	8236	2456	5089	1950	1104	824	1308	1114	2808	4828	8399	364	2078	1270	55286
Bankstown (C) - North-West	20	0	6641	1226	2282	2167	3281	1235	3485	294	491	319	1134	579	1840	3146	3477	292	1152	806	33866
Bankstown (C) - South	34	52	7611	179	3569	2905	2926	1837	1564	93	348	303	1013	668	511	3558	2404	224	1378	735	31912
The Hills Shire (A) - Central	37	26	7829	428	7272	6413	23846	5829	1441	2561	5748	2485	12491	3943	4317	6192	12409	2213	4289	2000	111770
The Hills Shire (A) - North	1411	453	1819	701	4764	2728	11422	6605	2183	1472	1717	1778	7505	2387	1711	5606	5868	1514	2709	1472	65826
The Hills Shire (A) - South	136	13	902	18	1516	777	2383	680	400	149	327	229	4716	559	381	5051	2320	153	1449	393	22550
Blacktown (C) - North	379	421	4545	1076	5196	4117	9296	5467	3738	845	1497	1781	5915	1978	2134	9384	5663	1294	3218	1499	69444
Blacktown (C) - South-East	51	133	16501	2858	9148	9471	14040	5631	11408	606	1425	1230	2100	2634	4736	6322	11682	535	5379	2277	108168
Blacktown (C) - South-West	164	54	6410	1450	4078	5713	10805	4656	12022	134	446	1039	2530	2190	2581	5918	6623	409	2532	1179	70935
Blue Mountains (C)	348	7	831	214	1845	519	4562	4097	1161	354	503	516	2264	977	1988	3972	6556	733	1429	699	33574
Botany Bay (C)	13	37	5584	491	4301	6769	7355	5774	32683	1175	1071	2201	3698	3384	4479	1447	4477	513	2283	1669	89404
Burwood (A)	0	8	455	35	1076	1728	4691	1988	3307	829	1056	809	1741	1050	1620	4447	5890	139	840	746	32456
Camden (A)	645	52	3041	458	4613	2084	11655	5571	3000	900	1672	1561	7189	1941	2384	5259	6361	1248	2559	838	63030
Campbelltown (C) - North	52	102	12537	230	3371	3174	4247	2433	4468	159	406	873	1112	982	1655	4440	4264	213	2029	979	47728
Campbelltown (C) - South	64	323	1281	122	1517	770	9558	5586	1585	393	930	715	1344	1152	2763	6269	12416	459	1886	791	49925
Canada Bay (A) - Concord	8	15	3371	131	2464	3639	3519	1978	617	780	6434	731	2593	980	357	1814	8506	408	1646	787	40777
Canada Bay (A) - Drummoyne	15	0	338	0	986	623	2701	1721	441	87	425	556	1594	452	590	1637	2113	299	1174	350	16101
Canterbury (C)	35	8	3610	70	4253	3182	6511	3503	3061	452	741	749	1788	1145	2818	4401	8182	372	2069	1468	48416
Cessnock (C)	768	965	3086	277	2833	713	4346	5002	1292	184	289	508	1377	958	1699	2365	3121	426	1560	593	32363
Fairfield (C) - East	85	26	4170	172	2238	1922	7261	5516	1998	240	572	642	1374	1375	3015	5760	7187	415	2249	1258	47474
Fairfield (C) - West	379	67	12495	589	5668	7801	6379	3204	7254	226	810	739	2400	2844	1546	4174	4740	473	2917	1496	66201
Gosford (C) - East	165	34	634	126	2693	673	6076	4027	622	363	801	610	1943	953	1013	3157	4046	467	1455	587	30446
Gosford (C) - West	1365	278	6071	564	3966	1736	7377	4695	1874	831	1235	971	2941	2136	5426	4757	14281	845	2978	1399	65727
Hawkesbury (C)	2050	56	5097	383	4249	1131	5803	3693	1765	618	518	641	1651	1227	4663	4350	5377	742	2185	1025	47224

Holroyd (C)	71	32	10598	715	4325	5070	6632	2769	7169	252	827	793	1756	997	2506	3968	5407	228	2422	1317	57855
Hornsby (A) - North	393	10	1580	174	2467	1294	3119	1646	1563	185	436	355	1940	643	570	4101	4011	250	1088	470	26295
Hornsby (A) - South	54	16	5463	335	2937	2131	11024	5000	1503	791	1779	1220	4942	1869	2845	10012	13315	674	2898	1207	70016
Hunters Hill (A)	0	7	149	20	586	107	590	679	104	61	187	248	779	218	560	1454	2399	37	373	227	8786
Hurstville (C)	46	0	2236	157	3018	2474	5355	2804	1605	259	2547	757	2578	1126	1974	3672	6401	428	1814	947	40200
Kiama (A)	466	5	275	58	857	216	1393	1958	457	69	225	225	634	283	562	785	1089	349	419	168	10493
Kogarah (C)	15	23	583	679	1192	368	1670	2146	850	263	3035	578	1618	483	2586	3070	14054	382	876	689	35159
Ku-ring-gai (A)	116	28	1715	145	3385	2289	4831	3167	1042	1350	1498	1317	6752	1462	1660	9826	13696	571	1904	1359	58114
Lake Macquarie (C) - East	35	154	1687	200	2834	428	3547	2214	549	125	433	305	973	644	701	2394	4411	248	1271	345	23497
Lake Macquarie (C) - North	72	1125	5615	287	4263	1165	8239	4692	2488	466	2693	807	2269	1318	3474	4225	7452	667	3009	848	55173
Lake Macquarie (C) - West	167	1037	1851	720	1915	269	2376	1726	956	98	292	294	1243	767	558	2319	4690	267	947	443	22936
Lane Cove (A)	50	0	2155	52	1352	1721	2337	1314	284	842	810	373	3729	1401	583	1662	4709	284	670	640	24969
Leichhardt (A)	152	6	1419	61	2691	1529	5135	3261	956	1097	817	889	4028	1991	1941	3291	6092	802	1606	948	38712
Liverpool (C) - East	51	36	10335	624	4460	5213	12605	4850	7862	1380	1755	1568	4198	5335	13023	8373	20325	972	3103	1805	107871
Liverpool (C) - West	1905	76	3591	1521	5769	4915	12952	4785	10961	1309	1039	1123	4617	2347	1528	10823	7692	837	2376	1157	81322
Maitland (C)	406	1223	3945	698	3895	910	6138	3272	1795	187	665	857	2143	1442	2447	4059	6220	373	2689	737	44101
Manly (A)	92	16	475	138	1463	563	2286	3070	197	346	849	762	2520	508	882	2377	3464	346	843	554	21752
Marrickville (A)	25	19	4255	72	3238	3611	6770	3250	2463	1015	758	717	3547	1045	2135	4819	5253	1058	2430	1027	47504
Mosman (A)	72	18	275	12	1022	225	1994	1491	331	240	514	597	1824	344	791	1608	2032	1039	633	546	15609
Newcastle (C) - Inner City	110	441	5025	969	4062	1365	5361	5996	5984	1960	5002	1430	10356	2412	7745	4028	7240	745	2743	1150	74125
Newcastle (C) - Outer West	413	355	3131	2192	3492	1235	3210	2220	1366	290	436	393	1198	623	1000	6888	3466	391	1457	547	34302
Newcastle (C) - Throsby	130	43	2576	296	2861	1032	10548	5605	1790	564	1907	792	4499	1376	3055	4403	16291	848	2366	805	61786
North Sydney (A)	182	717	7702	874	7851	4927	7634	7948	2450	11105	17252	3680	55556	8051	4268	9401	11531	2395	4672	5635	173832
Parramatta (C) - Inner	56	157	8582	3146	6166	5046	12703	6310	4512	2149	19876	2457	11552	5306	35447	7739	31816	1572	5386	2953	172930
Parramatta (C) - North-East	37	8	3872	11	1031	922	1229	962	402	175	617	344	1281	528	531	1362	2827	154	773	401	17467
Parramatta (C) - North-West	4	19	1811	0	1122	758	2963	879	833	74	228	95	708	261	188	1111	3205	131	515	290	15195
Parramatta (C) - South	3	13	1745	26	904	885	1319	619	2285	89	154	130	645	294	1071	2440	1114	547	404	303	14992
Penrith (C) - East	677	60	7792	2115	6107	7662	7503	5513	10924	1674	1975	2727	8634	4817	3858	9261	12100	1491	4560	1489	100940
Penrith (C) - West	115	266	4548	786	3783	1710	11777	5429	2991	444	1024	960	3192	1559	6190	4638	8756	1769	2618	1142	63699
Pittwater (A)	71	16	2779	76	3700	2343	4528	3293	578	527	875	885	3481	1000	1047	2841	5345	907	1789	1010	37093

Port Stephens (A)	599	249	6672	282	3166	874	6514	4791	1948	311	380	1040	1957	1146	7652	2895	4259	819	2059	951	48562
Randwick (C)	79	5	2199	250	4684	1353	4087	5701	4007	671	849	943	4167	2431	5454	17607	21116	1534	2210	1670	81015
Rockdale (C)	37	23	2131	120	2868	885	9786	5496	15622	1983	1543	1990	4748	3991	13279	3969	6070	1519	2011	1466	79535
Ryde (C)	156	142	11870	1183	8577	18507	12508	6096	1387	14208	1480	2013	21932	4067	5306	13669	21220	672	4698	3714	153404
Shellharbour (C)	132	264	854	189	2140	711	5206	2900	1110	73	473	420	844	637	2037	3218	4517	340	1291	433	27791
Shoalhaven (C) - Pt A	259	45	2689	307	1353	309	3296	1514	936	304	311	344	1105	711	4106	2137	4727	321	902	463	26137
Shoalhaven (C) - Pt B	999	47	915	222	1952	216	2775	3255	512	152	203	539	899	693	519	1962	2531	524	680	408	20002
Strathfield (A)	111	45	4491	1007	3227	8277	5005	1898	8964	453	1702	723	1754	1050	965	3495	1837	415	1209	1158	47786
Sutherland Shire (A) - East	70	117	6882	443	5897	2849	13795	6166	1598	422	1565	1159	4005	1174	1731	5146	11929	761	3135	1250	70095
Sutherland Shire (A) - West	30	8	1811	249	3773	1077	6258	4113	1407	156	1010	575	5075	1061	5086	6514	6862	472	2593	617	48749
Sydney (C) - East	30	83	1250	117	2622	2121	5635	8872	929	6527	1724	1441	14370	3735	12727	5890	16112	3420	2973	2298	92877
Sydney (C) - Inner	123	1921	3366	3175	12046	4724	25286	35050	8756	25952	159557	11977	114019	26043	34142	13037	14160	8487	9147	10841	521809
Sydney (C) - South	17	36	5223	691	4492	9898	11910	5727	8471	7619	2161	2696	12500	3887	6577	4276	7400	3520	5041	2596	104738
Sydney (C) - West	4	30	830	245	4587	2385	5269	5088	3773	10124	3123	1293	13630	2664	5038	20270	12434	7181	2124	2174	102269
Warringah (A)	164	80	6907	632	6164	10083	15484	6059	2197	1630	1984	1677	7373	2353	2962	9802	14395	1206	4298	1884	97334
Willoughby (C)	118	222	4562	763	7257	4099	11141	4151	2017	8797	3208	2035	11306	3114	3193	4792	19533	898	3642	2236	97083
Waverley (A)	38	67	667	123	2096	964	7159	4125	479	781	1220	655	3784	1708	1821	3979	5858	1243	1581	1109	39455
Wingecarribee (A)	1360	133	2568	209	1909	462	3320	2444	900	345	355	658	1467	620	808	2203	3444	380	990	567	25143
Wollondilly (A)	839	2198	2307	386	2841	620	2134	1357	1134	144	208	256	1140	468	846	1819	1752	295	813	451	22008
Wollongong (C) - Inner	83	817	4138	338	3356	1610	6799	6049	3090	675	5011	1466	4458	2499	7540	10509	12780	1021	2884	1303	76424
Wollongong (C) Bal	273	2419	7702	918	4195	1088	6801	3541	3079	181	757	626	1841	1777	1557	3795	6896	649	2652	833	51578
Woollahra (A)	78	46	509	59	2439	869	4671	3230	197	561	1240	1282	3218	1009	2453	4096	4283	939	1462	1044	33687
Wyong (A) - North-East	236	280	1298	1032	2456	1947	5275	3143	2415	212	589	580	2122	864	1005	3086	6009	744	1969	709	35970
Wyong (A) - South and West	205	81	5659	426	3406	1293	7004	5169	1747	408	1101	796	1904	1564	3711	3766	5985	553	1839	824	47441
No fixed address	1062	569	5355	1538	78273	4438	7305	2854	15761	3100	1682	1006	8743	20502	4548	7989	13270	3763	7835	5408	195001
Total GMA	21391	19021	336482	46687	362703	226648	553841	336742	283175	133048	303555	91428	482727	181509	308042	412384	636549	80111	186932	106561	510953

Source: SGS modelling. 2015

TABLE 21 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2065

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncla	Total
Ashfield (A)	9	0	457	32	1241	532	3316	1825	442	130	338	1431	1177	523	2001	2118	4827	173	659	458	21688
Auburn (C)	62	25	11891	2572	7154	9752	10594	4298	6868	2130	9056	1416	6590	3303	8633	5456	10206	2867	4317	2326	109518
Bankstown (C) - North-East	10	12	9314	309	2250	2024	8566	2547	5292	2021	1146	855	1362	1157	2923	5039	8766	379	2157	1320	57449
Bankstown (C) - North-West	21	0	6829	1264	2363	2250	3412	1281	3624	294	509	331	1180	602	1915	3283	3628	303	1197	839	35125
Bankstown (C) - South	35	54	7810	184	3697	3017	3043	1906	1626	93	361	314	1055	694	532	3714	2509	233	1429	764	33069
The Hills Shire (A) - Central	40	27	8065	440	7532	6659	24801	6048	1500	2654	5968	2576	13009	4098	4494	6462	12950	2300	4450	2079	116151
The Hills Shire (A) - North	1476	470	1863	724	4934	2834	11881	6854	2269	1525	1783	1843	7816	2480	1780	5851	6123	1574	2812	1528	68420
The Hills Shire (A) - South	143	13	931	18	1570	808	2478	705	415	156	339	237	4911	583	396	5271	2422	159	1502	409	23465
Blacktown (C) - North	397	440	4677	1110	5381	4276	9668	5672	3888	875	1555	1846	6159	2055	2221	9794	5910	1346	3341	1558	72171
Blacktown (C) - South-East	54	139	17027	2954	9475	9835	14603	5842	11864	627	1480	1274	2187	2737	4929	6598	12191	556	5583	2367	112322
Blacktown (C) - South-West	172	57	6598	1499	4225	5932	11238	4830	12501	139	463	1077	2634	2276	2687	6177	6912	425	2628	1226	73695
Blue Mountains (C)	364	7	854	221	1910	538	4744	4250	1208	368	522	536	2357	1016	2068	4145	6842	762	1484	727	34926
Botany Bay (C)	13	37	5764	508	4455	7027	7650	5991	33987	1217	1112	2282	3850	3516	4661	1509	4674	533	2370	1735	92891
Burwood (A)	0	8	470	35	1114	1795	4879	2063	3444	859	1097	837	1813	1092	1687	4642	6148	145	871	775	33773
Camden (A)	674	54	3111	473	4776	2163	12122	5781	3119	933	1735	1618	7487	2017	2482	5489	6638	1297	2656	872	65498
Campbelltown (C) - North	55	107	12911	238	3492	3295	4417	2524	4647	164	422	905	1158	1020	1723	4635	4449	222	2106	1018	49507
Campbelltown (C) - South	67	336	1319	126	1571	799	9941	5796	1648	408	966	741	1400	1197	2876	6543	12958	477	1958	823	51949
Canada Bay (A) - Concord	9	15	3492	135	2551	3776	3659	2053	641	808	6680	758	2700	1018	371	1893	8877	425	1709	817	42387
Canada Bay (A) - Drummoyne	16	0	348	0	1021	648	2808	1786	459	91	440	576	1660	470	614	1708	2205	311	1220	364	16744
Canterbury (C)	36	8	3711	70	4405	3305	6770	3635	3183	467	768	774	1862	1190	2934	4592	8539	387	2148	1526	50310
Cessnock (C)	804	1004	3180	285	2934	740	4519	5189	1344	190	300	527	1434	996	1768	2469	3257	444	1619	617	33621
Fairfield (C) - East	101	27	4271	178	2319	1995	7552	5723	2078	248	593	666	1431	1429	3138	6012	7500	432	2334	1307	49334
Fairfield (C) - West	396	70	12839	608	5869	8100	6635	3325	7542	232	840	766	2500	2953	1610	4355	4946	492	3028	1556	68664
Gosford (C) - East	173	35	652	129	2789	698	6319	4179	646	375	832	632	2023	989	1055	3296	4223	485	1510	609	31650
Gosford (C) - West	1430	289	6255	580	4106	1802	7672	4872	1949	861	1282	1006	3062	2220	5649	4964	14904	879	3092	1454	68329
Hawkesbury (C)	2145	59	5237	396	4400	1174	6035	3831	1836	641	537	664	1720	1276	4854	4539	5612	772	2268	1066	49062

Holroyd (C)	75	33	10896	739	4480	5265	6898	2873	7455	260	859	823	1829	1036	2608	4142	5643	240	2514	1369	60036
Hornsby (A) - North	411	10	1629	180	2555	1343	3244	1708	1626	192	453	366	2020	668	593	4281	4186	260	1129	489	27343
Hornsby (A) - South	57	17	5646	346	3042	2213	11465	5186	1562	819	1847	1266	5147	1941	2961	10450	13896	701	3008	1254	72825
Hunters Hill (A)	0	7	155	20	608	111	613	704	107	63	194	257	812	228	582	1517	2503	38	387	236	9141
Hurstville (C)	46	0	2294	162	3125	2568	5570	2910	1669	268	2645	784	2685	1170	2055	3832	6680	445	1883	985	41779
Kiama (A)	487	5	284	58	887	226	1448	2031	475	71	234	234	660	293	586	819	1137	363	435	175	10907
Kogarah (C)	15	23	601	703	1235	382	1736	2227	884	271	3151	600	1685	501	2692	3206	14666	397	909	717	36599
Ku-ring-gai (A)	122	29	1772	150	3507	2376	5024	3287	1083	1398	1554	1367	7032	1518	1727	10255	14294	593	1976	1413	60478
Lake Macquarie (C) - East	37	160	1735	210	2936	444	3688	2296	571	156	451	317	1013	669	730	2498	4603	258	1319	358	24448
Lake Macquarie (C) - North	76	1170	5787	296	4416	1209	8570	4869	2591	480	2797	836	2362	1369	3615	4409	7777	694	3125	882	57329
Lake Macquarie (C) - West	174	1079	1910	745	1983	280	2470	1791	994	98	303	306	1293	797	581	2421	4894	278	982	460	23840
Lane Cove (A)	53	0	2213	54	1400	1787	2430	1363	295	873	841	388	3884	1456	607	1735	4915	296	697	666	25952
Leichhardt (A)	157	6	1459	61	2788	1587	5341	3383	995	1136	848	922	4195	2070	2020	3436	6358	834	1666	985	40246
Liverpool (C) - East	54	38	10628	645	4619	5413	13108	5032	8176	1430	1822	1626	4372	5543	13556	8738	21211	1011	3220	1876	112118
Liverpool (C) - West	1996	79	3692	1570	5974	5103	13470	4965	11397	1357	1079	1165	4807	2439	1591	11298	8026	871	2466	1202	84546
Maitland (C)	424	1272	4060	722	4033	945	6383	3395	1866	193	691	888	2232	1499	2547	4236	6492	388	2790	766	45823
Manly (A)	99	17	489	145	1514	583	2378	3185	205	358	882	790	2626	528	919	2482	3616	360	876	576	22626
Marrickville (A)	26	19	4364	72	3354	3750	7042	3372	2561	1052	786	743	3694	1086	2223	5028	5480	1099	2522	1067	49340
Mosman (A)	76	18	283	12	1059	234	2074	1546	354	249	534	620	1899	358	823	1679	2121	1079	657	567	16242
Newcastle (C) - Inner City	116	459	5191	1001	4207	1417	5574	6221	6222	2032	5192	1483	10785	2506	8061	4205	7556	774	2848	1196	77047
Newcastle (C) - Outer West	433	369	3212	2264	3619	1283	3338	2304	1420	304	453	407	1247	648	1042	7189	3617	406	1513	568	35636
Newcastle (C) - Throsby	141	45	2652	305	2963	1071	10971	5815	1859	587	1980	821	4684	1429	3180	4595	17002	882	2456	836	64276
North Sydney (A)	191	747	7935	911	8131	5115	7938	8246	2548	11504	17911	3810	57855	8366	4443	9813	12034	2492	4848	5857	180695
Parramatta (C) - Inner	58	163	8864	3250	6385	5240	13213	6546	4693	2227	20634	2547	12030	5513	36897	8076	33204	1635	5590	3070	179835
Parramatta (C) - North-East	37	8	3998	11	1067	957	1278	998	419	181	640	356	1334	548	553	1421	2950	161	802	417	18138
Parramatta (C) - North-West	4	19	1864	0	1163	786	3079	913	865	77	238	100	737	272	195	1159	3343	148	534	301	15796
Parramatta (C) - South	3	13	1802	26	936	919	1373	643	2376	93	160	134	671	306	1114	2547	1161	569	419	316	15580
Penrith (C) - East	707	63	8018	2188	6324	7955	7803	5719	11361	1737	2051	2826	8991	5006	4015	9665	12628	1548	4734	1548	104889
Penrith (C) - West	121	277	4682	812	3918	1776	12248	5632	3110	461	1063	995	3324	1621	6443	4840	9138	1839	2718	1187	66205
Pittwater (A)	75	17	2857	78	3832	2432	4709	3417	601	546	908	918	3625	1039	1090	2967	5578	943	1857	1050	38540

Port Stephens (A)	627	260	6876	292	3278	907	6776	4970	2025	322	394	1079	2038	1191	7964	3021	4444	851	2136	988	50439
Randwick (C)	83	5	2263	258	4852	1405	4251	5915	4166	695	882	977	4340	2526	5677	18376	22036	1595	2294	1736	84331
Rockdale (C)	38	24	2192	125	2969	918	10178	5704	16242	2052	1602	2064	4944	4147	13824	4143	6336	1581	2088	1524	82694
Ryde (C)	163	148	12246	1221	8883	19218	13009	6324	1441	14718	1536	2088	22839	4226	5523	14265	22145	698	4876	3861	159427
Shellharbour (C)	139	275	879	195	2217	739	5415	3009	1155	76	491	436	878	662	2121	3359	4714	353	1340	450	28902
Shoalhaven (C) - Pt A	270	46	2772	317	1401	320	3428	1571	974	315	323	355	1151	739	4274	2230	4933	334	936	481	27173
Shoalhaven (C) - Pt B	1046	48	939	230	2022	224	2887	3376	533	157	210	559	936	719	540	2047	2642	545	705	424	20790
Strathfield (A)	116	47	4639	1041	3343	8594	5204	1970	9321	469	1768	749	1827	1091	1004	3648	1917	432	1254	1204	49639
Sutherland Shire (A) - East	74	121	7072	459	6106	2958	14348	6397	1663	437	1625	1201	4171	1219	1802	5371	12449	791	3254	1299	72818
Sutherland Shire (A) - West	32	9	1860	258	3908	1118	6509	4267	1464	163	1049	596	5286	1101	5294	6798	7160	491	2690	642	50696
Sydney (C) - East	31	86	1280	117	2716	2202	5861	9205	967	6762	1789	1495	14965	3881	13247	6147	16815	3557	3086	2389	96598
Sydney (C) - Inner	128	1999	3476	3281	12477	4905	26299	36365	9104	26887	165643	12417	118737	27062	35538	13608	14777	8825	9494	11270	542292
Sydney (C) - South	18	38	5354	714	4652	10278	12387	5942	8809	7895	2243	2796	13017	4038	6845	4463	7723	3659	5233	2699	108804
Sydney (C) - West	4	32	856	253	4751	2477	5480	5278	3924	10488	3243	1341	14194	2768	5243	21154	12976	7467	2206	2260	106394
Warringah (A)	171	84	7104	653	6384	10471	16105	6286	2285	1688	2059	1738	7677	2445	3083	10230	15022	1254	4461	1959	101156
Willoughby (C)	123	232	4691	789	7516	4257	11587	4306	2097	9108	3330	2109	11773	3235	3324	5001	20384	933	3781	2324	100901
Waverley (A)	40	69	686	127	2171	1001	7446	4280	498	808	1266	679	3940	1775	1896	4153	6113	1292	1641	1153	41032
Wingecarribee (A)	1425	138	2640	216	1977	480	3453	2536	936	358	369	683	1527	644	842	2299	3594	394	1028	590	26127
Wollondilly (A)	877	2287	2378	399	2942	644	2219	1408	1179	148	216	266	1187	486	881	1899	1828	307	844	469	22865
Wollongong (C) - Inner	88	850	4259	349	3476	1671	7072	6276	3215	700	5202	1520	4643	2597	7849	10968	13337	1062	2993	1355	79479
Wollongong (C) Bal	286	2517	7963	950	4345	1129	7073	3674	3202	187	786	649	1917	1847	1620	3961	7196	676	2753	866	53596
Woollahra (A)	82	48	523	59	2526	902	4859	3351	205	581	1287	1330	3352	1048	2554	4275	4470	976	1518	1086	35031
Wyong (A) - North-East	249	292	1336	1066	2543	2023	5487	3261	2511	221	612	601	2210	898	1046	3220	6271	773	2044	736	37400
Wyong (A) - South and West	215	84	5847	439	3528	1342	7284	5363	1817	422	1142	825	1982	1625	3863	3930	6246	576	1908	857	49297
No fixed address	1111	592	5512	1588	81068	4608	7598	2961	16389	3212	1746	1042	9105	21304	4735	8338	13848	3913	8132	5622	202424
Total GMA	22408	19785	346490	48218	375651	23534	57601	34937	29448	13784	31514	94782	502705	18860	32063	43039	66430	83314	19402	11077	531028

Source: SGS modelling. 2015

TABLE 22 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2070

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncl a	Total
Ashfield (A)	9	0	472	32	1286	553	3449	1893	461	135	350	1483	1225	542	2083	2212	5039	179	684	476	22563
Auburn (C)	66	26	12243	2653	7409	10127	11018	4459	7142	2207	9401	1468	6863	3433	8985	5695	10651	2981	4481	2417	113724
Bankstown (C) - North-East	10	12	9623	319	2329	2103	8909	2642	5503	2095	1190	886	1418	1202	3042	5259	9149	395	2238	1373	59698
Bankstown (C) - North-West	21	0	7021	1304	2448	2335	3549	1329	3769	294	528	344	1228	626	1994	3425	3786	315	1242	872	36433
Bankstown (C) - South	37	57	8014	189	3829	3132	3164	1979	1690	93	376	326	1098	721	553	3876	2618	242	1482	793	34270
The Hills Shire (A) - Central	42	28	8308	452	7800	6914	25794	6274	1561	2749	6197	2671	13547	4260	4678	6744	13515	2391	4618	2160	120705
The Hills Shire (A) - North	1543	488	1907	748	5109	2945	12357	7113	2358	1579	1853	1911	8139	2577	1852	6107	6389	1636	2919	1587	71117
The Hills Shire (A) - South	149	14	960	19	1626	840	2576	731	430	164	351	245	5114	607	413	5500	2528	165	1558	426	24417
Blacktown (C) - North	415	460	4813	1145	5572	4440	10056	5884	4044	906	1615	1914	6414	2135	2313	10221	6169	1400	3469	1619	75005
Blacktown (C) - South-East	57	144	17569	3052	9814	10212	15188	6061	12338	649	1537	1320	2278	2844	5130	6886	12722	578	5794	2462	116637
Blacktown (C) - South-West	180	59	6791	1548	4377	6160	11687	5011	12998	143	480	1117	2743	2366	2798	6446	7213	443	2727	1275	76564
Blue Mountains (C)	380	8	877	229	1979	559	4934	4409	1257	383	542	557	2454	1056	2152	4326	7140	792	1540	756	36332
Botany Bay (C)	14	37	5950	525	4614	7296	7956	6215	35342	1261	1155	2366	4010	3653	4850	1573	4879	554	2461	1804	96515
Burwood (A)	0	9	487	35	1153	1865	5074	2140	3587	890	1138	866	1888	1135	1756	4844	6417	150	903	805	35143
Camden (A)	705	56	3182	489	4946	2245	12608	5998	3244	967	1802	1677	7799	2097	2583	5729	6927	1349	2756	907	68063
Campbelltown (C) - North	58	111	13297	247	3617	3420	4594	2619	4832	168	438	938	1207	1060	1793	4837	4643	231	2185	1058	51354
Campbelltown (C) - South	69	350	1358	129	1627	830	10339	6013	1714	423	1003	769	1459	1243	2994	6829	13523	496	2032	855	54056
Canada Bay (A) - Concord	10	15	3618	141	2642	3919	3804	2132	666	836	6935	786	2811	1057	385	1974	9264	442	1774	849	44062
Canada Bay (A) - Drummoyne	18	0	358	0	1057	674	2919	1854	477	94	457	597	1728	490	639	1783	2301	323	1267	379	17414
Canterbury (C)	38	8	3816	70	4561	3431	7040	3772	3309	482	797	800	1939	1236	3054	4792	8911	402	2231	1586	52278
Cessnock (C)	842	1045	3276	294	3039	768	4700	5382	1397	197	311	547	1494	1035	1840	2577	3399	462	1681	642	34928
Fairfield (C) - East	122	28	4375	185	2401	2071	7855	5938	2161	256	616	690	1490	1484	3266	6274	7827	449	2422	1359	51270
Fairfield (C) - West	415	73	13192	628	6078	8410	6900	3450	7842	239	872	794	2604	3067	1676	4545	5162	512	3143	1618	71220
Gosford (C) - East	180	36	670	133	2888	724	6571	4336	671	389	865	655	2106	1026	1098	3440	4408	505	1567	633	32903
Gosford (C) - West	1497	300	6445	597	4252	1871	7980	5055	2027	891	1330	1043	3188	2307	5880	5181	15555	914	3209	1512	71035
Hawkesbury (C)	2245	61	5380	410	4557	1220	6277	3973	1909	665	557	688	1791	1327	5053	4736	5858	802	2354	1108	50972

Holroyd (C)	80	35	11202	763	4641	5467	7175	2981	7752	268	892	854	1905	1077	2713	4323	5889	252	2609	1423	62301
Hornsby (A) - North	430	11	1680	186	2646	1395	3374	1772	1693	199	470	378	2104	694	616	4469	4368	270	1172	508	28433
Hornsby (A) - South	60	18	5836	358	3150	2299	11924	5379	1623	848	1918	1314	5360	2017	3081	10907	14502	729	3122	1303	75748
Hunters Hill (A)	0	7	160	20	630	114	636	729	111	65	202	266	847	237	606	1583	2612	40	400	246	9511
Hurstville (C)	46	0	2353	167	3237	2667	5794	3019	1736	278	2747	813	2796	1215	2139	4000	6971	463	1955	1025	43420
Kiama (A)	509	5	293	58	919	236	1505	2107	493	75	243	243	687	303	611	854	1187	376	452	182	11338
Kogarah (C)	15	23	619	727	1279	397	1806	2310	919	279	3271	622	1754	520	2803	3347	15305	414	943	745	38099
Ku-ring-gai (A)	128	30	1831	155	3633	2467	5224	3412	1125	1448	1613	1419	7324	1577	1796	10702	14917	616	2051	1469	62938
Lake Macquarie (C) - East	38	166	1784	220	3042	461	3835	2381	593	195	468	328	1056	695	760	2606	4804	269	1369	372	25443
Lake Macquarie (C) - North	79	1217	5964	305	4575	1256	8913	5052	2698	495	2904	866	2459	1423	3762	4602	8117	722	3245	917	59571
Lake Macquarie (C) - West	182	1123	1971	771	2054	291	2569	1859	1034	98	314	318	1346	828	605	2526	5108	289	1019	478	24781
Lane Cove (A)	57	0	2273	56	1449	1856	2527	1414	306	905	873	403	4045	1514	632	1810	5129	308	724	692	26974
Leichhardt (A)	161	6	1501	61	2888	1648	5556	3510	1035	1177	880	957	4368	2151	2103	3586	6635	867	1728	1024	41842
Liverpool (C) - East	57	39	10929	667	4785	5620	13632	5221	8502	1482	1892	1686	4553	5759	14111	9119	22136	1052	3342	1950	116533
Liverpool (C) - West	2092	82	3795	1620	6186	5299	14008	5153	11851	1407	1121	1208	5005	2535	1656	11793	8375	906	2559	1249	87899
Maitland (C)	443	1324	4179	747	4176	982	6639	3523	1940	200	717	920	2325	1558	2650	4420	6775	403	2896	797	47614
Manly (A)	106	17	504	152	1568	605	2473	3304	213	371	916	819	2735	549	957	2591	3774	375	910	599	23537
Marrickville (A)	28	19	4475	72	3474	3894	7325	3498	2664	1090	816	771	3847	1130	2314	5246	5718	1142	2618	1109	51248
Mosman (A)	80	18	292	12	1098	243	2156	1603	379	258	554	645	1978	372	857	1753	2214	1121	681	589	16902
Newcastle (C) - Inner City	122	477	5363	1034	4357	1472	5797	6455	6469	2107	5390	1538	11232	2604	8391	4390	7886	804	2956	1243	80085
Newcastle (C) - Outer West	454	384	3295	2338	3750	1332	3472	2391	1476	320	471	422	1299	673	1085	7503	3775	423	1570	590	37023
Newcastle (C) - Throsby	153	47	2729	315	3069	1111	11410	6033	1932	611	2056	851	4878	1485	3310	4796	17743	917	2550	869	66866
North Sydney (A)	199	778	8175	950	8421	5311	8255	8556	2650	11918	18595	3944	60249	8693	4626	10242	12559	2593	5030	6088	187831
Parramatta (C) - Inner	61	169	9156	3357	6612	5441	13742	6790	4881	2307	21421	2640	12527	5730	38406	8428	34653	1700	5803	3192	187016
Parramatta (C) - North-East	37	8	4128	11	1105	994	1329	1035	436	188	665	370	1389	570	577	1482	3079	168	831	434	18835
Parramatta (C) - North-West	4	19	1919	0	1205	815	3199	947	900	80	248	105	767	283	201	1209	3488	166	554	313	16422
Parramatta (C) - South	3	13	1860	26	969	955	1428	667	2470	96	167	138	699	318	1160	2658	1211	592	434	328	16192
Penrith (C) - East	739	65	8251	2262	6549	8258	8116	5933	11815	1802	2130	2929	9364	5203	4179	10087	13178	1608	4915	1610	108994
Penrith (C) - West	126	288	4820	840	4058	1845	12738	5843	3233	478	1103	1031	3460	1685	6707	5051	9536	1913	2821	1234	68811
Pittwater (A)	79	18	2937	79	3969	2524	4898	3546	624	566	942	952	3776	1080	1135	3097	5821	982	1928	1092	40043
Port Stephens	657	270	7087	303	3395	940	7048	5155	2105	334	410	1119	2123	1238	8289	3153	4637	886	2215	1026	52390

(A)																					
Randwick (C)	87	5	2329	266	5026	1460	4421	6137	4331	721	916	1014	4520	2625	5908	19178	22997	1659	2380	1804	87785
Rockdale (C)	39	24	2254	131	3075	952	10586	5919	16887	2124	1663	2141	5148	4310	14391	4324	6613	1645	2167	1585	85978
Ryde (C)	171	153	12633	1259	9200	19956	13530	6560	1496	15247	1595	2166	23784	4391	5749	14887	23111	726	5062	4014	165688
Shellharbour (C)	146	286	905	201	2296	768	5631	3121	1201	79	510	452	914	687	2209	3506	4919	366	1392	467	30057
Shoalhaven (C) - Pt A	282	48	2857	328	1451	332	3566	1631	1013	327	336	368	1200	768	4449	2328	5149	348	972	499	28250
Shoalhaven (C) - Pt B	1096	50	963	239	2094	233	3002	3502	554	163	218	580	975	746	562	2136	2757	567	731	441	21610
Strathfield (A)	121	49	4793	1076	3462	8924	5411	2045	9693	485	1836	777	1902	1134	1045	3808	2001	449	1301	1252	51564
Sutherland Shire (A) - East	78	125	7268	474	6324	3070	14922	6637	1731	453	1687	1245	4344	1266	1876	5605	12991	823	3377	1351	75648
Sutherland Shire (A) - West	34	9	1910	267	4048	1161	6770	4427	1524	169	1089	618	5505	1143	5512	7095	7472	510	2792	668	52723
Sydney (C) - East	32	90	1311	117	2814	2285	6096	9550	1005	7006	1858	1551	15586	4033	13788	6415	17548	3700	3203	2484	100469
Sydney (C) - Inner	134	2080	3591	3390	12925	5093	27352	37729	9467	27856	17196 1	12874	12365 1	28120	36992	14203	15421	9176	9854	1171 6	563582
Sydney (C) - South	18	40	5489	738	4818	10673	12884	6165	9160	8181	2329	2899	13556	4196	7124	4658	8061	3804	5432	2806	113029
Sydney (C) - West	5	33	882	260	4920	2573	5699	5475	4080	10866	3368	1391	14781	2876	5456	22077	13541	7764	2290	2349	110687
Warringah (A)	178	88	7305	675	6612	10873	16750	6522	2375	1748	2138	1801	7995	2540	3209	10676	15676	1304	4630	2036	105130
Willoughby (C)	128	242	4824	815	7784	4421	12051	4467	2180	9431	3457	2185	12260	3361	3460	5219	21272	970	3925	2416	104870
Waverley (A)	41	73	705	131	2249	1039	7744	4440	517	837	1314	703	4103	1844	1973	4334	6380	1343	1704	1198	42672
Wingecarribee (A)	1493	144	2714	222	2048	499	3591	2631	973	371	383	708	1590	669	877	2399	3750	410	1066	614	27150
Wollondilly (A)	917	2379	2452	412	3046	669	2308	1461	1226	152	224	276	1236	506	917	1983	1907	320	877	488	23755
Wollongong (C) - Inner	92	884	4384	360	3599	1734	7356	6512	3345	725	5401	1576	4835	2698	8171	11447	13919	1105	3107	1408	82658
Wollongong (C) Bal	299	2618	8233	983	4500	1173	7356	3812	3331	193	816	673	1996	1919	1685	4135	7510	703	2858	900	55694
Woollahra (A)	85	50	538	59	2616	936	5054	3476	214	601	1336	1379	3491	1088	2658	4462	4665	1014	1577	1129	36429
Wyong (A) - North-East	263	303	1376	1101	2633	2102	5707	3383	2612	230	636	622	2301	934	1088	3361	6545	803	2122	765	38887
Wyong (A) - South and West	225	87	6042	453	3655	1394	7576	5565	1889	436	1185	856	2063	1689	4021	4102	6518	600	1980	891	51226
No fixed address	1163	616	5674	1640	83964	4785	7903	3072	17042	3328	1813	1080	9482	22136	4929	8702	14452	4069	8441	5844	210132
Total GMA	23476	20579	35679 8	49800	38906 1	24436 6	59906 6	36247 8	30623 8	14282 4	32717 3	98259	52351 0	19598 0	33374 5	44918 8	69327 2	86646	20138 0	1151 50	551899 2

Source: SGS modelling. 2015

TABLE 23 SYDNEY EMPLOYMENT BY INDUSTRY AND SLA, 2075

	Agric	Min	Manu	Elec	Const	Whol	Retail	Acco	Trans	Info	Finan	Rent	Prof	Admi	Public	Educ	Healt	Arts	Other	Uncl a	Total
Ashfield (A)	9	0	488	32	1333	576	3587	1963	481	140	362	1537	1275	562	2169	2309	5260	186	710	495	23475
Auburn (C)	69	27	12605	2735	7673	10516	11459	4625	7427	2287	9760	1522	7147	3567	9352	5945	11116	3099	4651	2513	118093
Bankstown (C) - North-East	10	12	9943	330	2412	2184	9266	2741	5722	2170	1235	919	1477	1249	3167	5489	9549	411	2322	1427	62035
Bankstown (C) - North-West	22	0	7220	1345	2536	2424	3691	1379	3920	294	548	356	1278	652	2075	3574	3951	327	1290	907	37790
Bankstown (C) - South	39	59	8224	194	3966	3252	3290	2054	1757	93	390	338	1143	749	576	4046	2732	252	1537	825	35516
The Hills Shire (A) - Central	45	30	8558	465	8078	7179	26827	6510	1624	2849	6434	2768	14109	4428	4870	7038	14104	2485	4792	2245	125439
The Hills Shire (A) - North	1614	506	1953	773	5292	3059	12853	7381	2451	1635	1924	1980	8476	2677	1927	6374	6667	1700	3030	1648	73921
The Hills Shire (A) - South	156	14	991	19	1684	873	2679	758	446	172	364	254	5326	632	430	5740	2639	172	1616	443	25407
Blacktown (C) - North	435	480	4952	1182	5770	4611	10459	6104	4206	938	1677	1985	6680	2219	2408	10667	6438	1456	3601	1682	77951
Blacktown (C) - South-East	61	150	18129	3155	10164	10605	15798	6288	12831	671	1596	1368	2373	2955	5340	7187	13276	601	6014	2560	121120
Blacktown (C) - South-West	189	62	6990	1600	4535	6396	12155	5198	13515	148	498	1158	2856	2459	2913	6727	7528	460	2831	1327	79545
Blue Mountains (C)	397	8	902	236	2049	580	5131	4574	1309	398	563	578	2556	1098	2240	4515	7452	824	1599	786	37795
Botany Bay (C)	15	37	6142	543	4778	7575	8275	6449	36752	1306	1200	2453	4175	3795	5047	1640	5094	575	2555	1875	100282
Burwood (A)	0	9	503	35	1194	1937	5277	2221	3735	922	1182	896	1966	1181	1828	5056	6698	156	937	837	36570
Camden (A)	736	58	3255	505	5122	2331	13112	6223	3373	1002	1871	1738	8123	2179	2688	5979	7228	1403	2861	943	70731
Campbelltown (C) - North	61	116	13694	257	3747	3551	4777	2717	5026	172	455	972	1258	1101	1866	5049	4844	241	2268	1100	53270
Campbelltown (C) - South	72	365	1397	133	1686	862	10753	6238	1783	438	1042	797	1520	1292	3117	7127	14113	516	2109	890	56248
Canada Bay (A) - Concord	11	15	3748	146	2736	4067	3956	2213	692	866	7201	815	2928	1098	400	2059	9668	460	1842	882	45803
Canada Bay (A) - Drummoyne	19	0	368	0	1095	701	3035	1924	496	97	474	618	1800	510	665	1861	2401	335	1317	394	18110
Canterbury (C)	39	9	3923	70	4724	3563	7321	3914	3441	498	828	828	2019	1285	3179	5001	9300	418	2317	1649	54324
Cessnock (C)	882	1088	3375	303	3148	797	4887	5583	1453	204	322	568	1557	1075	1914	2690	3547	481	1744	668	36286
Fairfield (C) - East	146	29	4481	192	2487	2150	8169	6161	2248	265	639	715	1552	1542	3399	6548	8168	466	2514	1412	53287
Fairfield (C) - West	434	76	13555	648	6294	8733	7176	3581	8154	246	905	824	2713	3185	1745	4742	5387	532	3262	1682	73873
Gosford (C) - East	188	38	689	137	2991	751	6834	4500	697	403	898	679	2193	1065	1143	3591	4600	524	1627	658	34206
Gosford (C) - West	1568	312	6641	614	4403	1943	8300	5245	2108	923	1380	1080	3319	2398	6121	5406	16233	951	3332	1572	73850
Hawkesbury (C)	2349	64	5528	424	4720	1267	6528	4121	1986	690	578	713	1866	1381	5260	4942	6114	833	2443	1152	52958

Holroyd (C)	84	36	11518	787	4808	5677	7462	3093	8061	277	927	886	1985	1119	2823	4512	6146	264	2708	1479	64653
Hornsby (A) - North	449	11	1733	192	2740	1449	3508	1838	1761	206	488	391	2192	721	639	4664	4559	281	1216	528	29567
Hornsby (A) - South	63	18	6032	370	3262	2388	12401	5579	1687	877	1992	1363	5582	2095	3206	11385	15134	758	3240	1355	78788
Hunters Hill (A)	0	7	166	20	653	119	661	755	115	67	210	275	883	247	630	1652	2726	41	414	255	9896
Hurstville (C)	46	0	2414	172	3352	2769	6027	3133	1806	288	2852	843	2911	1263	2227	4174	7275	482	2029	1066	45128
Kiama (A)	532	5	303	58	951	247	1565	2186	513	78	252	252	716	314	637	891	1239	390	469	189	11787
Kogarah (C)	15	23	637	753	1325	413	1878	2397	956	288	3396	646	1826	540	2917	3494	15972	431	979	775	39660
Ku-ring-gai (A)	135	31	1891	160	3763	2562	5433	3541	1170	1500	1674	1473	7628	1638	1869	11169	15567	640	2128	1527	65499
Lake Macquarie (C) - East	40	173	1835	231	3151	479	3988	2469	615	243	487	341	1100	722	790	2720	5014	280	1421	386	26485
Lake Macquarie (C) - North	83	1266	6147	314	4739	1304	9270	5241	2810	510	3016	898	2560	1478	3916	4803	8471	751	3369	954	61900
Lake Macquarie (C) - West	190	1168	2034	797	2128	302	2671	1929	1075	98	326	331	1402	860	630	2637	5330	300	1057	496	25759
Lane Cove (A)	61	0	2335	58	1500	1927	2628	1467	318	939	905	418	4212	1575	658	1889	5353	320	752	719	28036
Leichhardt (A)	166	6	1544	61	2991	1711	5779	3642	1076	1219	913	993	4549	2236	2189	3744	6924	901	1793	1065	43501
Liverpool (C) - East	60	41	11238	689	4956	5835	14177	5417	8841	1536	1964	1748	4742	5984	14689	9517	23101	1094	3469	2027	121125
Liverpool (C) - West	2192	85	3901	1672	6406	5502	14568	5347	12323	1459	1164	1253	5211	2635	1723	12310	8740	944	2656	1298	91386
Maitland (C)	463	1378	4300	773	4324	1019	6904	3656	2017	207	745	954	2422	1619	2758	4613	7071	419	3005	828	49475
Manly (A)	114	18	519	160	1623	627	2572	3428	222	385	951	848	2849	570	997	2704	3938	390	945	623	24484
Marrickville (A)	29	19	4590	72	3599	4044	7619	3628	2770	1129	846	799	4007	1175	2410	5474	5966	1187	2717	1153	53232
Mosman (A)	85	18	300	12	1139	253	2241	1662	405	267	575	670	2060	387	892	1830	2310	1165	706	611	17589
Newcastle (C) - Inner City	129	497	5541	1068	4513	1528	6028	6697	6726	2185	5595	1595	11697	2706	8733	4582	8230	835	3068	1293	83244
Newcastle (C) - Outer West	476	400	3381	2414	3886	1383	3611	2481	1535	337	489	437	1353	699	1129	7831	3940	440	1630	613	38465
Newcastle (C) - Throsby	167	49	2809	326	3179	1154	11867	6259	2007	637	2134	882	5079	1542	3445	5006	18517	953	2648	902	69562
North Sydney (A)	208	810	8422	991	8721	5515	8584	8877	2756	12346	19305	4082	62742	9033	4815	10690	13106	2698	5219	6328	195250
Parramatta (C) - Inner	64	176	9457	3468	6847	5650	14293	7043	5076	2389	22239	2737	13046	5954	39977	8796	36164	1768	6024	3318	194486
Parramatta (C) - North-East	37	8	4263	11	1143	1032	1382	1073	454	195	690	383	1447	593	601	1547	3213	175	862	451	19559
Parramatta (C) - North-West	4	19	1976	0	1249	845	3324	983	935	83	259	110	799	294	208	1262	3639	187	575	325	17075
Parramatta (C) - South	3	13	1920	26	1004	992	1486	693	2568	100	173	143	728	331	1207	2774	1263	615	450	342	16829
Penrith (C) - East	773	68	8491	2339	6782	8574	8441	6155	12288	1869	2212	3035	9751	5407	4349	10527	13753	1670	5103	1674	113261
Penrith (C) - West	132	300	4962	868	4203	1916	13247	6062	3361	496	1146	1069	3603	1751	6981	5271	9952	1989	2928	1283	71520
Pittwater (A)	83	18	3020	81	4111	2620	5094	3679	649	586	977	988	3932	1122	1181	3234	6074	1021	2002	1135	41607
Port Stephens	688	281	7304	314	3516	976	7331	5348	2188	347	426	1162	2210	1287	8627	3290	4839	921	2297	1066	54417

(A)																					
Randwick (C)	92	6	2397	275	5207	1517	4598	6368	4504	747	952	1051	4707	2728	6150	20015	24000	1725	2469	1875	91381
Rockdale (C)	40	25	2318	136	3183	988	11010	6142	17558	2198	1727	2221	5361	4479	14982	4513	6903	1712	2249	1648	89394
Ryde (C)	179	159	13033	1299	9528	20722	14071	6805	1554	15795	1657	2246	24767	4562	5984	15536	24118	755	5254	4173	172197
Shellharbour (C)	153	297	932	207	2377	799	5857	3238	1250	83	529	469	952	713	2300	3659	5133	380	1445	485	31258
Shoalhaven (C) - Pt A	295	50	2944	339	1503	344	3710	1692	1054	339	348	381	1250	798	4631	2429	5374	362	1009	519	29370
Shoalhaven (C) - Pt B	1148	52	988	247	2168	241	3123	3633	576	169	226	602	1016	774	585	2229	2877	590	759	458	22462
Strathfield (A)	126	50	4951	1112	3586	9266	5627	2123	10079	502	1907	806	1981	1179	1087	3976	2088	466	1349	1302	53564
Sutherland Shire (A) - East	82	130	7468	491	6549	3187	15521	6886	1801	468	1751	1291	4524	1315	1953	5850	13557	856	3505	1404	78590
Sutherland Shire (A) - West	35	10	1962	277	4193	1206	7041	4593	1585	176	1131	641	5733	1187	5738	7404	7797	530	2897	694	54830
Sydney (C) - East	33	93	1342	117	2914	2371	6341	9908	1045	7258	1929	1609	16231	4191	14351	6695	18313	3848	3324	2583	104497
Sydney (C) - Inner	140	2164	3709	3502	13388	5288	28447	39144	9843	28859	17852 1	13347	12876 8	29219	38505	14825	16093	9541	10228	1217 9	585710
Sydney (C) - South	19	42	5626	762	4990	11082	13400	6397	9525	8477	2418	3006	14117	4359	7413	4861	8414	3954	5639	2917	117419
Sydney (C) - West	5	35	909	268	5096	2673	5927	5680	4243	11257	3497	1443	15392	2987	5678	23040	14131	8074	2378	2441	115154
Warringah (A)	186	91	7513	698	6848	11291	17421	6766	2469	1809	2219	1866	8325	2639	3340	11143	16359	1355	4806	2117	109261
Willoughby (C)	134	252	4962	843	8062	4591	12533	4635	2267	9766	3588	2264	12767	3492	3601	5447	22199	1009	4074	2512	108997
Waverley (A)	43	76	725	136	2329	1079	8054	4606	538	867	1364	729	4272	1916	2054	4523	6658	1396	1769	1246	44379
Wingecarribee (A)	1563	150	2789	229	2121	518	3735	2730	1012	385	398	734	1655	694	913	2503	3914	426	1107	638	28214
Wollondilly (A)	958	2476	2529	425	3154	695	2401	1516	1274	156	232	286	1287	526	955	2070	1990	333	911	508	24681
Wollongong (C) - Inner	97	920	4512	371	3727	1800	7651	6757	3480	752	5607	1634	5035	2804	8506	11946	14526	1149	3225	1464	85964
Wollongong (C) Bal	313	2724	8513	1018	4661	1218	7650	3955	3464	199	848	698	2079	1993	1754	4316	7837	732	2968	936	57874
Woollahra (A)	89	53	554	59	2708	971	5258	3606	223	622	1387	1431	3635	1130	2768	4657	4868	1054	1637	1174	37883
Wyong (A) - North-East	277	316	1416	1137	2727	2183	5937	3510	2716	239	660	645	2397	971	1133	3508	6831	834	2203	794	40434
Wyong (A) - South and West	235	91	6243	467	3786	1447	7879	5774	1965	451	1230	887	2148	1755	4186	4281	6803	625	2054	926	53231
No fixed address	1217	641	5841	1693	86962	4968	8220	3187	17721	3448	1883	1118	9874	23002	5132	9082	15083	4232	8761	6074	218136
Total GMA	24599	21407	36741 5	51435	40295 0	25373 8	62304 6	37607 4	31846 5	14799 0	33966 3	10186 4	54517 7	20364 3	34739 0	46880 4	72350 1	90113	20901 8	1197 01	573599 2

TABLE 24 SYDNEY AGE GROUP BY SLA, 2015 TO 2075

SLA		2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075
Ashfield	0-4	2,806	2,883	3,026	3,027	3,055	3,120	3,211	3,300	3,368	3,421	3,470	3,518	3,564
	5-9	2,208	2,390	2,563	2,674	2,698	2,723	2,785	2,874	2,960	3,025	3,085	3,145	3,203
	10-14	1,904	1,992	2,221	2,349	2,378	2,378	2,405	2,467	2,552	2,632	2,709	2,788	2,867
	15-19	1,924	1,882	2,045	2,275	2,365	2,379	2,384	2,418	2,485	2,571	2,662	2,754	2,848
	20-24	3,183	2,995	3,044	3,176	3,306	3,379	3,401	3,417	3,469	3,562	3,663	3,765	3,867
	25-29	4,428	4,137	4,080	4,123	4,310	4,472	4,572	4,617	4,650	4,725	4,809	4,892	4,973
	30-34	4,268	4,274	4,191	4,141	4,167	4,330	4,493	4,606	4,663	4,704	4,741	4,775	4,806
	35-39	3,553	3,788	3,960	3,881	3,846	3,864	4,018	4,180	4,295	4,356	4,403	4,449	4,492
	40-44	3,209	3,207	3,535	3,696	3,745	3,735	3,760	3,920	4,088	4,207	4,315	4,424	4,532
	45-49	2,877	2,836	2,979	3,278	3,455	3,501	3,500	3,537	3,697	3,861	4,023	4,189	4,359
	50-54	2,739	2,560	2,656	2,804	3,089	3,250	3,301	3,312	3,358	3,517	3,706	3,904	4,110
	55-59	2,414	2,392	2,406	2,488	2,528	2,755	2,907	2,965	2,985	3,033	3,089	3,144	3,198
	60-64	2,041	2,094	2,202	2,228	2,276	2,302	2,518	2,668	2,730	2,756	2,775	2,792	2,808
	65-69	1,726	1,789	1,953	2,071	2,116	2,163	2,195	2,414	2,568	2,635	2,686	2,736	2,785
	70-74	1,325	1,545	1,730	1,913	1,974	2,005	2,056	2,099	2,319	2,476	2,610	2,750	2,895
	75-79	1,217	1,196	1,500	1,690	1,867	1,927	1,969	2,031	2,085	2,314	2,615	2,952	3,331
	80-84	1,031	1,047	1,138	1,458	1,634	1,807	1,875	1,936	2,009	2,078	2,145	2,213	2,282
	85+	1,461	1,548	1,721	1,987	2,452	2,875	3,290	3,606	3,866	4,117	4,378	4,653	4,941
		44,314	44,556	46,950	49,258	51,262	52,966	54,641	56,369	58,151	59,989	61,885	63,842	65,860
Auburn	0-4	6,288	7,587	8,455	9,098	9,936	10,899	11,960	12,736	13,381	13,994	14,619	15,264	15,930
	5-9	4,869	5,904	7,130	7,966	8,648	9,377	10,227	10,937	11,595	12,202	12,816	13,454	14,117
	10-14	4,131	4,764	5,841	6,960	7,675	8,242	8,890	9,453	10,064	10,685	11,330	12,008	12,721
	15-19	4,401	4,599	5,335	6,385	7,164	7,737	8,265	8,690	9,194	9,796	10,444	11,130	11,855
	20-24	6,412	6,350	6,798	7,622	8,573	9,405	10,095	10,510	10,986	11,615	12,302	13,023	13,779
	25-29	8,613	8,384	8,724	9,354	10,536	11,738	12,795	13,389	13,880	14,522	15,222	15,949	16,701
	30-34	8,149	8,809	9,047	9,548	10,372	11,579	12,811	13,607	14,180	14,727	15,285	15,857	16,443
	35-39	6,267	7,760	8,533	8,893	9,510	10,263	11,382	12,270	12,978	13,550	14,107	14,680	15,269
	40-44	5,149	6,189	7,645	8,470	9,229	9,882	10,610	11,465	12,307	13,041	13,776	14,547	15,353
	45-49	4,760	5,307	6,363	7,738	8,830	9,606	10,236	10,722	11,538	12,408	13,315	14,281	15,309
	50-54	4,506	4,875	5,535	6,597	7,933	8,957	9,697	10,084	10,525	11,350	12,320	13,367	14,495
	55-59	4,030	4,487	5,003	5,668	6,231	7,302	8,209	8,673	8,989	9,406	9,865	10,342	10,837
	60-64	3,181	3,867	4,402	4,943	5,494	5,967	6,965	7,644	8,050	8,366	8,675	8,991	9,314
	65-69	2,389	2,987	3,696	4,209	4,635	5,088	5,507	6,277	6,874	7,260	7,621	7,996	8,386
	70-74	1,688	2,245	2,851	3,538	3,965	4,324	4,730	5,003	5,693	6,256	6,792	7,370	7,993
	75-79	1,259	1,537	2,066	2,636	3,183	3,524	3,839	4,104	4,338	4,959	5,770	6,710	7,800
	80-84	869	1,036	1,334	1,805	2,166	2,572	2,844	3,042	3,251	3,461	3,680	3,910	4,154

	85+	917	1,053	1,299	1,654	2,214	2,785	3,398	3,856	4,255	4,665	5,109	5,593	6,119
		77,880	87,740	100,056	113,083	126,296	139,244	152,459	162,463	172,077	182,261	193,047	204,472	216,572
Bankstown - North-East	0-4	5,328	5,591	5,882	6,181	6,465	6,814	7,232	7,702	8,152	8,585	9,031	9,494	9,975
	5-9	4,804	5,336	5,764	6,060	6,268	6,530	6,888	7,367	7,868	8,338	8,818	9,321	9,846
	10-14	4,565	4,870	5,505	5,935	6,174	6,371	6,645	7,066	7,579	8,104	8,652	9,233	9,846
	15-19	4,511	4,764	5,206	5,837	6,227	6,463	6,678	7,021	7,483	8,029	8,620	9,249	9,917
	20-24	4,661	4,683	5,053	5,477	5,874	6,193	6,429	6,693	7,048	7,505	8,003	8,530	9,087
	25-29	4,695	4,693	4,844	5,124	5,535	5,927	6,249	6,540	6,829	7,196	7,595	8,012	8,446
	30-34	4,756	4,924	5,049	5,163	5,351	5,739	6,141	6,524	6,849	7,163	7,486	7,820	8,163
	35-39	4,525	4,924	5,243	5,337	5,460	5,661	6,071	6,546	6,975	7,334	7,688	8,055	8,435
	40-44	4,416	4,645	5,193	5,512	5,737	5,904	6,130	6,625	7,163	7,644	8,131	8,645	9,185
	45-49	4,303	4,506	4,859	5,421	5,864	6,131	6,319	6,619	7,175	7,771	8,396	9,067	9,785
	50-54	4,283	4,343	4,678	5,028	5,689	6,176	6,468	6,726	7,072	7,680	8,395	9,171	10,012
	55-59	3,967	4,173	4,355	4,698	4,925	5,543	6,029	6,371	6,652	7,010	7,403	7,814	8,243
	60-64	3,331	3,764	4,064	4,284	4,522	4,720	5,326	5,849	6,204	6,493	6,780	7,075	7,378
	65-69	2,820	3,142	3,652	3,957	4,151	4,378	4,583	5,225	5,763	6,130	6,480	6,845	7,227
	70-74	2,188	2,652	3,034	3,538	3,779	3,960	4,189	4,432	5,081	5,622	6,146	6,715	7,332
	75-79	1,732	1,983	2,486	2,880	3,283	3,494	3,682	3,937	4,192	4,826	5,654	6,621	7,747
	80-84	1,381	1,438	1,729	2,204	2,519	2,874	3,075	3,289	3,541	3,796	4,064	4,349	4,650
	85+	1,592	1,677	1,843	2,193	2,792	3,377	3,985	4,526	5,031	5,555	6,126	6,752	7,437
		67,856	72,107	78,441	84,828	90,615	96,256	102,120	109,060	116,656	124,781	133,471	142,767	152,710
Bankstown - North-West	0-4	5,449	5,741	5,945	6,110	6,256	6,474	6,757	7,068	7,344	7,594	7,843	8,095	8,349
	5-9	4,915	5,480	5,826	5,990	6,066	6,204	6,436	6,761	7,088	7,375	7,658	7,947	8,241
	10-14	4,671	5,001	5,563	5,867	5,975	6,053	6,209	6,485	6,828	7,168	7,514	7,871	8,241
	15-19	4,617	4,893	5,261	5,769	6,026	6,141	6,240	6,443	6,742	7,102	7,485	7,885	8,301
	20-24	4,771	4,808	5,107	5,414	5,684	5,884	6,008	6,143	6,350	6,638	6,950	7,273	7,605
	25-29	4,805	4,818	4,896	5,065	5,356	5,630	5,839	6,002	6,153	6,365	6,596	6,831	7,070
	30-34	4,865	5,056	5,103	5,104	5,178	5,452	5,738	5,987	6,171	6,336	6,502	6,667	6,833
	35-39	4,630	5,057	5,299	5,276	5,284	5,379	5,672	6,007	6,284	6,487	6,677	6,868	7,060
	40-44	4,518	4,770	5,247	5,449	5,552	5,609	5,728	6,079	6,454	6,761	7,061	7,370	7,688
	45-49	4,405	4,627	4,910	5,357	5,674	5,825	5,905	6,074	6,464	6,873	7,291	7,730	8,190
	50-54	4,383	4,459	4,728	4,970	5,504	5,867	6,044	6,173	6,372	6,793	7,290	7,818	8,379
	55-59	4,057	4,285	4,402	4,643	4,766	5,265	5,633	5,847	5,993	6,200	6,429	6,662	6,899
	60-64	3,407	3,866	4,107	4,235	4,376	4,485	4,976	5,367	5,590	5,744	5,888	6,032	6,176
	65-69	2,883	3,227	3,690	3,912	4,017	4,160	4,283	4,794	5,192	5,422	5,627	5,836	6,049
	70-74	2,237	2,725	3,065	3,497	3,657	3,762	3,914	4,068	4,576	4,973	5,337	5,724	6,136
	75-79	1,772	2,036	2,511	2,846	3,176	3,320	3,440	3,613	3,777	4,268	4,909	5,643	6,483
	80-84	1,415	1,477	1,747	2,178	2,437	2,730	2,873	3,019	3,190	3,358	3,529	3,708	3,892
	85+	1,628	1,721	1,862	2,167	2,700	3,208	3,723	4,153	4,532	4,913	5,319	5,756	6,224

		69,428	74,046	79,268	83,850	87,685	91,447	95,418	100,082	105,100	110,370	115,903	121,715	127,817
Bankstown - South	0-4	4,464	4,572	4,587	4,729	4,890	5,103	5,369	5,545	5,661	5,751	5,835	5,916	5,995
	5-9	4,027	4,363	4,495	4,636	4,741	4,891	5,114	5,304	5,463	5,585	5,697	5,808	5,918
	10-14	3,827	3,982	4,290	4,541	4,670	4,771	4,934	5,087	5,263	5,427	5,590	5,753	5,918
	15-19	3,784	3,896	4,059	4,465	4,710	4,841	4,958	5,055	5,196	5,377	5,568	5,763	5,960
	20-24	3,910	3,830	3,940	4,190	4,442	4,638	4,773	4,819	4,894	5,026	5,170	5,315	5,461
	25-29	3,938	3,838	3,778	3,920	4,186	4,439	4,639	4,708	4,743	4,820	4,907	4,993	5,077
	30-34	3,986	4,027	3,938	3,950	4,047	4,298	4,559	4,697	4,756	4,798	4,837	4,873	4,907
	35-39	3,794	4,027	4,089	4,083	4,130	4,240	4,507	4,712	4,843	4,912	4,967	5,020	5,070
	40-44	3,702	3,799	4,047	4,217	4,340	4,422	4,551	4,769	4,974	5,120	5,253	5,387	5,520
	45-49	3,609	3,685	3,788	4,147	4,435	4,592	4,692	4,766	4,982	5,204	5,424	5,649	5,881
	50-54	3,592	3,552	3,647	3,847	4,303	4,625	4,802	4,843	4,911	5,143	5,423	5,713	6,016
	55-59	3,323	3,413	3,396	3,594	3,725	4,151	4,476	4,587	4,619	4,695	4,783	4,869	4,954
	60-64	2,791	3,078	3,169	3,278	3,421	3,535	3,954	4,210	4,309	4,350	4,380	4,409	4,435
	65-69	2,361	2,569	2,846	3,027	3,140	3,279	3,403	3,760	4,002	4,106	4,186	4,265	4,344
	70-74	1,832	2,168	2,365	2,707	2,858	2,966	3,110	3,191	3,526	3,765	3,970	4,184	4,406
	75-79	1,452	1,621	1,936	2,203	2,483	2,617	2,734	2,834	2,911	3,231	3,651	4,123	4,654
	80-84	1,160	1,176	1,347	1,686	1,905	2,152	2,283	2,368	2,458	2,543	2,626	2,710	2,795
	85+	1,333	1,371	1,437	1,677	2,111	2,529	2,959	3,257	3,493	3,720	3,957	4,206	4,469
		56,884	58,968	61,154	64,896	68,537	72,090	75,818	78,514	81,004	83,572	86,223	88,957	91,778
Blacktown - North	0-4	8,996	10,612	12,962	15,138	17,702	20,663	23,233	25,042	26,603	28,129	29,710	31,363	33,090
	5-9	8,097	9,853	12,385	14,708	17,059	19,682	21,998	23,812	25,526	27,159	28,840	30,610	32,470
	10-14	7,464	8,811	11,401	13,858	16,173	18,478	20,425	21,983	23,667	25,406	27,236	29,184	31,254
	15-19	7,304	8,225	10,376	12,944	15,423	17,719	19,397	20,643	22,086	23,791	25,646	27,631	29,753
	20-24	7,333	8,241	9,945	12,142	14,622	17,065	18,766	19,776	20,902	22,345	23,927	25,608	27,392
	25-29	8,130	9,047	10,819	12,726	15,375	18,222	20,350	21,554	22,594	23,901	25,330	26,831	28,406
	30-34	8,671	10,013	11,836	13,740	16,003	19,014	21,551	23,169	24,413	25,635	26,901	28,215	29,578
	35-39	8,241	9,921	12,178	13,994	16,070	18,454	20,974	22,885	24,475	25,836	27,196	28,612	30,086
	40-44	7,622	9,083	11,657	13,875	16,191	18,445	20,295	22,201	24,096	25,814	27,572	29,435	31,406
	45-49	6,918	8,263	10,497	13,035	15,750	18,224	19,900	21,100	22,960	24,964	27,084	29,368	31,828
	50-54	6,367	7,359	9,396	11,524	14,668	17,609	19,531	20,558	21,697	23,657	25,963	28,479	31,222
	55-59	5,635	6,649	8,229	10,152	11,950	14,913	17,168	18,357	19,238	20,353	21,583	22,876	24,233
	60-64	4,797	5,790	7,310	8,781	10,412	12,030	14,392	15,985	17,021	17,884	18,749	19,646	20,575
	65-69	3,871	4,814	6,237	7,651	9,023	10,540	11,688	13,487	14,932	15,944	16,922	17,951	19,032
	70-74	2,724	3,901	5,167	6,512	7,721	8,959	10,042	10,753	12,372	13,746	15,087	16,552	18,148
	75-79	1,841	2,654	4,048	5,233	6,676	7,856	8,770	9,490	10,143	11,726	13,793	16,217	19,057
	80-84	1,263	1,680	2,592	3,857	4,949	6,254	7,080	7,666	8,283	8,916	9,584	10,298	11,058
	85+	1,151	1,611	2,346	3,477	5,040	6,742	8,420	9,670	10,789	11,961	13,244	14,657	16,212
		106,426	126,527	159,380	193,348	230,808	270,867	303,978	328,131	351,796	377,167	404,369	433,532	464,798

Blacktown - South-East	0-4	9,593	10,179	10,231	10,249	10,434	10,771	11,561	12,134	12,558	12,936	13,310	13,688	14,069
	5-9	8,629	9,442	9,768	9,955	10,058	10,262	10,947	11,538	12,049	12,489	12,920	13,359	13,805
	10-14	7,943	8,448	8,981	9,376	9,535	9,636	10,165	10,652	11,171	11,683	12,201	12,736	13,288
	15-19	7,774	7,896	8,178	8,750	9,089	9,240	9,654	10,003	10,425	10,940	11,489	12,058	12,649
	20-24	7,803	7,912	7,851	8,211	8,614	8,896	9,340	9,583	9,867	10,275	10,719	11,176	11,646
	25-29	8,657	8,690	8,542	8,614	9,055	9,497	10,128	10,445	10,666	10,991	11,348	11,710	12,077
	30-34	9,244	9,610	9,352	9,303	9,433	9,908	10,724	11,227	11,525	11,789	12,052	12,315	12,576
	35-39	8,782	9,510	9,612	9,479	9,475	9,623	10,436	11,088	11,553	11,882	12,184	12,488	12,792
	40-44	8,125	8,710	9,185	9,392	9,544	9,620	10,101	10,756	11,374	11,871	12,352	12,846	13,353
	45-49	7,366	7,921	8,274	8,813	9,278	9,503	9,905	10,224	10,837	11,479	12,132	12,816	13,531
	50-54	6,782	7,062	7,403	7,794	8,629	9,177	9,720	9,962	10,242	10,878	11,630	12,427	13,273
	55-59	6,006	6,377	6,492	6,864	7,044	7,763	8,543	8,895	9,082	9,360	9,669	9,984	10,303
	60-64	5,113	5,549	5,764	5,942	6,135	6,273	7,159	7,745	8,035	8,225	8,400	8,575	8,748
	65-69	4,139	4,614	4,913	5,175	5,318	5,494	5,817	6,533	7,048	7,332	7,581	7,834	8,092
	70-74	2,914	3,726	4,071	4,402	4,551	4,671	4,997	5,210	5,838	6,320	6,758	7,223	7,715
	75-79	1,966	2,533	3,175	3,537	3,928	4,096	4,364	4,598	4,788	5,390	6,177	7,075	8,099
	80-84	1,348	1,607	2,032	2,599	2,913	3,255	3,524	3,714	3,910	4,100	4,294	4,494	4,701
	85+	1,233	1,540	1,842	2,343	2,959	3,507	4,188	4,685	5,092	5,499	5,932	6,396	6,892
		113,417	121,325	125,666	130,795	135,994	141,192	151,273	158,992	166,058	173,439	181,148	189,199	197,609
Blacktown - South West	0-4	8,803	9,126	9,156	9,053	9,094	9,279	9,855	10,352	10,751	11,112	11,473	11,840	12,211
	5-9	7,923	8,465	8,742	8,793	8,767	8,841	9,332	9,843	10,315	10,729	11,137	11,555	11,982
	10-14	7,303	7,574	8,037	8,281	8,311	8,302	8,665	9,088	9,563	10,036	10,517	11,016	11,533
	15-19	7,147	7,079	7,319	7,728	7,922	7,960	8,230	8,534	8,925	9,398	9,903	10,430	10,979
	20-24	7,176	7,093	7,026	7,251	7,508	7,664	7,962	8,176	8,447	8,827	9,239	9,667	10,108
	25-29	7,956	7,790	7,645	7,608	7,892	8,182	8,633	8,911	9,131	9,442	9,782	10,129	10,482
	30-34	8,485	8,615	8,370	8,217	8,222	8,535	9,142	9,578	9,866	10,127	10,389	10,652	10,915
	35-39	8,064	8,526	8,602	8,373	8,259	8,290	8,896	9,460	9,890	10,207	10,502	10,801	11,102
	40-44	7,458	7,809	8,220	8,295	8,319	8,288	8,610	9,177	9,737	10,197	10,647	11,111	11,589
	45-49	6,769	7,101	7,405	7,783	8,087	8,187	8,443	8,723	9,277	9,861	10,458	11,085	11,744
	50-54	6,230	6,331	6,626	6,884	7,520	7,906	8,286	8,499	8,768	9,344	10,025	10,749	11,520
	55-59	5,514	5,718	5,810	6,062	6,140	6,687	7,282	7,589	7,775	8,040	8,335	8,636	8,942
	60-64	4,694	4,975	5,158	5,248	5,348	5,404	6,102	6,607	6,878	7,065	7,241	7,417	7,593
	65-69	3,787	4,137	4,397	4,570	4,635	4,733	4,959	5,574	6,033	6,299	6,535	6,776	7,023
	70-74	2,665	3,341	3,643	3,887	3,967	4,024	4,260	4,445	4,998	5,429	5,826	6,247	6,696
	75-79	1,802	2,271	2,841	3,124	3,423	3,529	3,720	3,923	4,099	4,630	5,325	6,120	7,030
	80-84	1,236	1,441	1,818	2,294	2,539	2,804	3,004	3,169	3,347	3,522	3,701	3,887	4,080
	85+	1,126	1,381	1,648	2,068	2,578	3,021	3,570	3,997	4,359	4,724	5,114	5,532	5,982
		104,138	108,774	112,465	115,520	118,529	121,635	128,951	135,643	142,160	148,990	156,147	163,649	171,511
Blue	0-4	4,848	5,004	5,229	5,358	5,520	5,802	6,069	6,325	6,544	6,739	6,930	7,121	7,311

Mountains														
	5-9	4,994	5,249	5,512	5,792	5,941	6,172	6,417	6,715	7,011	7,264	7,511	7,760	8,010
	10-14	4,994	5,023	5,380	5,697	5,860	6,030	6,200	6,451	6,763	7,070	7,380	7,697	8,022
	15-19	4,841	4,759	4,909	5,292	5,556	5,751	5,856	6,025	6,277	6,585	6,911	7,248	7,595
	20-24	3,917	3,786	3,807	3,971	4,196	4,413	4,515	4,600	4,734	4,928	5,138	5,353	5,572
	25-29	3,578	3,503	3,448	3,518	3,742	3,996	4,152	4,252	4,341	4,472	4,614	4,758	4,902
	30-34	4,116	4,258	4,249	4,245	4,341	4,643	4,897	5,091	5,224	5,342	5,458	5,572	5,685
	35-39	4,717	4,994	5,239	5,244	5,298	5,479	5,790	6,109	6,364	6,542	6,705	6,866	7,026
	40-44	5,370	5,165	5,587	5,933	6,124	6,285	6,432	6,801	7,189	7,500	7,800	8,106	8,416
	45-49	5,609	5,486	5,465	5,961	6,378	6,651	6,757	6,925	7,338	7,770	8,207	8,663	9,136
	50-54	5,709	5,637	5,653	5,697	6,313	6,836	7,056	7,180	7,380	7,835	8,372	8,939	9,536
	55-59	5,946	5,666	5,757	5,839	5,979	6,711	7,194	7,439	7,593	7,822	8,076	8,333	8,590
	60-64	5,712	5,901	5,785	5,942	6,204	6,458	7,180	7,716	8,003	8,189	8,359	8,526	8,689
	65-69	4,908	5,466	5,785	5,810	5,958	6,267	6,467	7,211	7,777	8,088	8,358	8,630	8,904
	70-74	3,495	4,502	5,126	5,499	5,714	5,971	6,226	6,446	7,220	7,814	8,350	8,917	9,515
	75-79	2,326	3,114	4,089	4,669	5,253	5,576	5,791	6,058	6,306	7,096	8,128	9,302	10,637
	80-84	1,596	1,907	2,582	3,415	3,879	4,413	4,655	4,872	5,126	5,374	5,625	5,883	6,147
	85+	1,644	1,803	2,139	2,858	3,676	4,437	5,159	5,733	6,230	6,726	7,251	7,811	8,408
		78,320	81,220	85,741	90,741	95,931	101,891	106,816	111,950	117,419	123,156	129,172	135,483	142,102
Botany Bay	0-4	2,871	3,133	3,209	3,379	3,544	3,732	3,955	4,140	4,292	4,428	4,562	4,698	4,834
	5-9	2,507	2,722	2,941	3,108	3,219	3,349	3,528	3,709	3,880	4,028	4,172	4,320	4,469
	10-14	2,190	2,394	2,618	2,894	3,034	3,127	3,258	3,405	3,577	3,747	3,918	4,095	4,277
	15-19	2,167	2,301	2,526	2,800	2,981	3,091	3,189	3,296	3,440	3,616	3,802	3,996	4,197
	20-24	2,707	2,636	2,803	3,043	3,267	3,441	3,568	3,651	3,765	3,927	4,102	4,283	4,468
	25-29	3,314	3,206	3,246	3,425	3,702	3,960	4,169	4,289	4,387	4,528	4,681	4,836	4,994
	30-34	3,567	3,656	3,670	3,770	3,918	4,197	4,485	4,683	4,816	4,934	5,051	5,167	5,283
	35-39	3,384	3,760	3,928	4,013	4,116	4,263	4,566	4,839	5,050	5,201	5,341	5,481	5,621
	40-44	3,114	3,367	3,733	3,985	4,159	4,274	4,433	4,708	4,986	5,212	5,431	5,655	5,885
	45-49	2,797	3,040	3,227	3,688	4,016	4,194	4,317	4,445	4,719	5,006	5,298	5,604	5,924
	50-54	2,480	2,675	2,895	3,136	3,558	3,858	4,035	4,125	4,248	4,518	4,837	5,176	5,534
	55-59	2,220	2,394	2,545	2,800	2,949	3,316	3,602	3,741	3,826	3,949	4,085	4,223	4,363
	60-64	2,050	2,179	2,314	2,530	2,694	2,809	3,165	3,416	3,550	3,639	3,722	3,804	3,886
	65-69	1,790	1,974	2,093	2,296	2,429	2,559	2,675	2,997	3,238	3,374	3,493	3,615	3,738
	70-74	1,537	1,702	1,890	2,072	2,185	2,287	2,416	2,513	2,820	3,058	3,274	3,504	3,747
	75-79	1,174	1,441	1,586	1,820	2,086	2,218	2,334	2,453	2,558	2,884	3,310	3,796	4,350
	80-84	867	1,001	1,198	1,410	1,587	1,808	1,932	2,032	2,142	2,249	2,359	2,472	2,589
	85+	800	954	1,152	1,438	1,844	2,228	2,626	2,930	3,191	3,451	3,728	4,024	4,341
		41,538	44,534	47,573	51,606	55,289	58,711	62,255	65,371	68,486	71,749	75,167	78,749	82,501
Burwood	0-4	2,010	2,376	2,599	2,706	2,788	2,885	3,005	3,253	3,527	3,805	4,099	4,413	4,749
	5-9	1,708	2,034	2,336	2,538	2,609	2,668	2,762	3,002	3,285	3,565	3,862	4,180	4,523
	10-14	1,641	1,818	2,130	2,420	2,515	2,547	2,608	2,818	3,097	3,392	3,709	4,053	4,427

	15-19	1,915	1,984	2,160	2,420	2,551	2,600	2,636	2,816	3,076	3,381	3,717	4,084	4,485
	20-24	3,411	3,372	3,450	3,624	3,825	3,959	4,034	4,268	4,605	5,022	5,485	5,988	6,532
	25-29	4,345	4,408	4,437	4,532	4,806	5,051	5,228	5,559	5,948	6,420	6,940	7,498	8,095
	30-34	3,249	3,578	3,655	3,663	3,737	3,934	4,132	4,461	4,798	5,140	5,502	5,886	6,292
	35-39	2,538	3,070	3,332	3,367	3,399	3,459	3,641	3,990	4,356	4,691	5,036	5,404	5,795
	40-44	2,207	2,522	2,981	3,229	3,332	3,367	3,431	3,768	4,175	4,562	4,971	5,412	5,889
	45-49	2,121	2,258	2,531	2,933	3,158	3,241	3,279	3,490	3,877	4,301	4,759	5,263	5,817
	50-54	2,129	2,111	2,257	2,518	2,841	3,027	3,112	3,288	3,543	3,942	4,412	4,936	5,519
	55-59	1,953	2,082	2,101	2,242	2,322	2,565	2,739	2,941	3,146	3,396	3,674	3,971	4,290
	60-64	1,631	1,858	2,023	2,034	2,097	2,149	2,379	2,655	2,886	3,094	3,308	3,536	3,776
	65-69	1,405	1,584	1,808	1,955	2,029	2,101	2,158	2,501	2,826	3,079	3,333	3,606	3,899
	70-74	1,152	1,369	1,573	1,788	1,876	1,930	2,004	2,154	2,531	2,868	3,211	3,593	4,018
	75-79	1,006	1,105	1,358	1,551	1,742	1,821	1,883	2,046	2,232	2,633	3,160	3,789	4,541
	80-84	831	909	1,046	1,284	1,443	1,616	1,697	1,845	2,035	2,235	2,450	2,685	2,941
	85+	937	1,095	1,241	1,442	1,804	2,143	2,482	2,866	3,264	3,691	4,169	4,705	5,308
		36,189	39,534	43,018	46,245	48,873	51,063	53,210	57,721	63,208	69,217	75,798	83,003	90,894
Camden	0-4	4,495	6,470	8,218	9,665	11,449	13,494	15,697	16,703	17,311	17,861	18,409	18,964	19,526
	5-9	4,884	6,176	8,286	10,110	11,899	13,862	16,029	17,129	17,913	18,598	19,272	19,961	20,663
	10-14	4,552	6,070	7,549	9,692	11,594	13,375	15,295	16,253	17,069	17,880	18,706	19,559	20,441
	15-19	4,134	5,359	6,998	8,518	10,213	11,846	13,415	14,097	14,713	15,465	16,268	17,104	17,973
	20-24	4,034	4,970	6,205	7,807	9,560	11,265	12,815	13,335	13,749	14,341	14,986	15,651	16,338
	25-29	4,704	5,851	6,814	8,116	9,962	11,921	13,773	14,403	14,729	15,203	15,723	16,252	16,791
	30-34	5,016	7,020	8,183	9,195	10,778	12,931	15,164	16,093	16,543	16,951	17,358	17,767	18,175
	35-39	4,816	6,998	9,060	10,250	11,854	13,744	16,164	17,408	18,163	18,710	19,219	19,732	20,247
	40-44	4,659	6,035	8,361	10,437	12,412	14,276	16,251	17,549	18,582	19,426	20,248	21,094	21,964
	45-49	4,044	5,514	6,972	9,308	11,549	13,492	15,240	15,956	16,935	17,968	19,023	20,130	21,289
	50-54	3,566	4,738	6,239	7,689	9,909	12,010	13,779	14,321	14,744	15,685	16,798	17,981	19,237
	55-59	3,087	4,092	5,306	6,785	8,129	10,244	12,201	12,879	13,167	13,592	14,066	14,548	15,039
	60-64	2,628	3,542	4,596	5,797	7,020	8,189	10,141	11,113	11,545	11,837	12,110	12,383	12,656
	65-69	2,148	2,943	3,936	4,959	5,944	7,011	8,043	9,160	9,896	10,312	10,680	11,056	11,439
	70-74	1,494	2,415	3,243	4,239	5,121	6,000	6,958	7,355	8,253	8,949	9,585	10,262	10,980
	75-79	1,093	1,686	2,617	3,451	4,470	5,311	6,134	6,552	6,832	7,704	8,844	10,147	11,636
	80-84	752	1,159	1,742	2,656	3,467	4,423	5,180	5,537	5,836	6,130	6,431	6,743	7,066
	85+	859	1,213	1,750	2,589	3,798	5,128	6,629	7,510	8,175	8,843	9,555	10,319	11,138
		60,965	82,251	106,074	131,265	159,127	188,520	218,907	233,355	244,156	255,457	267,281	279,652	292,596
Campbelltown - North	0-4	6,222	7,224	8,213	8,725	9,217	9,823	10,500	11,010	11,409	11,765	12,117	12,472	12,829
	5-9	5,531	6,709	7,933	8,743	9,205	9,696	10,302	10,848	11,343	11,770	12,187	12,612	13,044
	10-14	5,323	5,997	7,430	8,481	8,999	9,388	9,864	10,327	10,844	11,353	11,868	12,399	12,946
	15-19	5,595	5,823	6,780	8,089	8,810	9,245	9,621	9,959	10,393	10,918	11,476	12,056	12,657
	20-24	5,912	6,036	6,538	7,377	8,068	8,601	8,993	9,218	9,504	9,907	10,345	10,795	11,258

	25-29	6,045	6,433	6,775	7,193	7,855	8,503	9,030	9,304	9,514	9,814	10,142	10,475	10,812
	30-34	5,862	6,680	7,180	7,411	7,766	8,422	9,077	9,494	9,759	9,993	10,226	10,458	10,688
	35-39	5,319	6,494	7,484	7,823	8,114	8,507	9,189	9,754	10,176	10,476	10,753	11,031	11,308
	40-44	5,019	5,797	7,220	8,040	8,515	8,859	9,265	9,858	10,437	10,904	11,357	11,822	12,297
	45-49	4,866	5,386	6,408	7,704	8,524	9,011	9,355	9,647	10,238	10,856	11,485	12,143	12,831
	50-54	5,005	5,059	5,830	6,718	7,779	8,537	9,005	9,220	9,491	10,091	10,799	11,550	12,345
	55-59	4,907	5,059	5,383	6,052	6,465	7,358	8,061	8,386	8,572	8,844	9,145	9,451	9,761
	60-64	4,306	4,808	5,221	5,467	5,819	6,141	6,980	7,544	7,837	8,031	8,210	8,388	8,564
	65-69	3,456	4,179	4,885	5,214	5,509	5,875	6,195	6,951	7,509	7,820	8,093	8,371	8,652
	70-74	2,212	3,344	4,188	4,832	5,188	5,497	5,857	6,102	6,846	7,419	7,940	8,493	9,080
	75-79	1,422	2,110	3,284	4,030	4,671	5,026	5,334	5,614	5,854	6,596	7,566	8,674	9,938
	80-84	904	1,248	1,905	2,890	3,422	3,948	4,254	4,480	4,722	4,957	5,196	5,443	5,699
	85+	835	1,081	1,525	2,229	2,959	3,619	4,301	4,807	5,232	5,656	6,107	6,590	7,107
		78,741	89,471	104,181	117,018	126,884	136,055	145,182	152,524	159,679	167,169	175,011	183,221	191,816
Campbelltown - South	0-4	5,039	5,279	5,292	5,109	5,065	5,128	5,220	5,271	5,273	5,248	5,218	5,184	5,148
	5-9	4,479	4,897	5,108	5,117	5,060	5,063	5,122	5,193	5,242	5,250	5,248	5,242	5,234
	10-14	4,311	4,383	4,778	4,962	4,946	4,902	4,905	4,944	5,011	5,064	5,110	5,154	5,194
	15-19	4,531	4,262	4,364	4,728	4,842	4,827	4,784	4,768	4,803	4,870	4,941	5,011	5,078
	20-24	4,787	4,421	4,215	4,315	4,433	4,490	4,472	4,414	4,392	4,419	4,454	4,487	4,517
	25-29	4,895	4,709	4,372	4,211	4,316	4,439	4,490	4,455	4,397	4,378	4,367	4,354	4,338
	30-34	4,748	4,884	4,632	4,341	4,268	4,396	4,513	4,545	4,510	4,458	4,404	4,347	4,289
	35-39	4,307	4,739	4,822	4,582	4,460	4,442	4,568	4,669	4,703	4,674	4,631	4,585	4,538
	40-44	4,065	4,236	4,643	4,706	4,680	4,626	4,607	4,719	4,823	4,864	4,890	4,914	4,934
	45-49	3,941	3,937	4,124	4,503	4,684	4,705	4,652	4,619	4,731	4,842	4,945	5,047	5,148
	50-54	4,053	3,706	3,753	3,929	4,272	4,456	4,478	4,415	4,386	4,501	4,649	4,800	4,952
	55-59	3,974	3,706	3,472	3,540	3,553	3,839	4,007	4,015	3,962	3,945	3,938	3,928	3,916
	60-64	3,487	3,516	3,367	3,201	3,198	3,206	3,468	3,611	3,622	3,583	3,535	3,487	3,437
	65-69	2,799	3,054	3,145	3,053	3,028	3,067	3,080	3,326	3,469	3,488	3,485	3,479	3,472
	70-74	1,792	2,432	2,695	2,826	2,851	2,870	2,912	2,921	3,162	3,309	3,419	3,530	3,642
	75-79	1,151	1,535	2,104	2,356	2,565	2,624	2,652	2,688	2,705	2,941	3,256	3,604	3,985
	80-84	732	909	1,221	1,685	1,880	2,060	2,115	2,145	2,182	2,211	2,237	2,262	2,286
	85+	676	788	978	1,300	1,623	1,888	2,137	2,301	2,417	2,523	2,629	2,739	2,851
		63,767	65,394	67,085	68,462	69,723	71,029	72,184	73,019	73,790	74,570	75,358	76,154	76,958
Canada Bay - Concord	0-4	2,785	3,331	3,757	3,866	3,965	4,110	4,280	4,411	4,504	4,577	4,646	4,712	4,777
	5-9	2,385	2,837	3,330	3,510	3,575	3,662	3,790	3,923	4,042	4,133	4,218	4,301	4,384
	10-14	1,985	2,581	3,036	3,309	3,409	3,459	3,541	3,643	3,770	3,889	4,007	4,125	4,244
	15-19	1,921	2,322	2,909	3,177	3,311	3,379	3,426	3,486	3,584	3,711	3,844	3,979	4,117
	20-24	2,750	2,949	3,369	3,745	3,983	4,130	4,207	4,239	4,306	4,423	4,552	4,681	4,810
	25-29	3,781	3,979	4,258	4,422	4,690	4,939	5,110	5,175	5,214	5,301	5,399	5,495	5,589

	30-34	4,032	4,579	4,825	4,829	4,915	5,183	5,443	5,596	5,668	5,720	5,768	5,813	5,855
	35-39	3,588	4,346	4,839	4,817	4,835	4,930	5,188	5,413	5,565	5,646	5,711	5,773	5,832
	40-44	3,256	3,798	4,511	4,743	4,856	4,914	5,007	5,235	5,461	5,623	5,772	5,921	6,069
	45-49	2,910	3,551	4,102	4,560	4,858	4,996	5,053	5,122	5,355	5,596	5,835	6,079	6,330
	50-54	2,673	3,162	3,788	4,089	4,557	4,865	5,000	5,033	5,105	5,348	5,640	5,944	6,261
	55-59	2,429	2,906	3,392	3,774	3,919	4,337	4,630	4,734	4,769	4,849	4,941	5,032	5,121
	60-64	2,061	2,543	3,025	3,309	3,467	3,558	3,939	4,186	4,285	4,327	4,360	4,389	4,417
	65-69	1,849	2,173	2,666	2,965	3,085	3,200	3,287	3,625	3,859	3,961	4,039	4,117	4,194
	70-74	1,425	1,933	2,263	2,644	2,790	2,875	2,985	3,056	3,378	3,608	3,806	4,012	4,226
	75-79	1,112	1,440	1,950	2,157	2,397	2,510	2,595	2,685	2,758	3,062	3,462	3,911	4,415
	80-84	852	1,020	1,334	1,704	1,919	2,153	2,261	2,341	2,431	2,515	2,598	2,682	2,767
	85+	884	1,034	1,265	1,549	1,951	2,321	2,688	2,954	3,168	3,375	3,591	3,819	4,059
		42,678	50,483	58,617	63,170	66,482	69,522	72,430	74,855	77,223	79,666	82,185	84,785	87,467
Canada Bay - Drummoyne	0-4	2,528	2,638	2,639	2,699	2,810	2,947	3,100	3,187	3,236	3,271	3,302	3,331	3,359
	5-9	2,162	2,250	2,337	2,450	2,533	2,625	2,745	2,834	2,904	2,954	2,998	3,041	3,082
	10-14	1,800	2,041	2,131	2,311	2,415	2,480	2,564	2,632	2,709	2,779	2,848	2,916	2,984
	15-19	1,743	1,839	2,039	2,218	2,346	2,423	2,481	2,518	2,575	2,652	2,732	2,813	2,894
	20-24	2,497	2,342	2,365	2,615	2,822	2,961	3,047	3,062	3,094	3,161	3,235	3,309	3,382
	25-29	3,431	3,164	2,993	3,087	3,324	3,541	3,701	3,739	3,747	3,788	3,837	3,884	3,930
	30-34	3,657	3,635	3,394	3,371	3,483	3,717	3,942	4,043	4,073	4,088	4,100	4,109	4,116
	35-39	3,255	3,442	3,401	3,363	3,426	3,535	3,757	3,910	3,998	4,035	4,059	4,081	4,101
	40-44	2,953	3,012	3,165	3,311	3,441	3,523	3,626	3,782	3,924	4,019	4,102	4,185	4,267
	45-49	2,640	2,812	2,880	3,184	3,443	3,582	3,659	3,700	3,848	3,999	4,147	4,297	4,450
	50-54	2,425	2,506	2,658	2,855	3,230	3,488	3,621	3,636	3,668	3,822	4,009	4,202	4,402
	55-59	2,203	2,303	2,381	2,635	2,777	3,110	3,353	3,420	3,427	3,465	3,512	3,557	3,601
	60-64	1,870	2,012	2,123	2,311	2,457	2,551	2,853	3,024	3,079	3,092	3,099	3,103	3,105
	65-69	1,676	1,724	1,869	2,070	2,186	2,294	2,381	2,618	2,772	2,830	2,871	2,910	2,949
	70-74	1,292	1,527	1,589	1,847	1,977	2,062	2,162	2,208	2,427	2,578	2,705	2,836	2,971
	75-79	1,009	1,138	1,365	1,506	1,699	1,799	1,879	1,939	1,982	2,188	2,460	2,764	3,104
	80-84	774	808	934	1,190	1,360	1,544	1,638	1,691	1,746	1,797	1,846	1,896	1,945
	85+	801	820	887	1,082	1,383	1,665	1,947	2,134	2,276	2,412	2,553	2,700	2,853
		38,718	40,014	41,150	44,105	47,110	49,846	52,455	54,076	55,485	56,931	58,414	59,936	61,497
Canterbury	0-4	11,426	11,877	12,243	12,530	12,949	13,487	14,120	14,588	14,922	15,192	15,449	15,700	15,946
	5-9	9,311	10,241	10,856	11,286	11,574	11,915	12,398	12,862	13,276	13,601	13,905	14,208	14,509
	10-14	8,091	8,616	9,582	10,191	10,505	10,712	11,022	11,369	11,784	12,181	12,572	12,969	13,370
	15-19	8,015	7,997	8,646	9,545	10,078	10,336	10,535	10,744	11,067	11,478	11,913	12,356	12,808
	20-24	9,476	9,312	9,470	10,097	10,748	11,199	11,469	11,583	11,787	12,132	12,507	12,887	13,270
	25-29	11,651	11,174	11,287	11,585	12,350	13,068	13,592	13,799	13,926	14,184	14,473	14,759	15,042
	30-34	11,983	12,019	11,915	12,109	12,467	13,212	13,948	14,374	14,583	14,744	14,897	15,042	15,180
	35-39	10,789	11,613	11,952	12,016	12,196	12,496	13,218	13,825	14,237	14,472	14,667	14,855	15,037

	40-44	10,142	10,486	11,484	11,960	12,321	12,529	12,833	13,451	14,057	14,501	14,912	15,326	15,742
	45-49	9,680	9,726	10,266	11,286	12,092	12,494	12,704	12,907	13,520	14,155	14,786	15,435	16,103
	50-54	8,989	9,143	9,405	9,976	11,204	12,020	12,419	12,528	12,730	13,361	14,118	14,909	15,734
	55-59	8,103	8,429	8,777	9,105	9,395	10,447	11,212	11,493	11,597	11,813	12,061	12,307	12,550
	60-64	6,926	7,619	8,112	8,488	8,887	9,167	10,201	10,867	11,143	11,274	11,379	11,479	11,573
	65-69	5,908	6,417	7,184	7,683	7,994	8,332	8,605	9,511	10,142	10,429	10,657	10,883	11,108
	70-74	4,819	5,467	6,070	6,850	7,221	7,478	7,803	8,009	8,867	9,489	10,028	10,591	11,179
	75-79	3,948	4,200	4,899	5,540	6,256	6,581	6,840	7,094	7,300	8,121	9,198	10,411	11,777
	80-84	2,980	3,110	3,438	4,108	4,617	5,205	5,495	5,702	5,931	6,148	6,363	6,581	6,803
	85+	2,612	3,016	3,428	3,958	4,968	5,940	6,915	7,617	8,183	8,734	9,311	9,921	10,563
		144,851	150,460	159,015	168,313	177,825	186,618	195,330	202,323	209,054	216,009	223,196	230,622	238,295
Fairfield - East	0-4	7,328	7,650	7,736	7,894	8,080	8,380	8,770	9,173	9,522	9,838	10,152	10,471	10,793
	5-9	6,657	7,456	7,791	7,990	8,098	8,301	8,634	9,069	9,499	9,875	10,246	10,625	11,012
	10-14	6,815	6,897	7,644	8,093	8,247	8,375	8,614	8,996	9,462	9,925	10,396	10,883	11,387
	15-19	7,276	7,238	7,368	8,171	8,578	8,761	8,926	9,217	9,634	10,140	10,680	11,242	11,827
	20-24	7,778	7,574	7,605	7,827	8,184	8,492	8,693	8,889	9,179	9,587	10,031	10,489	10,962
	25-29	7,481	7,457	7,368	7,445	7,841	8,262	8,590	8,829	9,043	9,346	9,678	10,016	10,360
	30-34	7,057	7,238	7,227	7,194	7,295	7,699	8,124	8,477	8,727	8,954	9,181	9,408	9,635
	35-39	6,657	7,212	7,388	7,414	7,451	7,602	8,039	8,513	8,896	9,176	9,437	9,701	9,966
	40-44	6,897	6,973	7,498	7,766	7,917	8,017	8,208	8,711	9,238	9,670	10,092	10,526	10,973
	45-49	7,005	7,014	7,121	7,752	8,223	8,461	8,600	8,847	9,404	9,991	10,591	11,221	11,881
	50-54	7,035	6,973	7,030	7,262	8,031	8,581	8,862	9,051	9,333	9,942	10,661	11,425	12,237
	55-59	6,811	6,826	6,793	6,986	7,137	7,903	8,478	8,799	9,010	9,313	9,650	9,993	10,342
	60-64	5,689	6,397	6,440	6,542	6,757	6,941	7,721	8,328	8,665	8,896	9,113	9,329	9,545
	65-69	4,507	5,281	5,955	6,129	6,258	6,495	6,705	7,505	8,120	8,473	8,786	9,106	9,432
	70-74	3,277	4,231	4,956	5,703	5,969	6,155	6,420	6,672	7,498	8,141	8,731	9,358	10,025
	75-79	2,622	3,000	3,877	4,642	5,234	5,483	5,697	5,982	6,247	7,054	8,108	9,313	10,692
	80-84	1,905	2,200	2,546	3,388	3,845	4,317	4,556	4,787	5,053	5,315	5,582	5,860	6,148
	85+	1,711	2,134	2,576	3,153	3,956	4,712	5,483	6,116	6,667	7,221	7,813	8,448	9,129
		127,861	133,576	139,473	147,349	154,007	160,653	167,799	175,836	184,391	193,363	202,771	212,637	222,982
Fairfield - West	0-4	4,187	4,366	4,539	4,653	4,762	4,940	5,168	5,468	5,756	6,031	6,313	6,604	6,904
	5-9	3,807	4,256	4,572	4,710	4,773	4,893	5,088	5,406	5,743	6,055	6,372	6,701	7,044
	10-14	3,898	3,936	4,487	4,770	4,861	4,936	5,076	5,362	5,720	6,085	6,465	6,864	7,284
	15-19	4,163	4,131	4,323	4,816	5,056	5,164	5,260	5,494	5,824	6,217	6,641	7,090	7,565
	20-24	4,449	4,323	4,462	4,614	4,824	5,006	5,123	5,298	5,549	5,878	6,238	6,615	7,012
	25-29	4,279	4,256	4,322	4,388	4,621	4,870	5,062	5,263	5,466	5,730	6,018	6,317	6,627
	30-34	4,033	4,131	4,240	4,241	4,300	4,538	4,788	5,052	5,276	5,490	5,709	5,933	6,163
	35-39	3,807	4,116	4,335	4,370	4,392	4,481	4,737	5,074	5,378	5,626	5,868	6,118	6,374
	40-44	3,945	3,980	4,401	4,578	4,666	4,726	4,837	5,192	5,585	5,929	6,276	6,639	7,019
	45-49	4,007	4,003	4,178	4,569	4,847	4,988	5,068	5,273	5,686	6,126	6,586	7,077	7,600

	50-54	4,025	3,980	4,125	4,280	4,733	5,058	5,222	5,395	5,642	6,096	6,630	7,206	7,828
	55-59	3,892	3,895	3,985	4,118	4,207	4,658	4,996	5,245	5,446	5,710	6,001	6,302	6,615
	60-64	3,251	3,651	3,778	3,856	3,983	4,091	4,550	4,964	5,238	5,454	5,666	5,884	6,106
	65-69	2,572	3,015	3,496	3,613	3,688	3,828	3,951	4,474	4,909	5,195	5,464	5,743	6,033
	70-74	1,873	2,416	2,910	3,361	3,518	3,628	3,784	3,977	4,534	4,992	5,430	5,902	6,413
	75-79	1,498	1,712	2,277	2,736	3,085	3,232	3,357	3,566	3,777	4,326	5,043	5,875	6,841
	80-84	1,089	1,256	1,495	1,997	2,266	2,545	2,685	2,853	3,055	3,259	3,471	3,696	3,932
	85+	976	1,218	1,513	1,858	2,332	2,777	3,231	3,646	4,031	4,428	4,859	5,328	5,840
		73,105	76,239	81,844	86,852	90,771	94,699	98,888	104,808	111,471	118,557	126,094	134,110	142,635
Hawkesbury	0-4	4,470	4,696	4,852	4,920	5,087	5,343	5,681	5,948	6,028	6,050	6,064	6,074	6,081
	5-9	4,310	4,611	4,880	5,079	5,223	5,423	5,731	6,024	6,161	6,222	6,270	6,315	6,356
	10-14	4,407	4,396	4,749	5,060	5,236	5,385	5,627	5,882	6,040	6,154	6,261	6,367	6,469
	15-19	4,579	4,358	4,396	4,790	5,072	5,246	5,430	5,612	5,727	5,855	5,990	6,124	6,257
	20-24	4,607	4,481	4,387	4,558	4,844	5,090	5,294	5,418	5,463	5,542	5,632	5,720	5,805
	25-29	4,307	4,292	4,238	4,269	4,549	4,854	5,128	5,275	5,275	5,296	5,327	5,354	5,378
	30-34	4,019	4,348	4,340	4,362	4,493	4,803	5,149	5,377	5,405	5,387	5,365	5,340	5,311
	35-39	3,995	4,320	4,638	4,697	4,778	4,937	5,304	5,622	5,736	5,747	5,741	5,732	5,719
	40-44	4,351	4,189	4,591	4,958	5,162	5,294	5,506	5,849	6,056	6,158	6,242	6,323	6,402
	45-49	4,635	4,340	4,275	4,725	5,096	5,310	5,483	5,646	5,859	6,047	6,226	6,406	6,588
	50-54	4,472	4,499	4,322	4,316	4,809	5,203	5,459	5,581	5,619	5,813	6,054	6,302	6,555
	55-59	4,057	4,207	4,303	4,214	4,301	4,824	5,257	5,460	5,460	5,481	5,517	5,548	5,577
	60-64	3,380	3,792	3,977	4,111	4,309	4,482	5,067	5,468	5,556	5,541	5,513	5,481	5,447
	65-69	2,974	3,172	3,575	3,823	3,985	4,189	4,393	4,921	5,198	5,269	5,308	5,343	5,375
	70-74	2,190	2,747	2,989	3,395	3,599	3,759	3,984	4,143	4,544	4,794	4,994	5,199	5,409
	75-79	1,491	1,966	2,495	2,753	3,093	3,281	3,463	3,640	3,711	4,068	4,542	5,067	5,650
	80-84	948	1,242	1,676	2,177	2,478	2,818	3,021	3,177	3,274	3,345	3,413	3,479	3,545
	85+	966	1,139	1,462	1,981	2,562	3,090	3,653	4,077	4,339	4,565	4,797	5,038	5,287
		64,159	66,796	70,141	74,189	78,676	83,332	88,631	93,119	95,451	97,334	99,254	101,213	103,209
Holroyd	0-4	8,484	8,855	9,092	9,319	9,670	10,096	10,586	11,005	11,341	11,633	11,917	12,202	12,487
	5-9	7,068	7,817	8,313	8,585	8,817	9,099	9,482	9,899	10,294	10,624	10,943	11,266	11,591
	10-14	5,951	6,697	7,470	7,914	8,181	8,362	8,618	8,945	9,341	9,727	10,115	10,513	10,919
	15-19	5,809	6,068	6,847	7,575	8,015	8,240	8,411	8,632	8,958	9,361	9,788	10,228	10,683
	20-24	6,721	6,595	6,938	7,648	8,216	8,581	8,801	8,944	9,170	9,508	9,876	10,252	10,637
	25-29	8,749	8,426	8,505	8,833	9,475	10,049	10,468	10,694	10,874	11,158	11,470	11,785	12,101
	30-34	9,391	9,502	9,431	9,521	9,821	10,433	11,030	11,438	11,692	11,910	12,123	12,333	12,539
	35-39	8,186	8,874	9,147	9,145	9,298	9,550	10,118	10,649	11,049	11,314	11,552	11,788	12,023
	40-44	6,953	7,671	8,432	8,732	9,016	9,191	9,428	9,944	10,470	10,882	11,274	11,674	12,081
	45-49	6,149	6,614	7,333	8,034	8,615	8,923	9,087	9,290	9,805	10,342	10,883	11,446	12,032
	50-54	5,760	5,885	6,434	7,079	8,019	8,623	8,923	9,058	9,273	9,806	10,439	11,106	11,810
	55-59	5,264	5,548	5,783	6,308	6,608	7,366	7,917	8,166	8,302	8,520	8,763	9,009	9,256
	60-64	4,619	5,029	5,398	5,647	5,930	6,131	6,833	7,325	7,567	7,713	7,843	7,971	8,097

	65-69	4,126	4,236	4,739	5,087	5,311	5,549	5,739	6,384	6,858	7,105	7,314	7,526	7,739
	70-74	3,170	3,781	4,014	4,481	4,740	4,920	5,143	5,311	5,925	6,388	6,801	7,237	7,696
	75-79	2,404	2,825	3,520	3,746	4,175	4,402	4,582	4,782	4,958	5,557	6,341	7,232	8,242
	80-84	1,709	1,977	2,429	3,002	3,397	3,839	4,059	4,238	4,442	4,638	4,836	5,040	5,249
	85+	1,778	1,968	2,310	2,828	3,599	4,313	5,029	5,574	6,033	6,488	6,968	7,480	8,024
		102,290	108,369	116,135	123,482	130,905	137,668	144,254	150,279	156,353	162,672	169,247	176,088	183,205
Hornsby - North	0-4	3,954	3,958	4,027	4,017	4,072	4,217	4,410	4,570	4,691	4,791	4,887	4,982	5,075
	5-9	4,260	4,281	4,404	4,458	4,485	4,590	4,771	4,965	5,143	5,285	5,420	5,555	5,690
	10-14	4,411	4,490	4,643	4,739	4,788	4,855	4,990	5,163	5,370	5,569	5,765	5,965	6,168
	15-19	4,556	4,494	4,669	4,804	4,932	5,030	5,122	5,240	5,416	5,635	5,866	6,103	6,345
	20-24	4,266	4,054	4,083	4,217	4,395	4,554	4,659	4,720	4,820	4,976	5,146	5,318	5,492
	25-29	3,599	3,419	3,344	3,353	3,511	3,695	3,839	3,909	3,959	4,045	4,140	4,235	4,329
	30-34	3,982	4,019	3,919	3,827	3,854	4,061	4,283	4,427	4,507	4,572	4,633	4,692	4,749
	35-39	4,553	4,744	4,864	4,736	4,704	4,792	5,064	5,313	5,491	5,599	5,691	5,782	5,870
	40-44	4,968	4,962	5,270	5,381	5,450	5,510	5,638	5,928	6,217	6,433	6,636	6,840	7,047
	45-49	5,088	5,042	5,151	5,449	5,719	5,876	5,968	6,082	6,394	6,715	7,035	7,367	7,708
	50-54	4,886	4,761	4,837	4,921	5,399	5,760	5,945	6,016	6,134	6,459	6,846	7,251	7,675
	55-59	4,371	4,358	4,356	4,414	4,477	4,949	5,306	5,456	5,525	5,645	5,781	5,917	6,052
	60-64	3,637	3,839	3,922	3,922	4,015	4,117	4,577	4,891	5,033	5,108	5,172	5,233	5,291
	65-69	3,098	3,235	3,496	3,557	3,612	3,744	3,862	4,283	4,582	4,727	4,845	4,963	5,080
	70-74	2,382	2,785	2,973	3,213	3,316	3,415	3,560	3,665	4,072	4,371	4,634	4,909	5,196
	75-79	1,838	2,147	2,573	2,769	3,047	3,187	3,309	3,443	3,556	3,968	4,508	5,118	5,806
	80-84	1,362	1,569	1,904	2,311	2,563	2,873	3,030	3,154	3,292	3,423	3,554	3,687	3,823
	85+	1,798	1,973	2,263	2,745	3,430	4,079	4,744	5,242	5,651	6,051	6,470	6,914	7,384
		67,008	68,130	70,697	72,834	75,768	79,304	83,077	86,466	89,853	93,372	97,029	100,829	104,779
Hornsby - South	0-4	5,877	6,141	6,359	6,582	6,817	7,067	7,355	7,641	7,877	8,080	8,277	8,473	8,669
	5-9	6,335	6,642	6,955	7,305	7,508	7,693	7,958	8,302	8,636	8,913	9,180	9,449	9,719
	10-14	6,557	6,967	7,332	7,766	8,016	8,137	8,323	8,632	9,018	9,390	9,764	10,146	10,536
	15-19	6,767	6,973	7,374	7,873	8,258	8,431	8,542	8,760	9,094	9,502	9,935	10,380	10,839
	20-24	6,333	6,288	6,448	6,911	7,359	7,632	7,770	7,890	8,092	8,391	8,715	9,045	9,382
	25-29	5,349	5,303	5,280	5,494	5,879	6,192	6,403	6,536	6,648	6,822	7,012	7,203	7,395
	30-34	5,925	6,235	6,188	6,270	6,452	6,806	7,143	7,401	7,568	7,709	7,846	7,981	8,112
	35-39	6,768	7,362	7,680	7,759	7,875	8,032	8,446	8,883	9,219	9,441	9,639	9,834	10,027
	40-44	7,384	7,698	8,323	8,818	9,124	9,235	9,403	9,911	10,438	10,848	11,238	11,635	12,037
	45-49	7,559	7,822	8,135	8,932	9,575	9,847	9,954	10,169	10,736	11,324	11,915	12,530	13,168
	50-54	7,260	7,385	7,639	8,065	9,040	9,653	9,915	10,058	10,300	10,892	11,594	12,333	13,111
	55-59	6,506	6,760	6,878	7,234	7,495	8,294	8,850	9,122	9,276	9,520	9,791	10,064	10,338
	60-64	5,408	5,958	6,194	6,426	6,721	6,901	7,634	8,177	8,451	8,614	8,759	8,900	9,038
	65-69	4,618	5,020	5,521	5,828	6,048	6,274	6,442	7,160	7,695	7,971	8,206	8,441	8,678

	70-74	3,550	4,324	4,696	5,268	5,552	5,723	5,937	6,127	6,838	7,372	7,848	8,349	8,877
	75-79	2,741	3,333	4,064	4,538	5,102	5,342	5,520	5,756	5,970	6,692	7,635	8,705	9,919
	80-84	2,023	2,436	3,008	3,792	4,291	4,815	5,054	5,273	5,528	5,773	6,019	6,271	6,530
	85+	2,682	3,062	3,575	4,504	5,745	6,836	7,911	8,764	9,489	10,204	10,958	11,761	12,614
		99,642	105,709	111,648	119,363	126,858	132,910	138,559	144,562	150,872	157,457	164,330	171,502	178,987
Hunter's Hill	0-4	729	736	809	820	832	873	918	962	1,002	1,038	1,075	1,111	1,149
	5-9	863	839	866	907	920	954	997	1,049	1,103	1,150	1,197	1,244	1,293
	10-14	901	923	1,001	1,014	1,019	1,047	1,082	1,132	1,195	1,257	1,321	1,387	1,455
	15-19	1,064	1,062	1,146	1,197	1,231	1,272	1,302	1,348	1,413	1,492	1,576	1,664	1,755
	20-24	719	699	761	772	798	838	862	883	915	959	1,006	1,055	1,105
	25-29	565	559	578	579	605	645	674	694	713	739	768	797	826
	30-34	661	690	683	676	683	728	772	808	834	859	883	907	932
	35-39	815	866	914	917	917	946	1,005	1,067	1,118	1,157	1,193	1,230	1,267
	40-44	959	969	1,088	1,110	1,121	1,148	1,181	1,256	1,337	1,403	1,469	1,536	1,606
	45-49	1,034	1,025	1,059	1,139	1,199	1,248	1,275	1,314	1,401	1,494	1,588	1,687	1,791
	50-54	949	1,006	1,059	1,062	1,160	1,254	1,301	1,331	1,377	1,472	1,583	1,701	1,827
	55-59	863	913	1,001	1,052	1,072	1,201	1,294	1,346	1,383	1,434	1,490	1,547	1,605
	60-64	815	829	905	994	1,037	1,077	1,204	1,301	1,358	1,399	1,437	1,475	1,513
	65-69	737	746	809	898	930	976	1,013	1,136	1,233	1,291	1,343	1,395	1,449
	70-74	555	708	770	811	832	868	909	947	1,068	1,163	1,251	1,345	1,444
	75-79	459	540	733	772	841	891	930	979	1,026	1,162	1,339	1,542	1,775
	80-84	431	457	598	782	877	996	1,056	1,112	1,177	1,242	1,308	1,377	1,449
	85+	775	866	992	1,206	1,509	1,818	2,125	2,376	2,598	2,823	3,063	3,321	3,598
		13,894	14,433	15,773	16,708	17,583	18,779	19,899	21,041	22,253	23,534	24,889	26,322	27,837
Hurstville	0-4	5,735	6,140	6,496	6,662	6,864	7,141	7,482	7,714	7,868	7,986	8,096	8,202	8,304
	5-9	5,127	5,768	6,193	6,520	6,688	6,877	7,161	7,414	7,631	7,794	7,944	8,091	8,236
	10-14	4,761	5,116	5,770	6,204	6,393	6,511	6,705	6,902	7,134	7,351	7,564	7,778	7,993
	15-19	4,913	4,987	5,407	6,042	6,381	6,537	6,668	6,787	6,971	7,208	7,457	7,711	7,967
	20-24	6,005	5,980	6,132	6,500	6,891	7,172	7,351	7,409	7,518	7,714	7,928	8,143	8,358
	25-29	6,999	6,844	6,899	7,019	7,450	7,874	8,196	8,304	8,357	8,486	8,632	8,774	8,914
	30-34	6,728	7,064	6,999	7,029	7,203	7,624	8,055	8,284	8,381	8,448	8,509	8,565	8,615
	35-39	6,109	6,841	7,222	7,212	7,283	7,453	7,891	8,236	8,458	8,571	8,659	8,743	8,821
	40-44	5,825	6,180	6,950	7,345	7,567	7,685	7,878	8,240	8,587	8,832	9,054	9,276	9,497
	45-49	5,712	5,900	6,324	7,081	7,597	7,841	7,979	8,090	8,450	8,820	9,184	9,557	9,939
	50-54	5,765	5,730	5,991	6,398	7,170	7,683	7,945	7,999	8,104	8,480	8,933	9,403	9,892
	55-59	5,249	5,599	5,658	5,950	6,157	6,838	7,344	7,513	7,560	7,677	7,814	7,948	8,079
	60-64	4,529	5,046	5,437	5,552	5,762	5,936	6,611	7,028	7,186	7,249	7,294	7,334	7,371
	65-69	3,821	4,234	4,782	5,186	5,399	5,621	5,809	6,408	6,814	6,985	7,116	7,244	7,370
	70-74	3,030	3,581	4,055	4,626	4,873	5,040	5,264	5,392	5,953	6,351	6,690	7,044	7,411
	75-79	2,563	2,839	3,450	3,902	4,390	4,612	4,798	4,965	5,096	5,651	6,380	7,199	8,117
	80-84	2,067	2,177	2,502	3,088	3,479	3,917	4,139	4,286	4,446	4,594	4,740	4,888	5,036

	85+	2,422	2,659	2,966	3,464	4,351	5,196	6,054	6,654	7,129	7,586	8,062	8,562	9,088
		87,359	92,684	99,234	105,777	111,900	117,558	123,329	127,627	131,642	135,784	140,055	144,461	149,006
Kogarah	0-4	3,718	3,953	4,164	4,341	4,551	4,812	5,088	5,263	5,380	5,473	5,561	5,647	5,731
	5-9	3,328	3,680	4,003	4,236	4,405	4,604	4,837	5,025	5,183	5,306	5,421	5,535	5,647
	10-14	3,217	3,416	3,833	4,170	4,367	4,521	4,698	4,852	5,026	5,191	5,354	5,518	5,684
	15-19	3,474	3,473	3,720	4,142	4,432	4,614	4,749	4,849	4,992	5,174	5,365	5,561	5,759
	20-24	4,154	4,122	4,230	4,503	4,842	5,122	5,296	5,356	5,447	5,602	5,771	5,941	6,113
	25-29	4,704	4,621	4,702	4,863	5,251	5,639	5,923	6,021	6,073	6,181	6,302	6,421	6,539
	30-34	4,614	4,809	4,824	4,958	5,174	5,567	5,934	6,123	6,209	6,272	6,332	6,389	6,442
	35-39	4,197	4,602	4,910	4,987	5,121	5,326	5,689	5,958	6,132	6,228	6,307	6,383	6,456
	40-44	4,169	4,367	4,891	5,224	5,469	5,645	5,839	6,128	6,400	6,598	6,779	6,962	7,145
	45-49	4,114	4,198	4,475	5,054	5,506	5,775	5,930	6,033	6,315	6,607	6,896	7,193	7,498
	50-54	3,968	3,991	4,202	4,503	5,119	5,573	5,814	5,873	5,964	6,255	6,605	6,969	7,349
	55-59	3,527	3,765	3,862	4,085	4,286	4,839	5,243	5,381	5,427	5,524	5,635	5,745	5,854
	60-64	2,986	3,341	3,597	3,733	3,943	4,128	4,640	4,948	5,071	5,127	5,171	5,212	5,250
	65-69	2,620	2,795	3,173	3,467	3,662	3,875	4,041	4,472	4,766	4,897	5,000	5,103	5,204
	70-74	2,030	2,447	2,663	3,011	3,216	3,380	3,562	3,661	4,051	4,332	4,574	4,827	5,091
	75-79	1,545	1,779	2,219	2,441	2,764	2,950	3,097	3,216	3,307	3,676	4,161	4,706	5,319
	80-84	1,193	1,252	1,501	1,910	2,190	2,507	2,672	2,776	2,886	2,989	3,091	3,195	3,300
	85+	1,344	1,440	1,615	1,967	2,525	3,064	3,601	3,971	4,264	4,547	4,844	5,157	5,487
		58,902	62,052	66,583	71,594	76,824	81,940	86,653	89,906	92,893	95,980	99,169	102,464	105,869
Ku-Ring-Gai	0-4	6,394	6,951	7,393	7,613	7,825	8,119	8,461	8,774	9,018	9,220	9,414	9,607	9,797
	5-9	8,250	9,077	9,813	10,266	10,473	10,740	11,123	11,583	12,013	12,359	12,688	13,017	13,347
	10-14	9,141	9,935	10,916	11,636	11,942	12,131	12,424	12,863	13,397	13,906	14,412	14,928	15,453
	15-19	9,179	9,830	10,694	11,587	12,117	12,381	12,560	12,857	13,307	13,860	14,444	15,043	15,657
	20-24	7,096	7,494	8,042	8,651	9,154	9,502	9,686	9,819	10,040	10,377	10,742	11,114	11,491
	25-29	4,553	4,576	4,722	4,913	5,220	5,502	5,697	5,805	5,887	6,021	6,169	6,316	6,464
	30-34	4,798	4,986	5,002	5,000	5,097	5,381	5,654	5,848	5,962	6,053	6,141	6,226	6,309
	35-39	6,634	7,380	7,722	7,711	7,764	7,925	8,343	8,759	9,064	9,252	9,415	9,575	9,732
	40-44	8,579	9,201	10,181	10,588	10,841	10,982	11,196	11,779	12,369	12,813	13,231	13,654	14,082
	45-49	9,486	9,925	10,664	11,617	12,344	12,706	12,860	13,114	13,803	14,512	15,221	15,955	16,713
	50-54	8,920	9,515	10,083	10,746	11,998	12,824	13,188	13,354	13,634	14,371	15,248	16,168	17,133
	55-59	7,485	8,200	8,855	9,326	9,591	10,624	11,348	11,676	11,839	12,110	12,415	12,720	13,024
	60-64	6,295	6,903	7,626	8,181	8,552	8,788	9,734	10,408	10,723	10,895	11,042	11,185	11,322
	65-69	5,659	5,844	6,533	7,183	7,477	7,764	7,981	8,854	9,487	9,796	10,051	10,307	10,563
	70-74	4,624	5,302	5,632	6,274	6,571	6,779	7,041	7,254	8,071	8,673	9,203	9,760	10,343
	75-79	3,614	4,282	5,043	5,392	5,980	6,267	6,483	6,749	6,979	7,797	8,867	10,077	11,446
	80-84	2,901	3,128	3,824	4,561	5,075	5,700	5,990	6,238	6,521	6,787	7,053	7,326	7,604
	85+	3,700	3,842	4,229	5,100	6,426	7,654	8,869	9,806	10,586	11,347	12,146	12,994	13,893
		117,309	126,372	136,973	146,346	154,447	161,769	168,638	175,541	182,699	190,148	197,902	205,972	214,370
Lane Cove	0-4	2,319	2,436	2,603	2,841	3,063	3,303	3,550	3,713	3,834	3,942	4,048	4,154	4,261

	5-9	2,201	2,417	2,603	2,841	3,030	3,230	3,451	3,624	3,777	3,907	4,033	4,162	4,292
	10-14	1,956	2,211	2,447	2,653	2,829	2,986	3,155	3,294	3,447	3,598	3,750	3,907	4,067
	15-19	1,839	2,063	2,339	2,633	2,870	3,047	3,189	3,293	3,424	3,586	3,758	3,937	4,121
	20-24	1,967	2,083	2,300	2,583	2,854	3,078	3,236	3,309	3,400	3,533	3,678	3,827	3,980
	25-29	2,544	2,633	2,760	3,030	3,374	3,696	3,946	4,056	4,133	4,250	4,379	4,510	4,642
	30-34	2,808	3,006	3,151	3,348	3,577	3,925	4,254	4,437	4,546	4,641	4,735	4,828	4,920
	35-39	2,769	3,036	3,318	3,547	3,748	3,976	4,318	4,572	4,754	4,879	4,993	5,107	5,221
	40-44	2,612	2,771	3,102	3,428	3,681	3,875	4,076	4,325	4,563	4,753	4,936	5,123	5,314
	45-49	2,416	2,574	2,750	3,150	3,505	3,749	3,914	4,026	4,258	4,501	4,748	5,005	5,273
	50-54	2,143	2,279	2,456	2,692	3,131	3,476	3,687	3,766	3,863	4,095	4,369	4,659	4,966
	55-59	1,937	2,044	2,173	2,394	2,577	2,968	3,269	3,392	3,455	3,554	3,664	3,776	3,888
	60-64	1,683	1,788	1,889	2,096	2,291	2,446	2,796	3,014	3,120	3,188	3,249	3,310	3,370
	65-69	1,516	1,572	1,683	1,818	1,955	2,109	2,236	2,503	2,694	2,797	2,887	2,977	3,068
	70-74	1,124	1,376	1,419	1,560	1,690	1,812	1,941	2,017	2,255	2,436	2,600	2,773	2,956
	75-79	773	983	1,184	1,282	1,475	1,606	1,714	1,799	1,870	2,100	2,402	2,746	3,137
	80-84	597	629	832	1,054	1,225	1,430	1,549	1,627	1,709	1,789	1,869	1,953	2,038
	85+	822	874	959	1,233	1,631	2,017	2,411	2,687	2,915	3,141	3,382	3,639	3,913
		34,027	36,776	39,967	44,183	48,506	52,730	56,690	59,453	62,017	64,691	67,481	70,391	73,427
Leichhardt	0-4	4,382	4,288	4,396	4,509	4,639	4,814	5,002	5,146	5,252	5,337	5,418	5,496	5,573
	5-9	3,220	3,283	3,282	3,404	3,481	3,570	3,686	3,808	3,922	4,011	4,093	4,175	4,256
	10-14	2,277	2,666	2,775	2,787	2,832	2,877	2,938	3,018	3,121	3,220	3,318	3,416	3,516
	15-19	1,755	2,138	2,517	2,628	2,720	2,779	2,811	2,855	2,934	3,037	3,147	3,258	3,372
	20-24	2,798	2,776	3,064	3,414	3,638	3,777	3,839	3,861	3,920	4,027	4,144	4,263	4,382
	25-29	4,663	4,587	4,575	4,817	5,148	5,426	5,602	5,663	5,703	5,798	5,905	6,011	6,116
	30-34	6,258	6,417	6,386	6,450	6,602	6,970	7,303	7,494	7,587	7,656	7,722	7,783	7,841
	35-39	6,037	6,188	6,465	6,520	6,584	6,721	7,055	7,348	7,551	7,661	7,750	7,836	7,918
	40-44	5,436	5,224	5,491	5,733	5,890	5,967	6,066	6,331	6,601	6,798	6,978	7,159	7,340
	45-49	4,433	4,597	4,545	4,847	5,153	5,305	5,354	5,416	5,661	5,916	6,169	6,428	6,695
	50-54	3,681	4,009	4,197	4,230	4,669	4,991	5,117	5,141	5,212	5,461	5,760	6,071	6,396
	55-59	3,229	3,462	3,770	3,952	4,061	4,499	4,792	4,892	4,925	5,008	5,103	5,198	5,292
	60-64	2,958	2,935	3,173	3,434	3,600	3,700	4,086	4,334	4,435	4,479	4,512	4,544	4,573
	65-69	2,488	2,627	2,636	2,877	3,009	3,125	3,203	3,525	3,750	3,850	3,927	4,003	4,078
	70-74	1,655	2,138	2,318	2,379	2,447	2,525	2,615	2,672	2,952	3,154	3,327	3,507	3,696
	75-79	1,043	1,402	1,850	2,021	2,245	2,353	2,427	2,506	2,574	2,858	3,231	3,651	4,122
	80-84	742	826	1,124	1,513	1,719	1,931	2,023	2,091	2,170	2,245	2,320	2,395	2,471
	85+	692	776	915	1,184	1,512	1,801	2,080	2,282	2,446	2,607	2,774	2,950	3,136
		57,746	60,340	63,479	66,698	69,949	73,130	75,999	78,382	80,717	83,121	85,597	88,147	90,773
Liverpool - East	0-4	8,916	9,296	9,567	9,877	10,164	10,554	11,027	11,486	11,874	12,218	12,557	12,899	13,244
	5-9	8,242	8,809	9,338	9,712	9,895	10,156	10,546	11,031	11,506	11,913	12,311	12,715	13,125
	10-14	8,037	8,013	8,719	9,348	9,596	9,755	10,017	10,417	10,912	11,400	11,892	12,400	12,922

	15-19	7,979	7,879	8,072	8,864	9,313	9,523	9,686	9,960	10,368	10,868	11,400	11,952	12,524
	20-24	8,150	8,051	8,157	8,495	8,933	9,280	9,485	9,657	9,932	10,331	10,765	11,212	11,670
	25-29	8,381	8,385	8,438	8,546	9,028	9,524	9,886	10,118	10,320	10,623	10,956	11,293	11,634
	30-34	8,635	8,802	8,878	8,891	9,054	9,566	10,078	10,471	10,736	10,971	11,203	11,434	11,664
	35-39	8,070	8,593	8,919	9,015	9,099	9,294	9,811	10,347	10,768	11,062	11,331	11,600	11,870
	40-44	7,947	7,924	8,587	9,009	9,239	9,366	9,574	10,118	10,686	11,140	11,579	12,029	12,489
	45-49	7,599	7,646	7,807	8,589	9,162	9,438	9,577	9,810	10,386	10,989	11,602	12,242	12,910
	50-54	7,210	7,176	7,385	7,705	8,560	9,156	9,440	9,602	9,860	10,460	11,171	11,924	12,721
	55-59	6,133	6,559	6,682	7,043	7,260	8,048	8,619	8,908	9,084	9,352	9,650	9,953	10,260
	60-64	4,956	5,541	6,021	6,286	6,530	6,715	7,457	8,009	8,299	8,486	8,658	8,828	8,997
	65-69	3,938	4,399	5,015	5,582	5,820	6,048	6,234	6,948	7,486	7,780	8,035	8,294	8,557
	70-74	2,902	3,508	4,004	4,677	4,930	5,090	5,301	5,485	6,139	6,639	7,091	7,570	8,077
	75-79	2,091	2,491	3,099	3,626	4,091	4,290	4,450	4,653	4,839	5,442	6,229	7,127	8,149
	80-84	1,412	1,674	2,069	2,661	3,004	3,377	3,558	3,722	3,913	4,099	4,288	4,483	4,684
	85+	1,244	1,593	1,979	2,533	3,215	3,833	4,452	4,945	5,369	5,792	6,241	6,721	7,234
		111,844	116,338	122,736	130,459	136,892	143,012	149,199	155,688	162,478	169,564	176,960	184,677	192,732
Liverpool - West	0-4	6,201	7,457	8,969	10,424	11,712	13,221	14,918	17,117	19,581	22,299	25,367	28,841	32,772
	5-9	5,733	7,077	8,759	10,250	11,400	12,719	14,266	16,440	18,978	21,746	24,871	28,430	32,481
	10-14	5,590	6,424	8,188	9,870	11,055	12,216	13,549	15,525	18,001	20,811	24,029	27,731	31,985
	15-19	5,550	6,314	7,568	9,367	10,732	11,925	13,100	14,840	17,101	19,842	23,037	26,732	31,002
	20-24	5,669	6,449	7,646	8,967	10,296	11,624	12,827	14,386	16,379	18,860	21,751	25,073	28,885
	25-29	5,830	6,721	7,906	9,016	10,407	11,931	13,372	15,074	17,017	19,391	22,133	25,251	28,791
	30-34	6,006	7,056	8,319	9,378	10,432	11,986	13,634	15,603	17,703	20,021	22,629	25,562	28,860
	35-39	5,613	6,903	8,361	9,510	10,481	11,640	13,275	15,421	17,759	20,188	22,888	25,934	29,370
	40-44	5,528	6,350	8,063	9,508	10,644	11,728	12,949	15,082	17,628	20,337	23,395	26,899	30,911
	45-49	5,286	6,131	7,318	9,076	10,560	11,820	12,951	14,616	17,136	20,065	23,446	27,382	31,960
	50-54	5,015	5,750	6,925	8,133	9,874	11,471	12,768	14,303	16,260	19,103	22,580	26,675	31,497
	55-59	4,265	5,265	6,262	7,437	8,364	10,091	11,662	13,272	14,978	17,070	19,496	22,255	25,391
	60-64	3,447	4,455	5,650	6,634	7,525	8,409	10,097	11,939	13,687	15,487	17,487	19,735	22,260
	65-69	2,738	3,535	4,713	5,898	6,706	7,576	8,431	10,367	12,352	14,201	16,233	18,546	21,177
	70-74	2,018	2,825	3,762	4,946	5,681	6,375	7,171	8,173	10,139	12,124	14,333	16,935	19,998
	75-79	1,454	2,005	2,917	3,834	4,718	5,373	6,019	6,935	7,982	9,948	12,603	15,960	20,198
	80-84	982	1,348	1,948	2,818	3,465	4,234	4,813	5,547	6,455	7,483	8,664	10,026	11,595
	85+	865	1,284	1,863	2,682	3,713	4,808	6,030	7,376	8,861	10,579	12,616	15,038	17,914
		77,789	93,349	115,138	137,748	157,767	179,146	201,833	232,017	267,996	309,554	357,557	413,004	477,049
Manly	0-4	3,263	3,256	3,329	3,428	3,561	3,736	3,923	4,060	4,161	4,245	4,326	4,406	4,485
	5-9	2,801	3,020	3,102	3,192	3,282	3,403	3,552	3,691	3,817	3,919	4,015	4,112	4,208
	10-14	2,235	2,566	2,791	2,909	3,000	3,081	3,180	3,286	3,412	3,534	3,656	3,780	3,905
	15-19	1,948	2,161	2,442	2,654	2,799	2,891	2,956	3,019	3,116	3,239	3,368	3,501	3,638
	20-24	2,180	2,199	2,367	2,635	2,835	2,975	3,056	3,092	3,152	3,251	3,359	3,468	3,579

	25-29	3,170	3,105	3,149	3,277	3,519	3,749	3,912	3,978	4,023	4,106	4,198	4,291	4,382
	30-34	3,946	3,907	3,913	3,995	4,130	4,409	4,668	4,819	4,898	4,963	5,025	5,085	5,143
	35-39	3,870	3,888	3,989	4,052	4,136	4,268	4,528	4,744	4,895	4,986	5,064	5,140	5,215
	40-44	3,531	3,501	3,678	3,844	3,984	4,080	4,192	4,401	4,608	4,764	4,909	5,057	5,205
	45-49	3,081	3,293	3,385	3,589	3,836	3,991	4,071	4,143	4,348	4,562	4,775	4,996	5,224
	50-54	2,725	2,850	3,102	3,202	3,575	3,862	4,002	4,045	4,118	4,331	4,586	4,854	5,134
	55-59	2,255	2,453	2,612	2,871	3,012	3,373	3,631	3,728	3,769	3,847	3,937	4,026	4,114
	60-64	1,978	2,123	2,357	2,522	2,658	2,761	3,082	3,288	3,378	3,425	3,465	3,503	3,539
	65-69	1,842	1,840	2,027	2,267	2,391	2,510	2,600	2,879	3,076	3,170	3,246	3,322	3,398
	70-74	1,457	1,661	1,735	1,936	2,049	2,137	2,237	2,300	2,551	2,736	2,897	3,067	3,244
	75-79	950	1,245	1,433	1,539	1,729	1,832	1,910	1,984	2,046	2,280	2,588	2,936	3,329
	80-84	740	745	981	1,152	1,285	1,460	1,546	1,606	1,674	1,739	1,804	1,870	1,937
	85+	788	717	745	944	1,216	1,464	1,709	1,885	2,029	2,171	2,319	2,476	2,643
		42,761	44,530	47,138	50,008	52,997	55,980	58,754	60,950	63,071	65,266	67,538	69,888	72,321
Marrickville	0-4	5,584	5,791	5,950	6,099	6,383	6,739	7,132	7,372	7,532	7,661	7,783	7,902	8,019
	5-9	3,746	4,211	4,453	4,639	4,821	5,031	5,291	5,493	5,663	5,796	5,920	6,043	6,166
	10-14	2,903	3,177	3,639	3,854	4,012	4,147	4,313	4,451	4,608	4,758	4,907	5,057	5,209
	15-19	2,850	3,036	3,349	3,751	4,022	4,181	4,307	4,395	4,522	4,686	4,858	5,035	5,214
	20-24	5,484	5,255	5,501	5,977	6,458	6,821	7,061	7,135	7,252	7,457	7,680	7,907	8,135
	25-29	8,463	8,001	8,018	8,306	8,987	9,639	10,134	10,293	10,377	10,558	10,763	10,966	11,166
	30-34	9,297	9,410	9,328	9,419	9,804	10,533	11,239	11,588	11,744	11,862	11,973	12,079	12,179
	35-39	8,229	8,761	9,112	9,166	9,414	9,778	10,455	10,941	11,254	11,428	11,571	11,709	11,843
	40-44	7,010	7,060	7,699	8,119	8,492	8,753	9,063	9,504	9,921	10,225	10,504	10,786	11,069
	45-49	5,990	6,157	6,362	7,006	7,613	7,973	8,194	8,330	8,716	9,116	9,513	9,922	10,343
	50-54	4,965	5,273	5,520	5,752	6,512	7,080	7,394	7,463	7,575	7,942	8,384	8,846	9,328
	55-59	4,226	4,456	4,827	5,098	5,337	6,017	6,526	6,693	6,746	6,865	7,002	7,139	7,273
	60-64	3,403	3,722	4,013	4,368	4,670	4,883	5,493	5,854	5,996	6,060	6,111	6,159	6,204
	65-69	2,815	3,055	3,349	3,639	3,851	4,069	4,247	4,697	5,003	5,139	5,247	5,353	5,459
	70-74	2,156	2,500	2,797	3,115	3,313	3,478	3,669	3,767	4,167	4,454	4,703	4,962	5,233
	75-79	1,706	1,842	2,245	2,525	2,879	3,069	3,224	3,346	3,439	3,822	4,325	4,891	5,528
	80-84	1,255	1,344	1,544	1,889	2,157	2,465	2,630	2,731	2,837	2,938	3,038	3,139	3,243
	85+	1,129	1,400	1,637	1,946	2,487	3,013	3,545	3,906	4,192	4,470	4,761	5,068	5,392
		81,211	84,452	89,342	94,668	101,213	107,670	113,916	117,959	121,544	125,237	129,042	132,964	137,004
Mosman	0-4	1,731	1,752	1,799	1,851	1,896	1,960	2,027	2,081	2,119	2,148	2,174	2,199	2,223
	5-9	1,741	1,828	1,894	1,946	1,972	2,015	2,072	2,135	2,194	2,238	2,278	2,316	2,354
	10-14	1,741	1,790	1,885	1,946	1,977	2,001	2,034	2,085	2,151	2,214	2,274	2,335	2,396
	15-19	1,527	1,562	1,647	1,746	1,810	1,843	1,856	1,881	1,928	1,991	2,057	2,124	2,191
	20-24	1,441	1,457	1,514	1,603	1,685	1,743	1,764	1,770	1,793	1,837	1,885	1,933	1,981
	25-29	1,771	1,677	1,704	1,755	1,853	1,946	2,000	2,018	2,027	2,055	2,088	2,119	2,149
	30-34	2,110	2,133	2,104	2,137	2,179	2,292	2,391	2,448	2,472	2,489	2,503	2,516	2,527
	35-39	2,132	2,200	2,313	2,299	2,300	2,339	2,445	2,541	2,605	2,636	2,659	2,681	2,701

	40-44	2,238	2,191	2,304	2,413	2,469	2,492	2,522	2,626	2,732	2,806	2,873	2,939	3,004
	45-49	2,208	2,229	2,237	2,394	2,532	2,596	2,608	2,633	2,746	2,862	2,976	3,092	3,210
	50-54	2,023	2,076	2,132	2,146	2,357	2,510	2,562	2,568	2,598	2,714	2,855	3,001	3,152
	55-59	1,818	1,886	1,980	2,041	2,082	2,297	2,436	2,481	2,492	2,527	2,569	2,609	2,648
	60-64	1,635	1,686	1,752	1,879	1,962	2,008	2,208	2,337	2,386	2,403	2,414	2,424	2,433
	65-69	1,595	1,496	1,590	1,698	1,751	1,811	1,848	2,029	2,154	2,206	2,243	2,281	2,317
	70-74	1,320	1,457	1,399	1,498	1,556	1,599	1,649	1,681	1,853	1,974	2,077	2,183	2,293
	75-79	836	1,161	1,352	1,345	1,462	1,526	1,568	1,615	1,655	1,832	2,066	2,328	2,621
	80-84	604	761	1,076	1,259	1,383	1,548	1,615	1,665	1,724	1,779	1,833	1,887	1,941
	85+	904	943	1,066	1,402	1,787	2,121	2,440	2,670	2,856	3,035	3,221	3,416	3,620
		29,376	30,285	31,747	33,359	35,014	36,648	38,044	39,265	40,486	41,745	43,043	44,382	45,762
North Sydney	0-4	4,013	4,350	4,617	4,757	4,939	5,164	5,410	5,616	5,784	5,929	6,071	6,213	6,353
	5-9	2,520	2,858	3,103	3,266	3,370	3,483	3,627	3,780	3,928	4,053	4,172	4,292	4,413
	10-14	2,002	2,371	2,660	2,872	2,984	3,055	3,146	3,260	3,402	3,541	3,680	3,823	3,968
	15-19	2,000	2,318	2,650	2,916	3,085	3,177	3,240	3,320	3,443	3,596	3,758	3,925	4,096
	20-24	4,237	4,371	4,747	5,185	5,556	5,811	5,956	6,043	6,192	6,418	6,662	6,912	7,166
	25-29	9,232	9,375	9,654	10,117	10,879	11,555	12,028	12,268	12,467	12,786	13,137	13,489	13,841
	30-34	9,910	10,519	10,767	10,993	11,366	12,091	12,774	13,226	13,511	13,755	13,994	14,228	14,456
	35-39	7,275	8,012	8,498	8,702	8,897	9,152	9,688	10,181	10,556	10,805	11,026	11,244	11,460
	40-44	5,547	5,937	6,542	6,916	7,180	7,329	7,513	7,912	8,325	8,648	8,954	9,266	9,583
	45-49	4,562	5,101	5,471	6,029	6,492	6,734	6,852	6,994	7,377	7,777	8,180	8,598	9,032
	50-54	4,125	4,572	5,061	5,382	6,056	6,521	6,743	6,834	6,992	7,390	7,863	8,361	8,884
	55-59	4,074	4,360	4,834	5,250	5,483	6,121	6,574	6,770	6,878	7,055	7,253	7,452	7,651
	60-64	3,760	4,149	4,498	4,911	5,212	5,396	6,010	6,432	6,640	6,765	6,876	6,984	7,089
	65-69	3,506	3,661	4,077	4,395	4,600	4,813	4,974	5,524	5,931	6,141	6,319	6,497	6,677
	70-74	2,564	3,176	3,395	3,804	4,031	4,190	4,376	4,512	5,031	5,421	5,768	6,134	6,519
	75-79	1,649	2,256	2,823	3,047	3,415	3,605	3,750	3,908	4,049	4,536	5,173	5,896	6,715
	80-84	1,078	1,366	1,850	2,368	2,693	3,047	3,219	3,356	3,515	3,669	3,823	3,982	4,144
	85+	1,140	1,249	1,514	2,029	2,627	3,152	3,672	4,064	4,396	4,725	5,072	5,441	5,834
		73,195	80,001	86,763	92,937	98,865	104,395	109,552	113,999	118,419	123,011	127,780	132,735	137,881
Parramatta - Inner	0-4	4,444	5,234	5,702	6,159	6,834	7,802	8,901	9,541	10,022	10,476	10,937	11,412	11,901
	5-9	3,557	4,359	4,949	5,471	6,026	6,799	7,711	8,301	8,798	9,254	9,713	10,190	10,684
	10-14	3,038	3,692	4,324	4,941	5,489	6,133	6,878	7,363	7,837	8,317	8,814	9,335	9,881
	15-19	3,076	3,457	4,002	4,685	5,309	5,966	6,626	7,014	7,419	7,900	8,418	8,965	9,541
	20-24	4,125	4,429	4,774	5,414	6,193	7,070	7,889	8,269	8,641	9,131	9,665	10,224	10,810
	25-29	5,677	5,960	6,250	6,781	7,771	9,011	10,211	10,756	11,148	11,658	12,212	12,786	13,380
	30-34	5,762	6,356	6,586	7,007	7,732	8,985	10,333	11,048	11,510	11,948	12,394	12,849	13,313
	35-39	4,728	5,779	6,244	6,605	7,193	8,078	9,316	10,108	10,689	11,155	11,606	12,069	12,544
	40-44	3,927	4,796	5,620	6,187	6,843	7,624	8,511	9,260	9,937	10,524	11,111	11,724	12,364
	45-49	3,516	4,112	4,775	5,659	6,525	7,386	8,182	8,629	9,283	9,978	10,701	11,469	12,286

	50-54	3,314	3,683	4,150	4,847	5,889	6,919	7,787	8,152	8,507	9,168	9,946	10,784	11,685
	55-59	2,978	3,396	3,673	4,184	4,678	5,709	6,670	7,093	7,349	7,686	8,057	8,441	8,837
	60-64	2,521	2,989	3,318	3,639	4,085	4,616	5,605	6,190	6,517	6,769	7,015	7,265	7,521
	65-69	2,105	2,530	2,920	3,291	3,678	4,202	4,728	5,426	5,940	6,270	6,578	6,897	7,228
	70-74	1,656	2,136	2,502	2,934	3,306	3,752	4,267	4,544	5,168	5,677	6,159	6,679	7,238
	75-79	1,287	1,651	2,085	2,488	3,015	3,472	3,933	4,233	4,473	5,111	5,942	6,906	8,021
	80-84	988	1,194	1,513	1,975	2,390	2,954	3,394	3,655	3,904	4,155	4,415	4,688	4,976
	85+	1,112	1,356	1,611	2,087	2,848	3,731	4,730	5,401	5,958	6,529	7,146	7,817	8,546
		57,810	67,110	74,998	84,354	95,802	110,211	125,673	134,982	143,099	151,705	160,829	170,501	180,755
Parramatta - North-East	0-4	3,606	3,928	4,258	4,479	4,722	4,950	5,203	5,420	5,597	5,752	5,904	6,057	6,210
	5-9	2,885	3,270	3,696	3,978	4,164	4,315	4,507	4,715	4,914	5,081	5,244	5,409	5,575
	10-14	2,470	2,770	3,229	3,592	3,793	3,893	4,021	4,183	4,377	4,567	4,758	4,954	5,156
	15-19	2,506	2,595	2,989	3,405	3,668	3,786	3,874	3,984	4,143	4,338	4,544	4,758	4,979
	20-24	3,368	3,326	3,565	3,936	4,278	4,486	4,612	4,697	4,826	5,014	5,218	5,427	5,641
	25-29	4,631	4,477	4,667	4,931	5,368	5,716	5,969	6,110	6,226	6,401	6,593	6,787	6,982
	30-34	4,675	4,773	4,918	5,096	5,343	5,698	6,039	6,276	6,429	6,561	6,691	6,820	6,947
	35-39	3,834	4,335	4,663	4,804	4,971	5,126	5,444	5,742	5,970	6,125	6,266	6,406	6,546
	40-44	3,189	3,597	4,197	4,499	4,728	4,839	4,976	5,260	5,549	5,778	5,998	6,223	6,452
	45-49	2,862	3,085	3,566	4,113	4,507	4,687	4,784	4,902	5,184	5,479	5,776	6,087	6,411
	50-54	2,695	2,765	3,099	3,523	4,066	4,389	4,552	4,631	4,751	5,034	5,369	5,723	6,097
	55-59	2,419	2,549	2,743	3,042	3,233	3,618	3,898	4,029	4,105	4,220	4,349	4,480	4,612
	60-64	2,047	2,243	2,478	2,646	2,822	2,929	3,273	3,516	3,640	3,717	3,787	3,856	3,925
	65-69	1,706	1,898	2,181	2,393	2,542	2,666	2,764	3,081	3,317	3,443	3,551	3,661	3,772
	70-74	1,342	1,602	1,869	2,133	2,284	2,380	2,494	2,581	2,886	3,117	3,325	3,545	3,777
	75-79	1,044	1,238	1,557	1,808	2,082	2,203	2,299	2,404	2,498	2,805	3,207	3,664	4,184
	80-84	804	896	1,130	1,435	1,650	1,872	1,984	2,076	2,180	2,281	2,383	2,488	2,597
	85+	901	1,017	1,203	1,516	1,965	2,363	2,762	3,068	3,327	3,585	3,857	4,149	4,459
		46,984	50,364	56,007	61,332	66,184	69,917	73,456	76,676	79,919	83,299	86,821	90,493	94,319
Parramatta - North-West	0-4	3,085	3,347	3,546	3,721	3,917	4,055	4,204	4,331	4,425	4,498	4,568	4,635	4,701
	5-9	2,469	2,786	3,077	3,304	3,455	3,535	3,642	3,768	3,884	3,973	4,056	4,139	4,221
	10-14	2,112	2,360	2,689	2,984	3,147	3,189	3,250	3,342	3,460	3,571	3,681	3,791	3,903
	15-19	2,141	2,212	2,488	2,829	3,043	3,102	3,131	3,184	3,275	3,392	3,515	3,641	3,769
	20-24	2,875	2,835	2,969	3,270	3,549	3,675	3,728	3,754	3,815	3,921	4,036	4,153	4,270
	25-29	3,955	3,816	3,887	4,096	4,453	4,683	4,824	4,883	4,922	5,006	5,100	5,194	5,286
	30-34	4,000	4,068	4,096	4,233	4,432	4,668	4,881	5,015	5,082	5,131	5,176	5,219	5,259
	35-39	3,281	3,694	3,883	3,990	4,124	4,200	4,399	4,588	4,719	4,790	4,847	4,902	4,956
	40-44	2,727	3,065	3,494	3,737	3,923	3,964	4,021	4,203	4,387	4,519	4,640	4,762	4,884
	45-49	2,446	2,629	2,969	3,417	3,739	3,840	3,867	3,917	4,098	4,284	4,468	4,658	4,853
	50-54	2,304	2,357	2,580	2,927	3,373	3,595	3,679	3,701	3,756	3,936	4,153	4,379	4,615

	55-59	2,069	2,172	2,284	2,527	2,682	2,963	3,150	3,220	3,245	3,300	3,365	3,428	3,491
	60-64	1,751	1,911	2,063	2,198	2,341	2,400	2,645	2,809	2,877	2,907	2,930	2,951	2,971
	65-69	1,460	1,618	1,816	1,988	2,108	2,184	2,234	2,462	2,622	2,692	2,747	2,802	2,855
	70-74	1,149	1,365	1,556	1,772	1,895	1,950	2,015	2,063	2,281	2,437	2,572	2,712	2,859
	75-79	893	1,055	1,296	1,502	1,727	1,805	1,858	1,921	1,975	2,193	2,481	2,804	3,167
	80-84	687	763	940	1,192	1,369	1,533	1,603	1,659	1,724	1,784	1,844	1,904	1,966
	85+	772	867	1,002	1,259	1,630	1,935	2,231	2,451	2,630	2,803	2,984	3,175	3,376
		40,176	42,918	46,635	50,944	54,907	57,276	59,362	61,270	63,175	65,138	67,162	69,250	71,402
Parramatta - South	0-4	2,835	3,062	3,276	3,444	3,631	3,773	3,926	4,044	4,129	4,194	4,256	4,316	4,374
	5-9	2,269	2,549	2,844	3,058	3,202	3,288	3,401	3,518	3,624	3,705	3,779	3,853	3,926
	10-14	1,942	2,159	2,485	2,762	2,917	2,967	3,034	3,121	3,228	3,330	3,429	3,530	3,631
	15-19	1,969	2,023	2,300	2,618	2,820	2,886	2,923	2,973	3,056	3,163	3,275	3,390	3,506
	20-24	2,645	2,593	2,744	3,026	3,290	3,419	3,480	3,505	3,560	3,656	3,760	3,866	3,973
	25-29	3,638	3,491	3,592	3,791	4,128	4,357	4,504	4,560	4,593	4,667	4,752	4,835	4,917
	30-34	3,676	3,721	3,785	3,918	4,108	4,343	4,557	4,683	4,742	4,784	4,823	4,859	4,893
	35-39	3,015	3,379	3,588	3,693	3,822	3,907	4,108	4,284	4,403	4,466	4,516	4,564	4,610
	40-44	2,507	2,804	3,229	3,459	3,636	3,688	3,755	3,924	4,093	4,213	4,323	4,433	4,544
	45-49	2,249	2,405	2,744	3,162	3,466	3,572	3,610	3,658	3,824	3,995	4,163	4,337	4,515
	50-54	2,119	2,156	2,385	2,709	3,127	3,345	3,435	3,456	3,504	3,670	3,869	4,077	4,294
	55-59	1,902	1,987	2,111	2,339	2,486	2,757	2,941	3,007	3,028	3,077	3,135	3,192	3,248
	60-64	1,609	1,748	1,907	2,035	2,170	2,233	2,470	2,623	2,685	2,710	2,730	2,748	2,764
	65-69	1,342	1,480	1,678	1,840	1,954	2,032	2,086	2,299	2,447	2,510	2,560	2,608	2,656
	70-74	1,055	1,249	1,438	1,640	1,756	1,814	1,882	1,926	2,128	2,272	2,396	2,525	2,660
	75-79	821	965	1,198	1,390	1,601	1,679	1,735	1,794	1,843	2,045	2,311	2,610	2,946
	80-84	632	698	869	1,103	1,269	1,427	1,497	1,549	1,608	1,663	1,718	1,773	1,829
	85+	709	793	926	1,166	1,511	1,801	2,084	2,289	2,454	2,614	2,780	2,956	3,140
		36,934	39,261	43,096	47,154	50,893	53,288	55,429	57,215	58,948	60,735	62,575	64,472	66,425
Penrith - East	0-4	7,680	8,400	9,041	9,265	9,696	10,427	11,302	11,919	12,399	12,836	13,271	13,713	14,161
	5-9	7,020	7,883	8,782	9,245	9,620	10,225	11,016	11,666	12,246	12,756	13,260	13,776	14,303
	10-14	6,626	7,245	8,298	8,995	9,434	9,931	10,580	11,141	11,744	12,343	12,953	13,586	14,241
	15-19	6,747	6,915	7,741	8,632	9,252	9,796	10,336	10,762	11,274	11,890	12,546	13,232	13,946
	20-24	7,328	7,253	7,652	8,372	9,074	9,761	10,348	10,669	11,042	11,556	12,113	12,690	13,286
	25-29	7,944	8,005	8,151	8,460	9,170	10,018	10,787	11,178	11,474	11,883	12,328	12,782	13,245
	30-34	7,751	8,465	8,681	8,705	9,050	9,903	10,823	11,385	11,747	12,076	12,406	12,737	13,068
	35-39	7,134	8,117	8,960	9,011	9,244	9,779	10,711	11,435	11,976	12,377	12,754	13,134	13,518
	40-44	6,802	7,354	8,539	9,173	9,630	10,110	10,721	11,473	12,193	12,789	13,372	13,974	14,593
	45-49	6,440	6,931	7,674	8,673	9,467	10,098	10,630	11,026	11,748	12,505	13,281	14,097	14,953
	50-54	6,231	6,412	7,107	7,684	8,762	9,703	10,377	10,687	11,044	11,787	12,664	13,597	14,590
	55-59	6,032	6,087	6,473	7,016	7,407	8,508	9,449	9,887	10,146	10,508	10,908	11,317	11,734
	60-64	5,162	5,745	6,002	6,277	6,673	7,106	8,192	8,904	9,285	9,551	9,802	10,054	10,306

	65-69	4,312	4,923	5,663	5,829	6,086	6,549	7,002	7,903	8,569	8,959	9,308	9,665	10,029
	70-74	2,838	4,093	4,794	5,420	5,791	6,192	6,690	7,009	7,894	8,588	9,228	9,909	10,635
	75-79	1,856	2,622	3,864	4,451	5,080	5,516	5,936	6,284	6,577	7,441	8,569	9,861	11,342
	80-84	1,252	1,615	2,351	3,395	3,977	4,630	5,058	5,358	5,668	5,974	6,286	6,611	6,949
	85+	1,171	1,500	1,977	2,758	3,626	4,477	5,395	6,063	6,625	7,190	7,793	8,442	9,140
		100,325	109,565	121,752	131,360	141,039	152,727	165,354	174,747	183,651	193,008	202,842	213,177	224,039
Penrith - West	0-4	6,423	6,902	7,279	7,527	7,945	8,402	8,900	9,362	9,761	10,127	10,495	10,869	11,250
	5-9	5,871	6,476	7,070	7,511	7,882	8,239	8,674	9,163	9,640	10,064	10,486	10,919	11,362
	10-14	5,542	5,952	6,679	7,308	7,730	8,002	8,332	8,750	9,245	9,738	10,243	10,768	11,313
	15-19	5,644	5,682	6,231	7,014	7,581	7,893	8,140	8,453	8,875	9,381	9,922	10,487	11,079
	20-24	6,130	5,961	6,161	6,803	7,435	7,865	8,149	8,380	8,692	9,118	9,579	10,058	10,555
	25-29	6,644	6,579	6,564	6,873	7,514	8,071	8,494	8,780	9,032	9,375	9,749	10,131	10,522
	30-34	6,482	6,956	6,991	7,071	7,415	7,979	8,522	8,942	9,248	9,528	9,810	10,095	10,381
	35-39	5,966	6,669	7,213	7,320	7,574	7,880	8,434	8,982	9,428	9,766	10,086	10,410	10,739
	40-44	5,688	6,043	6,873	7,453	7,891	8,146	8,443	9,011	9,599	10,091	10,575	11,076	11,593
	45-49	5,386	5,695	6,178	7,048	7,758	8,137	8,371	8,660	9,248	9,867	10,503	11,173	11,879
	50-54	5,212	5,269	5,722	6,243	7,180	7,818	8,172	8,394	8,694	9,301	10,015	10,777	11,591
	55-59	5,044	5,003	5,212	5,701	6,069	6,853	7,440	7,765	7,987	8,291	8,626	8,970	9,322
	60-64	4,317	4,720	4,833	5,100	5,468	5,726	6,449	6,993	7,309	7,536	7,752	7,969	8,187
	65-69	3,605	4,045	4,558	4,735	4,987	5,277	5,514	6,207	6,746	7,068	7,361	7,660	7,967
	70-74	2,373	3,360	3,860	4,404	4,745	4,989	5,268	5,505	6,215	6,776	7,298	7,854	8,448
	75-79	1,552	2,153	3,108	3,617	4,163	4,444	4,674	4,936	5,178	5,871	6,776	7,816	9,010
	80-84	1,047	1,326	1,891	2,760	3,259	3,729	3,983	4,208	4,462	4,713	4,971	5,240	5,520
	85+	979	1,232	1,591	2,242	2,972	3,606	4,247	4,763	5,215	5,673	6,163	6,692	7,261
		83,905	90,024	98,014	106,730	115,567	123,057	130,206	137,252	144,574	152,286	160,409	168,966	177,979
Pittwater	0-4	3,738	3,797	4,016	4,106	4,263	4,517	4,767	4,925	5,031	5,113	5,191	5,265	5,337
	5-9	4,050	4,134	4,309	4,537	4,697	4,919	5,160	5,354	5,518	5,643	5,760	5,874	5,986
	10-14	3,887	4,143	4,356	4,509	4,661	4,835	5,016	5,174	5,355	5,526	5,693	5,862	6,031
	15-19	3,650	3,863	4,224	4,415	4,632	4,833	4,966	5,065	5,209	5,394	5,588	5,785	5,985
	20-24	3,106	3,152	3,394	3,684	3,951	4,188	4,324	4,367	4,437	4,560	4,692	4,826	4,959
	25-29	2,599	2,572	2,630	2,812	3,045	3,277	3,437	3,489	3,516	3,575	3,641	3,706	3,770
	30-34	2,961	3,096	3,120	3,168	3,281	3,538	3,765	3,880	3,931	3,968	4,002	4,033	4,062
	35-39	3,740	3,937	4,167	4,209	4,297	4,480	4,777	4,997	5,138	5,214	5,275	5,333	5,387
	40-44	4,367	4,228	4,583	4,827	5,017	5,190	5,360	5,618	5,862	6,038	6,198	6,358	6,517
	45-49	4,445	4,536	4,544	4,911	5,292	5,563	5,703	5,794	6,060	6,335	6,605	6,882	7,166
	50-54	4,452	4,471	4,676	4,687	5,220	5,697	5,934	5,986	6,074	6,364	6,713	7,076	7,452
	55-59	4,271	4,396	4,516	4,724	4,920	5,567	6,022	6,173	6,220	6,325	6,446	6,565	6,682
	60-64	3,965	4,115	4,346	4,509	4,740	4,974	5,581	5,945	6,087	6,148	6,195	6,237	6,276
	65-69	3,485	3,694	3,960	4,171	4,361	4,625	4,815	5,322	5,667	5,818	5,934	6,049	6,161
	70-74	2,766	3,226	3,536	3,787	3,972	4,185	4,403	4,519	4,996	5,337	5,630	5,935	6,252
	75-79	1,880	2,440	2,971	3,271	3,694	3,953	4,142	4,296	4,415	4,903	5,543	6,262	7,069

	80-84	1,386	1,618	2,151	2,624	2,961	3,397	3,615	3,751	3,896	4,031	4,165	4,300	4,436
	85+	1,671	1,796	2,141	2,764	3,564	4,335	5,086	5,602	6,010	6,404	6,815	7,247	7,701
		60,416	63,215	67,640	71,716	76,568	82,071	86,872	90,255	93,420	96,696	100,086	103,596	107,229
Randwick	0-4	8,836	9,506	9,959	10,135	10,421	10,834	11,301	11,705	12,023	12,285	12,536	12,785	13,032
	5-9	6,876	7,968	8,654	9,006	9,203	9,456	9,803	10,197	10,568	10,866	11,149	11,432	11,715
	10-14	5,901	6,635	7,690	8,266	8,502	8,653	8,871	9,173	9,548	9,905	10,259	10,621	10,988
	15-19	6,896	7,292	8,078	9,015	9,509	9,734	9,885	10,107	10,454	10,882	11,333	11,797	12,272
	20-24	12,865	12,584	13,061	13,874	14,696	15,284	15,595	15,790	16,135	16,667	17,243	17,830	18,425
	25-29	14,182	13,682	13,666	14,054	14,952	15,791	16,364	16,655	16,880	17,255	17,668	18,081	18,492
	30-34	13,048	13,551	13,419	13,456	13,776	14,572	15,327	15,835	16,133	16,370	16,598	16,819	17,033
	35-39	11,260	12,040	12,607	12,526	12,625	12,912	13,608	14,269	14,756	15,053	15,309	15,561	15,807
	40-44	9,936	10,332	11,218	11,701	12,028	12,208	12,458	13,091	13,739	14,224	14,678	15,139	15,605
	45-49	8,706	9,319	9,855	10,686	11,387	11,743	11,897	12,118	12,747	13,394	14,039	14,708	15,399
	50-54	7,886	8,230	8,938	9,414	10,494	11,237	11,568	11,700	11,938	12,575	13,334	14,131	14,966
	55-59	6,871	7,386	7,869	8,503	8,826	9,795	10,473	10,764	10,907	11,150	11,424	11,698	11,971
	60-64	5,991	6,372	6,980	7,421	7,762	7,991	8,860	9,463	9,744	9,894	10,021	10,145	10,264
	65-69	5,292	5,584	6,091	6,633	6,918	7,197	7,405	8,206	8,787	9,068	9,299	9,530	9,761
	70-74	4,239	4,918	5,334	5,827	6,087	6,292	6,542	6,731	7,485	8,038	8,524	9,035	9,570
	75-79	3,312	3,820	4,579	4,973	5,544	5,821	6,028	6,268	6,477	7,232	8,219	9,336	10,599
	80-84	2,605	2,759	3,292	3,986	4,465	5,024	5,285	5,498	5,743	5,974	6,205	6,441	6,682
	85+	3,082	3,256	3,575	4,223	5,314	6,342	7,356	8,124	8,764	9,388	10,044	10,739	11,475
		137,785	145,233	154,869	163,698	172,508	180,885	188,626	195,693	202,826	210,220	217,883	225,825	234,057
Rockdale	0-4	7,219	7,994	8,299	8,281	8,449	8,738	9,077	9,341	9,529	9,674	9,809	9,940	10,066
	5-9	5,868	6,606	7,213	7,425	7,534	7,701	7,951	8,216	8,458	8,640	8,808	8,974	9,137
	10-14	5,199	5,694	6,367	6,838	7,017	7,105	7,253	7,452	7,704	7,940	8,172	8,405	8,640
	15-19	5,227	5,436	5,914	6,511	6,823	6,949	7,027	7,139	7,333	7,584	7,849	8,117	8,389
	20-24	6,835	6,909	7,135	7,511	7,913	8,187	8,319	8,369	8,493	8,717	8,961	9,206	9,451
	25-29	9,371	9,026	9,039	9,194	9,717	10,210	10,537	10,655	10,725	10,893	11,082	11,268	11,450
	30-34	9,753	9,967	9,702	9,656	9,836	10,349	10,840	11,128	11,260	11,352	11,437	11,514	11,585
	35-39	8,339	9,430	9,644	9,425	9,443	9,607	10,083	10,505	10,789	10,936	11,051	11,160	11,264
	40-44	7,459	8,107	9,050	9,233	9,393	9,485	9,639	10,063	10,489	10,789	11,063	11,337	11,610
	45-49	6,733	7,338	7,934	8,761	9,329	9,572	9,657	9,773	10,210	10,659	11,101	11,555	12,020
	50-54	6,324	6,729	7,299	7,790	8,680	9,247	9,480	9,526	9,653	10,103	10,645	11,208	11,794
	55-59	5,726	6,273	6,674	7,155	7,387	8,155	8,684	8,867	8,924	9,064	9,227	9,388	9,545
	60-64	5,077	5,627	6,164	6,521	6,789	6,954	7,677	8,147	8,331	8,405	8,460	8,509	8,553
	65-69	4,596	4,951	5,511	5,972	6,192	6,408	6,566	7,229	7,688	7,884	8,033	8,179	8,323
	70-74	3,616	4,393	4,770	5,309	5,551	5,708	5,910	6,042	6,672	7,119	7,502	7,900	8,314
	75-79	2,982	3,384	4,165	4,520	5,012	5,235	5,399	5,577	5,725	6,350	7,171	8,093	9,128
	80-84	2,349	2,566	2,991	3,693	4,142	4,636	4,857	5,020	5,208	5,383	5,555	5,729	5,904
	85+	2,716	3,032	3,433	4,049	5,069	6,018	6,951	7,627	8,172	8,699	9,246	9,823	10,428
		105,386	113,461	121,303	127,846	134,277	140,266	145,906	150,679	155,363	160,192	165,172	170,306	175,600

Ryde	0-4	7,175	7,864	8,485	8,973	9,533	10,138	10,816	11,398	11,897	12,356	12,817	13,286	13,765
	5-9	6,279	6,993	7,734	8,405	8,880	9,334	9,898	10,475	11,032	11,529	12,024	12,532	13,053
	10-14	5,453	6,074	6,820	7,566	8,047	8,378	8,786	9,244	9,778	10,310	10,855	11,422	12,011
	15-19	5,779	5,969	6,628	7,412	8,013	8,390	8,715	9,067	9,530	10,083	10,674	11,294	11,942
	20-24	9,207	9,171	9,534	10,332	11,271	11,990	12,512	12,890	13,385	14,054	14,780	15,534	16,316
	25-29	10,108	10,111	10,361	10,882	11,913	12,869	13,640	14,125	14,547	15,115	15,732	16,364	17,011
	30-34	9,851	10,698	10,938	11,335	11,970	12,954	13,935	14,648	15,164	15,640	16,119	16,603	17,090
	35-39	8,838	10,048	10,948	11,325	11,795	12,341	13,304	14,194	14,915	15,465	15,987	16,518	17,055
	40-44	8,021	8,725	9,966	10,920	11,614	12,059	12,587	13,459	14,352	15,103	15,843	16,609	17,401
	45-49	7,364	7,874	8,639	9,937	10,977	11,579	11,998	12,436	13,293	14,197	15,127	16,108	17,142
	50-54	7,068	7,169	7,783	8,607	9,948	10,893	11,468	11,801	12,236	13,103	14,123	15,213	16,377
	55-59	6,456	6,791	7,061	7,749	8,281	9,404	10,282	10,751	11,070	11,503	11,980	12,469	12,970
	60-64	5,542	6,016	6,455	6,824	7,315	7,704	8,739	9,494	9,933	10,252	10,555	10,861	11,169
	65-69	4,742	5,195	5,782	6,275	6,696	7,126	7,499	8,458	9,201	9,651	10,060	10,479	10,910
	70-74	3,612	4,477	5,012	5,648	6,085	6,434	6,842	7,163	8,095	8,835	9,524	10,261	11,047
	75-79	3,051	3,395	4,271	4,829	5,557	5,966	6,319	6,686	7,021	7,969	9,207	10,630	12,266
	80-84	2,432	2,602	3,030	3,904	4,544	5,230	5,625	5,954	6,320	6,683	7,055	7,444	7,849
	85+	2,854	3,095	3,473	4,106	5,298	6,464	7,668	8,615	9,444	10,283	11,182	12,152	13,199
		113,831	122,266	132,919	145,029	157,738	169,252	180,631	190,856	201,213	212,131	223,642	235,778	248,572
Strathfield	0-4	2,161	2,352	2,820	2,946	3,028	3,168	3,341	3,559	3,772	3,976	4,186	4,404	4,631
	5-9	2,044	2,370	2,788	3,062	3,157	3,264	3,422	3,660	3,914	4,151	4,394	4,649	4,915
	10-14	2,114	2,406	2,962	3,271	3,380	3,461	3,588	3,816	4,098	4,385	4,686	5,005	5,342
	15-19	2,338	2,371	2,861	3,251	3,429	3,532	3,627	3,814	4,070	4,371	4,696	5,043	5,413
	20-24	3,218	3,195	3,519	3,838	4,080	4,269	4,405	4,586	4,836	5,154	5,501	5,868	6,256
	25-29	4,106	4,149	4,411	4,518	4,792	5,092	5,336	5,585	5,840	6,159	6,506	6,869	7,248
	30-34	3,511	3,806	4,059	4,067	4,148	4,414	4,696	4,989	5,244	5,489	5,742	6,002	6,272
	35-39	2,718	3,322	3,812	3,815	3,838	3,949	4,210	4,539	4,843	5,097	5,348	5,608	5,877
	40-44	2,422	2,878	3,638	3,879	3,985	4,070	4,200	4,539	4,915	5,249	5,589	5,947	6,324
	45-49	2,462	2,584	3,236	3,797	4,086	4,240	4,344	4,550	4,939	5,354	5,789	6,257	6,759
	50-54	2,374	2,390	2,779	3,273	3,729	4,018	4,183	4,350	4,580	4,978	5,445	5,954	6,505
	55-59	2,036	2,176	2,454	2,737	2,854	3,187	3,446	3,642	3,807	4,016	4,245	4,484	4,734
	60-64	1,688	1,852	2,185	2,349	2,455	2,543	2,852	3,132	3,327	3,485	3,642	3,803	3,970
	65-69	1,350	1,527	1,874	2,118	2,218	2,322	2,416	2,754	3,042	3,238	3,426	3,622	3,828
	70-74	1,080	1,249	1,572	1,846	1,947	2,025	2,129	2,253	2,585	2,864	3,133	3,426	3,744
	75-79	859	981	1,312	1,542	1,743	1,841	1,928	2,061	2,198	2,533	2,970	3,480	4,076
	80-84	666	722	928	1,207	1,368	1,549	1,647	1,762	1,899	2,038	2,184	2,339	2,503
	85+	742	852	1,079	1,322	1,668	2,003	2,349	2,668	2,970	3,282	3,623	3,996	4,405
		37,891	41,182	48,287	52,836	55,905	58,944	62,119	66,259	70,878	75,818	81,102	86,755	92,802
Sutherland Shire - East	0-4	6,980	7,193	7,587	7,795	7,987	8,261	8,615	8,862	9,021	9,136	9,240	9,339	9,433
	5-9	6,742	7,129	7,564	7,924	8,071	8,251	8,552	8,834	9,074	9,247	9,403	9,555	9,703

	10-14	6,480	6,875	7,475	7,895	8,068	8,169	8,373	8,599	8,870	9,120	9,362	9,605	9,847
	15-19	6,357	6,602	7,175	7,777	8,112	8,262	8,388	8,518	8,731	9,008	9,298	9,592	9,888
	20-24	6,722	6,487	6,903	7,453	7,870	8,143	8,307	8,353	8,459	8,660	8,880	9,100	9,318
	25-29	6,817	6,695	6,681	6,967	7,401	7,776	8,057	8,145	8,180	8,287	8,411	8,530	8,645
	30-34	6,956	7,267	7,323	7,266	7,374	7,760	8,160	8,373	8,454	8,502	8,544	8,580	8,610
	35-39	7,240	7,664	8,168	8,142	8,162	8,304	8,749	9,112	9,338	9,442	9,518	9,587	9,651
	40-44	7,578	7,531	8,207	8,661	8,876	8,963	9,144	9,543	9,925	10,185	10,417	10,647	10,875
	45-49	7,411	7,678	7,877	8,548	9,075	9,312	9,431	9,541	9,945	10,358	10,760	11,172	11,591
	50-54	7,179	7,267	7,752	7,966	8,789	9,364	9,637	9,681	9,788	10,219	10,740	11,279	11,838
	55-59	6,863	6,843	7,146	7,610	7,832	8,647	9,245	9,436	9,475	9,601	9,749	9,894	10,033
	60-64	6,009	6,385	6,569	6,853	7,124	7,297	8,088	8,579	8,755	8,811	8,845	8,874	8,897
	65-69	5,263	5,564	6,111	6,324	6,480	6,706	6,899	7,592	8,057	8,242	8,376	8,507	8,635
	70-74	4,048	4,884	5,341	5,892	6,136	6,310	6,559	6,703	7,385	7,862	8,263	8,680	9,111
	75-79	2,927	3,711	4,621	5,102	5,675	5,928	6,138	6,338	6,491	7,182	8,090	9,107	10,245
	80-84	2,280	2,475	3,275	4,127	4,619	5,171	5,438	5,619	5,816	5,997	6,173	6,350	6,528
	85+	2,580	2,803	3,185	4,033	5,112	6,070	7,038	7,720	8,253	8,763	9,292	9,846	10,425
		106,432	111,054	118,960	126,337	132,761	138,695	144,819	149,549	154,019	158,622	163,362	168,245	173,273
Sutherland Shire - West	0-4	7,425	7,528	7,712	7,816	7,940	8,152	8,441	8,667	8,816	8,922	9,018	9,108	9,193
	5-9	7,172	7,460	7,688	7,945	8,024	8,142	8,380	8,640	8,868	9,031	9,177	9,319	9,457
	10-14	6,893	7,194	7,597	7,916	8,021	8,062	8,205	8,410	8,669	8,907	9,137	9,367	9,597
	15-19	6,765	6,909	7,292	7,797	8,065	8,154	8,220	8,331	8,533	8,798	9,075	9,355	9,636
	20-24	7,153	6,790	7,016	7,473	7,823	8,036	8,140	8,170	8,267	8,458	8,667	8,875	9,081
	25-29	7,253	7,008	6,793	6,986	7,357	7,674	7,895	7,966	7,995	8,094	8,208	8,319	8,425
	30-34	7,400	7,605	7,446	7,286	7,331	7,657	7,996	8,189	8,262	8,304	8,338	8,368	8,391
	35-39	7,704	8,019	8,303	8,164	8,114	8,195	8,574	8,912	9,127	9,222	9,289	9,350	9,405
	40-44	8,062	7,882	8,340	8,684	8,824	8,845	8,961	9,334	9,700	9,947	10,166	10,384	10,599
	45-49	7,884	8,035	8,008	8,570	9,021	9,189	9,242	9,332	9,720	10,116	10,502	10,895	11,296
	50-54	7,639	7,605	7,878	7,988	8,736	9,240	9,444	9,468	9,566	9,981	10,482	11,000	11,537
	55-59	7,300	7,162	7,264	7,630	7,786	8,533	9,059	9,229	9,261	9,377	9,515	9,649	9,778
	60-64	6,393	6,681	6,678	6,871	7,082	7,201	7,925	8,391	8,556	8,605	8,633	8,655	8,671
	65-69	5,597	5,822	6,210	6,341	6,442	6,618	6,761	7,426	7,874	8,049	8,175	8,297	8,415
	70-74	4,304	5,110	5,429	5,908	6,101	6,227	6,428	6,556	7,218	7,678	8,065	8,465	8,879
	75-79	3,113	3,882	4,693	5,115	5,641	5,850	6,014	6,199	6,344	7,014	7,896	8,882	9,984
	80-84	2,427	2,589	3,325	4,137	4,592	5,102	5,329	5,495	5,685	5,857	6,025	6,193	6,362
	85+	2,743	2,933	3,236	4,042	5,080	5,989	6,896	7,550	8,066	8,559	9,068	9,602	10,160
		113,228	116,213	120,906	126,670	131,980	136,865	141,910	146,264	150,528	154,917	159,433	164,081	168,865
Sydney - East	0-4	2,021	2,190	2,261	2,224	2,257	2,331	2,426	2,538	2,641	2,734	2,827	2,921	3,017
	5-9	1,119	1,298	1,417	1,478	1,502	1,533	1,586	1,666	1,750	1,822	1,894	1,968	2,044
	10-14	817	935	1,085	1,178	1,208	1,222	1,250	1,305	1,377	1,447	1,519	1,593	1,670
	15-19	1,540	1,470	1,527	1,624	1,688	1,717	1,740	1,797	1,883	1,986	2,096	2,210	2,330

	20-24	5,497	4,943	4,709	4,693	4,886	5,049	5,141	5,256	5,443	5,696	5,971	6,255	6,550
	25-29	8,830	7,942	7,413	7,174	7,500	7,869	8,138	8,364	8,589	8,896	9,229	9,569	9,917
	30-34	8,003	7,779	7,233	6,890	6,943	7,296	7,657	7,990	8,248	8,479	8,710	8,943	9,177
	35-39	5,443	5,831	5,757	5,467	5,434	5,521	5,806	6,149	6,442	6,659	6,861	7,066	7,273
	40-44	3,877	4,163	4,487	4,490	4,545	4,583	4,667	4,953	5,266	5,524	5,776	6,036	6,304
	45-49	3,068	3,237	3,488	3,771	3,986	4,085	4,129	4,248	4,528	4,820	5,119	5,433	5,764
	50-54	2,627	2,741	2,912	3,135	3,496	3,720	3,821	3,903	4,035	4,307	4,627	4,968	5,332
	55-59	2,288	2,342	2,479	2,640	2,715	2,993	3,194	3,315	3,403	3,525	3,659	3,796	3,937
	60-64	1,936	1,999	2,095	2,232	2,327	2,380	2,633	2,840	2,963	3,048	3,128	3,209	3,290
	65-69	1,614	1,669	1,776	1,888	1,948	2,013	2,067	2,314	2,510	2,624	2,727	2,831	2,938
	70-74	1,135	1,363	1,458	1,578	1,638	1,682	1,745	1,813	2,043	2,223	2,388	2,565	2,753
	75-79	780	930	1,151	1,258	1,394	1,454	1,503	1,578	1,652	1,870	2,153	2,478	2,850
	80-84	516	589	721	918	1,031	1,153	1,210	1,271	1,346	1,418	1,492	1,570	1,650
	85+	462	516	605	759	959	1,137	1,316	1,469	1,605	1,742	1,888	2,046	2,215
		51,574	51,936	52,577	53,395	55,456	57,738	60,029	62,768	65,725	68,821	72,063	75,457	79,011
Sydney - Inner	0-4	1,039	1,178	1,370	1,464	1,541	1,623	1,719	1,842	1,967	2,090	2,217	2,352	2,492
	5-9	575	698	860	974	1,026	1,068	1,124	1,209	1,303	1,393	1,486	1,584	1,688
	10-14	420	503	659	777	825	851	886	948	1,026	1,106	1,191	1,282	1,380
	15-19	790	790	926	1,070	1,153	1,196	1,233	1,304	1,403	1,518	1,644	1,779	1,925
	20-24	2,819	2,656	2,850	3,090	3,337	3,516	3,642	3,815	4,054	4,354	4,684	5,036	5,412
	25-29	4,533	4,265	4,484	4,723	5,122	5,481	5,766	6,071	6,398	6,800	7,239	7,703	8,193
	30-34	4,113	4,179	4,373	4,535	4,741	5,081	5,425	5,799	6,143	6,481	6,832	7,199	7,581
	35-39	2,797	3,135	3,485	3,598	3,710	3,845	4,114	4,463	4,799	5,090	5,382	5,688	6,008
	40-44	1,992	2,239	2,722	2,956	3,104	3,192	3,306	3,595	3,923	4,223	4,531	4,859	5,208
	45-49	1,577	1,740	2,116	2,485	2,723	2,845	2,925	3,083	3,373	3,685	4,016	4,374	4,762
	50-54	1,350	1,474	1,766	2,066	2,389	2,591	2,707	2,833	3,006	3,293	3,630	4,000	4,405
	55-59	1,176	1,259	1,504	1,740	1,854	2,085	2,263	2,406	2,535	2,694	2,870	3,056	3,252
	60-64	995	1,075	1,270	1,471	1,589	1,658	1,866	2,062	2,207	2,330	2,454	2,583	2,718
	65-69	830	897	1,077	1,244	1,330	1,402	1,465	1,680	1,870	2,006	2,139	2,279	2,428
	70-74	583	734	884	1,040	1,118	1,171	1,236	1,316	1,522	1,699	1,874	2,065	2,274
	75-79	401	501	700	829	952	1,013	1,065	1,146	1,231	1,430	1,689	1,995	2,356
	80-84	265	317	439	606	704	803	857	923	1,002	1,084	1,171	1,264	1,363
	85+	238	277	368	501	656	792	933	1,066	1,196	1,332	1,482	1,647	1,830
		26,493	27,916	31,852	35,168	37,875	40,213	42,531	45,562	48,959	52,609	56,532	60,747	65,276
Sydney - South	0-4	2,380	3,127	3,871	4,327	4,635	4,923	5,249	5,667	6,097	6,526	6,975	7,452	7,957
	5-9	1,318	1,858	2,430	2,879	3,085	3,238	3,431	3,720	4,039	4,350	4,675	5,021	5,391
	10-14	962	1,339	1,863	2,297	2,482	2,581	2,705	2,915	3,179	3,454	3,747	4,064	4,404
	15-19	1,811	2,094	2,617	3,165	3,468	3,627	3,765	4,012	4,348	4,741	5,172	5,639	6,145
	20-24	6,467	7,025	8,049	9,135	10,038	10,665	11,122	11,736	12,565	13,596	14,734	15,959	17,277
	25-29	10,392	11,271	12,666	13,957	15,408	16,623	17,607	18,676	19,828	21,232	22,772	24,412	26,156

	30-34	9,422	11,062	12,351	13,400	14,260	15,412	16,569	17,841	19,039	20,236	21,491	22,813	24,203
	35-39	6,408	8,324	9,844	10,630	11,160	11,661	12,563	13,731	14,873	15,891	16,929	18,025	19,182
	40-44	4,564	5,945	7,694	8,736	9,335	9,680	10,097	11,061	12,159	13,185	14,252	15,398	16,627
	45-49	3,612	4,619	5,982	7,349	8,190	8,628	8,934	9,485	10,454	11,505	12,632	13,862	15,205
	50-54	3,093	3,912	4,992	6,110	7,186	7,858	8,267	8,714	9,315	10,281	11,419	12,677	14,065
	55-59	2,694	3,340	4,250	5,145	5,576	6,324	6,910	7,401	7,855	8,412	9,028	9,684	10,382
	60-64	2,279	2,852	3,590	4,350	4,780	5,027	5,699	6,343	6,841	7,275	7,719	8,186	8,676
	65-69	1,901	2,377	3,045	3,678	4,001	4,253	4,472	5,169	5,796	6,264	6,728	7,223	7,750
	70-74	1,336	1,954	2,497	3,077	3,364	3,552	3,775	4,048	4,719	5,306	5,894	6,544	7,262
	75-79	919	1,333	1,981	2,451	2,865	3,072	3,252	3,524	3,815	4,464	5,315	6,324	7,521
	80-84	608	842	1,241	1,793	2,119	2,436	2,618	2,839	3,107	3,385	3,683	4,005	4,352
	85+	544	737	1,041	1,484	1,973	2,404	2,849	3,280	3,707	4,159	4,661	5,220	5,843
		60,709	74,012	90,003	103,961	113,925	121,965	129,885	140,161	151,733	164,261	177,824	192,506	208,400
Sydney - West	0-4	1,746	2,039	2,255	2,323	2,463	2,639	2,839	3,034	3,219	3,396	3,579	3,769	3,968
	5-9	967	1,210	1,414	1,544	1,639	1,736	1,856	1,992	2,132	2,264	2,398	2,540	2,688
	10-14	706	872	1,083	1,232	1,319	1,383	1,463	1,561	1,678	1,797	1,922	2,055	2,196
	15-19	1,328	1,367	1,523	1,698	1,843	1,944	2,036	2,148	2,295	2,467	2,653	2,852	3,064
	20-24	4,742	4,594	4,693	4,903	5,335	5,716	6,015	6,285	6,633	7,075	7,559	8,071	8,614
	25-29	7,621	7,377	7,387	7,494	8,189	8,910	9,522	10,001	10,467	11,049	11,683	12,347	13,042
	30-34	6,912	7,232	7,206	7,196	7,579	8,261	8,960	9,553	10,051	10,531	11,026	11,538	12,068
	35-39	4,701	5,429	5,738	5,710	5,931	6,250	6,794	7,352	7,851	8,270	8,685	9,117	9,565
	40-44	3,348	3,876	4,478	4,690	4,961	5,188	5,460	5,922	6,418	6,861	7,312	7,788	8,290
	45-49	2,650	3,013	3,481	3,941	4,352	4,624	4,831	5,079	5,518	5,987	6,480	7,011	7,581
	50-54	2,268	2,552	2,906	3,277	3,819	4,212	4,471	4,666	4,917	5,350	5,858	6,411	7,013
	55-59	1,976	2,180	2,474	2,760	2,963	3,390	3,737	3,963	4,147	4,378	4,632	4,898	5,177
	60-64	1,672	1,861	2,090	2,333	2,540	2,695	3,082	3,396	3,611	3,786	3,960	4,140	4,326
	65-69	1,395	1,552	1,772	1,973	2,126	2,279	2,419	2,767	3,059	3,260	3,452	3,653	3,864
	70-74	980	1,271	1,454	1,650	1,788	1,904	2,042	2,168	2,490	2,761	3,024	3,309	3,620
	75-79	674	867	1,150	1,315	1,523	1,647	1,758	1,887	2,014	2,323	2,726	3,198	3,749
	80-84	446	549	721	960	1,126	1,306	1,416	1,520	1,640	1,762	1,889	2,025	2,170
	85+	399	481	605	795	1,048	1,289	1,541	1,756	1,956	2,164	2,391	2,640	2,913
		44,530	48,322	52,429	55,793	60,546	65,374	70,242	75,052	80,097	85,482	91,229	97,362	103,907
The Hills Shire - Central	0-4	4,879	5,240	5,473	5,580	5,712	6,057	6,626	6,977	7,221	7,437	7,650	7,865	8,081
	5-9	5,465	5,868	6,180	6,388	6,487	6,800	7,393	7,818	8,164	8,461	8,751	9,045	9,344
	10-14	5,502	6,005	6,366	6,691	6,839	7,100	7,633	8,026	8,417	8,801	9,189	9,589	10,001
	15-19	5,415	5,790	6,207	6,584	6,837	7,140	7,602	7,904	8,238	8,643	9,074	9,521	9,985
	20-24	4,931	5,107	5,356	5,718	6,030	6,397	6,844	7,046	7,255	7,554	7,878	8,211	8,554
	25-29	4,177	4,240	4,299	4,427	4,683	5,046	5,483	5,674	5,794	5,970	6,162	6,357	6,554
	30-34	4,668	5,037	4,999	4,942	5,016	5,413	5,970	6,271	6,438	6,584	6,729	6,874	7,017
	35-39	5,411	5,975	6,269	6,150	6,147	6,413	7,089	7,556	7,873	8,095	8,299	8,504	8,708

	40-44	5,932	6,151	6,685	6,966	7,119	7,370	7,887	8,427	8,911	9,299	9,673	10,057	10,450
	45-49	5,737	6,202	6,361	6,906	7,333	7,715	8,195	8,488	8,997	9,528	10,068	10,632	11,221
	50-54	5,327	5,727	6,085	6,278	6,937	7,579	8,179	8,411	8,648	9,183	9,815	10,485	11,194
	55-59	4,829	5,066	5,377	5,738	5,906	6,689	7,499	7,834	7,999	8,242	8,512	8,787	9,065
	60-64	4,262	4,458	4,645	4,950	5,165	5,425	6,312	6,849	7,106	7,272	7,425	7,578	7,728
	65-69	3,674	3,801	3,978	4,182	4,311	4,575	4,936	5,562	6,001	6,242	6,452	6,665	6,882
	70-74	2,717	3,273	3,391	3,594	3,718	3,920	4,274	4,471	5,010	5,423	5,797	6,194	6,613
	75-79	1,655	2,296	2,759	2,913	3,212	3,441	3,737	3,950	4,113	4,629	5,304	6,073	6,949
	80-84	1,013	1,328	1,818	2,226	2,475	2,843	3,134	3,315	3,489	3,659	3,830	4,008	4,191
	85+	913	1,120	1,410	1,898	2,425	2,954	3,594	4,033	4,384	4,733	5,104	5,501	5,926
		76,506	82,682	87,660	92,129	96,353	102,876	112,387	118,612	124,059	129,756	135,714	141,946	148,464
The Hills Shire - North	0-4	4,366	5,153	6,184	7,172	8,107	8,987	9,772	9,987	9,995	9,953	9,899	9,841	9,776
	5-9	4,896	5,769	6,985	8,213	9,206	10,088	10,903	11,190	11,299	11,323	11,323	11,316	11,303
	10-14	4,927	5,905	7,195	8,606	9,706	10,532	11,257	11,488	11,649	11,778	11,890	11,997	12,098
	15-19	4,846	5,693	7,019	8,469	9,706	10,591	11,212	11,314	11,401	11,566	11,741	11,911	12,077
	20-24	4,407	5,020	6,054	7,357	8,561	9,491	10,094	10,087	10,042	10,109	10,193	10,273	10,347
	25-29	3,745	4,165	4,856	5,692	6,651	7,487	8,087	8,123	8,020	7,990	7,974	7,953	7,928
	30-34	4,187	4,952	5,640	6,350	7,119	8,032	8,805	8,976	8,910	8,812	8,708	8,600	8,489
	35-39	4,838	5,877	7,083	7,898	8,723	9,513	10,453	10,815	10,897	10,834	10,739	10,640	10,534
	40-44	5,313	6,045	7,564	8,956	10,104	10,933	11,632	12,062	12,333	12,444	12,517	12,583	12,641
	45-49	5,139	6,098	7,184	8,890	10,412	11,444	12,086	12,150	12,450	12,750	13,026	13,300	13,573
	50-54	4,766	5,631	6,879	8,071	9,858	11,244	12,063	12,042	11,970	12,287	12,698	13,116	13,540
	55-59	4,321	4,980	6,079	7,383	8,383	9,928	11,059	11,215	11,072	11,030	11,015	10,993	10,966
	60-64	3,808	4,382	5,249	6,369	7,333	8,047	9,306	9,803	9,835	9,733	9,609	9,481	9,350
	65-69	3,296	3,735	4,497	5,379	6,118	6,787	7,279	7,958	8,304	8,353	8,349	8,339	8,325
	70-74	2,449	3,221	3,829	4,624	5,277	5,815	6,303	6,400	6,931	7,256	7,500	7,748	7,999
	75-79	1,491	2,263	3,126	3,746	4,565	5,104	5,510	5,654	5,693	6,192	6,859	7,594	8,402
	80-84	908	1,308	2,067	2,870	3,517	4,219	4,623	4,745	4,829	4,896	4,956	5,014	5,070
	85+	822	1,103	1,600	2,451	3,451	4,385	5,299	5,771	6,066	6,333	6,603	6,881	7,167
		68,527	81,302	99,090	118,495	136,797	152,628	165,744	169,779	171,697	173,636	175,598	177,581	179,587
The Hills Shire - South	0-4	3,124	3,473	3,836	4,031	4,205	4,449	4,783	4,997	5,145	5,271	5,394	5,516	5,638
	5-9	3,502	3,888	4,332	4,614	4,776	4,994	5,337	5,599	5,817	5,997	6,170	6,344	6,519
	10-14	3,525	3,979	4,463	4,834	5,035	5,215	5,511	5,749	5,998	6,238	6,479	6,726	6,978
	15-19	3,468	3,837	4,352	4,756	5,034	5,244	5,489	5,661	5,870	6,126	6,398	6,678	6,966
	20-24	3,155	3,384	3,755	4,131	4,440	4,699	4,941	5,047	5,170	5,354	5,555	5,759	5,968
	25-29	2,678	2,809	3,013	3,198	3,448	3,706	3,959	4,064	4,129	4,231	4,345	4,459	4,573
	30-34	2,993	3,337	3,502	3,570	3,693	3,976	4,310	4,492	4,587	4,667	4,745	4,821	4,896
	35-39	3,464	3,959	4,394	4,442	4,525	4,710	5,117	5,412	5,610	5,738	5,852	5,964	6,075
	40-44	3,801	4,075	4,689	5,032	5,241	5,413	5,694	6,036	6,349	6,591	6,820	7,054	7,291

	45-49	3,676	4,110	4,458	4,990	5,399	5,666	5,916	6,080	6,410	6,753	7,098	7,457	7,829
	50-54	3,411	3,795	4,266	4,535	5,108	5,566	5,905	6,025	6,162	6,508	6,920	7,354	7,810
	55-59	3,092	3,357	3,770	4,146	4,348	4,913	5,414	5,612	5,699	5,842	6,002	6,163	6,324
	60-64	2,727	2,954	3,256	3,576	3,803	3,984	4,555	4,906	5,063	5,155	5,235	5,315	5,392
	65-69	2,356	2,518	2,789	3,021	3,174	3,360	3,564	3,984	4,276	4,424	4,549	4,675	4,802
	70-74	1,747	2,169	2,376	2,597	2,737	2,879	3,086	3,203	3,569	3,843	4,087	4,344	4,614
	75-79	1,064	1,522	1,936	2,105	2,365	2,527	2,698	2,829	2,931	3,281	3,739	4,259	4,848
	80-84	649	880	1,278	1,609	1,823	2,088	2,263	2,375	2,486	2,593	2,701	2,811	2,924
	85+	587	743	990	1,372	1,786	2,170	2,594	2,888	3,123	3,355	3,599	3,858	4,134
		49,021	54,789	61,456	66,558	70,941	75,558	81,136	84,958	88,394	91,968	95,687	99,557	103,583
Warringah	0-4	10,408	10,527	10,743	10,988	11,174	11,452	11,838	12,225	12,536	12,794	13,041	13,285	13,524
	5-9	10,307	10,624	10,840	11,126	11,204	11,350	11,661	12,092	12,512	12,849	13,168	13,487	13,805
	10-14	9,320	10,235	10,635	10,929	11,035	11,072	11,249	11,598	12,052	12,487	12,919	13,358	13,803
	15-19	8,500	9,319	10,216	10,673	10,945	11,047	11,117	11,333	11,702	12,167	12,657	13,159	13,673
	20-24	8,014	8,404	9,084	9,848	10,323	10,585	10,704	10,806	11,023	11,373	11,753	12,138	12,528
	25-29	9,059	8,852	9,064	9,473	9,970	10,381	10,662	10,819	10,947	11,176	11,431	11,684	11,936
	30-34	10,768	10,848	10,723	10,771	10,882	11,347	11,828	12,184	12,393	12,560	12,720	12,874	13,022
	35-39	11,640	12,036	12,314	12,167	12,097	12,197	12,738	13,318	13,749	14,009	14,232	14,448	14,660
	40-44	12,322	12,134	12,724	13,063	13,215	13,224	13,374	14,011	14,679	15,179	15,647	16,119	16,595
	45-49	11,529	12,036	12,030	12,690	13,293	13,517	13,571	13,782	14,473	15,189	15,903	16,640	17,401
	50-54	9,994	10,877	11,465	11,538	12,574	13,277	13,546	13,659	13,914	14,639	15,505	16,412	17,361
	55-59	8,402	9,300	10,138	10,732	10,928	11,955	12,670	12,983	13,133	13,410	13,724	14,036	14,347
	60-64	7,173	7,703	8,557	9,356	9,712	9,858	10,831	11,534	11,856	12,024	12,166	12,301	12,431
	65-69	6,468	6,602	7,182	8,008	8,284	8,496	8,664	9,572	10,232	10,547	10,803	11,059	11,313
	70-74	5,510	5,999	6,215	6,847	7,084	7,218	7,437	7,630	8,470	9,085	9,624	10,188	10,779
	75-79	4,299	5,005	5,601	5,912	6,481	6,710	6,887	7,139	7,366	8,213	9,324	10,579	11,995
	80-84	3,333	3,700	4,430	5,096	5,572	6,181	6,445	6,684	6,970	7,242	7,513	7,790	8,071
	85+	4,240	4,528	5,093	6,169	7,688	9,048	10,401	11,454	12,336	13,199	14,105	15,063	16,077
		151,286	158,731	167,055	175,388	182,461	188,916	195,623	202,824	210,345	218,144	226,232	234,621	243,320
Waverly	0-4	4,849	4,985	5,039	5,100	5,228	5,400	5,597	5,725	5,802	5,854	5,899	5,941	5,981
	5-9	3,607	3,992	4,163	4,278	4,351	4,442	4,576	4,700	4,807	4,880	4,944	5,006	5,067
	10-14	2,777	3,313	3,696	3,887	3,974	4,019	4,094	4,181	4,294	4,398	4,498	4,599	4,699
	15-19	2,498	2,750	3,267	3,620	3,787	3,852	3,886	3,924	4,005	4,116	4,233	4,351	4,471
	20-24	3,820	3,705	3,906	4,345	4,632	4,787	4,853	4,853	4,893	4,991	5,099	5,206	5,313
	25-29	7,550	7,029	6,992	7,210	7,651	8,029	8,268	8,310	8,311	8,388	8,481	8,571	8,657
	30-34	8,773	8,462	8,268	8,337	8,517	8,951	9,355	9,545	9,596	9,614	9,625	9,632	9,633
	35-39	7,019	7,162	7,154	7,124	7,177	7,292	7,636	7,908	8,069	8,128	8,163	8,194	8,220
	40-44	5,565	5,701	5,982	6,102	6,228	6,281	6,369	6,609	6,844	6,996	7,130	7,262	7,392
	45-49	4,431	4,756	4,963	5,243	5,537	5,675	5,712	5,746	5,964	6,187	6,404	6,625	6,851
	50-54	3,612	3,925	4,267	4,460	4,948	5,265	5,385	5,379	5,416	5,632	5,898	6,172	6,456
	55-59	3,213	3,323	3,639	3,954	4,087	4,506	4,788	4,860	4,859	4,904	4,962	5,018	5,071

	60-64	2,703	2,893	3,029	3,324	3,500	3,580	3,943	4,159	4,226	4,237	4,238	4,237	4,234
	65-69	2,438	2,407	2,610	2,750	2,835	2,930	2,996	3,278	3,464	3,530	3,574	3,618	3,659
	70-74	1,887	2,215	2,248	2,435	2,541	2,609	2,696	2,739	3,005	3,187	3,337	3,493	3,654
	75-79	1,461	1,671	2,019	2,063	2,256	2,354	2,422	2,487	2,536	2,795	3,137	3,519	3,945
	80-84	1,134	1,213	1,429	1,748	1,957	2,187	2,287	2,349	2,421	2,487	2,550	2,614	2,679
	85+	1,394	1,385	1,496	1,757	2,202	2,611	3,009	3,282	3,494	3,695	3,904	4,122	4,350
		68,731	70,887	74,167	77,737	81,409	84,771	87,872	90,033	92,004	94,019	96,077	98,181	100,330
Willoughby	0-4	5,210	5,423	5,629	5,740	5,885	6,112	6,355	6,568	6,735	6,874	7,006	7,137	7,266
	5-9	4,841	5,116	5,323	5,514	5,615	5,763	5,956	6,182	6,397	6,569	6,731	6,894	7,057
	10-14	4,317	4,727	4,965	5,196	5,316	5,405	5,524	5,700	5,923	6,137	6,349	6,565	6,784
	15-19	4,049	4,420	4,781	5,042	5,236	5,354	5,420	5,530	5,711	5,937	6,176	6,421	6,671
	20-24	4,860	4,973	5,251	5,627	5,946	6,178	6,284	6,349	6,477	6,682	6,905	7,131	7,360
	25-29	5,929	5,853	5,905	6,079	6,442	6,797	7,022	7,131	7,216	7,366	7,534	7,701	7,867
	30-34	6,464	6,620	6,600	6,623	6,752	7,134	7,481	7,712	7,844	7,950	8,050	8,148	8,242
	35-39	6,454	6,865	7,070	7,054	7,096	7,250	7,617	7,970	8,228	8,383	8,516	8,645	8,772
	40-44	6,094	6,385	6,845	7,105	7,274	7,375	7,503	7,867	8,243	8,523	8,785	9,050	9,317
	45-49	5,653	5,975	6,273	6,736	7,136	7,352	7,425	7,546	7,925	8,316	8,707	9,111	9,527
	50-54	4,975	5,433	5,762	6,058	6,737	7,207	7,396	7,464	7,603	7,999	8,472	8,967	9,486
	55-59	4,255	4,665	5,078	5,432	5,599	6,207	6,616	6,785	6,864	7,008	7,172	7,335	7,497
	60-64	3,709	3,929	4,311	4,703	4,930	5,070	5,604	5,972	6,139	6,226	6,299	6,369	6,436
	65-69	3,238	3,377	3,617	3,984	4,153	4,316	4,427	4,895	5,233	5,393	5,524	5,655	5,785
	70-74	2,333	2,936	3,106	3,378	3,521	3,635	3,768	3,868	4,294	4,606	4,879	5,165	5,464
	75-79	1,727	2,066	2,636	2,855	3,160	3,315	3,422	3,550	3,663	4,084	4,637	5,261	5,965
	80-84	1,346	1,453	1,767	2,342	2,658	2,988	3,133	3,252	3,392	3,524	3,656	3,790	3,927
	85+	1,716	1,821	2,002	2,424	3,054	3,641	4,209	4,639	4,997	5,346	5,712	6,100	6,511
		77,171	82,036	86,923	91,890	96,509	101,099	105,162	108,982	112,883	116,923	121,108	125,443	129,933
Wollondilly	0-4	3,676	3,855	3,915	3,992	4,138	4,374	4,605	4,925	5,252	5,576	5,913	6,267	6,637
	5-9	3,769	4,117	4,313	4,451	4,572	4,778	4,999	5,369	5,778	6,172	6,581	7,012	7,467
	10-14	3,674	3,844	4,167	4,430	4,584	4,744	4,909	5,242	5,665	6,106	6,572	7,070	7,600
	15-19	3,484	3,550	3,727	4,086	4,327	4,504	4,617	4,873	5,234	5,661	6,127	6,627	7,164
	20-24	2,884	2,794	2,858	3,033	3,232	3,419	3,520	3,680	3,905	4,191	4,506	4,842	5,199
	25-29	2,696	2,605	2,565	2,637	2,824	3,033	3,172	3,333	3,507	3,725	3,964	4,215	4,480
	30-34	2,991	3,214	3,162	3,127	3,212	3,455	3,667	3,912	4,138	4,363	4,597	4,840	5,093
	35-39	3,315	3,592	3,832	3,815	3,867	4,022	4,278	4,632	4,973	5,271	5,570	5,884	6,210
	40-44	3,664	3,593	3,936	4,180	4,335	4,474	4,608	5,001	5,448	5,861	6,285	6,736	7,215
	45-49	3,591	3,750	3,727	4,076	4,389	4,603	4,707	4,950	5,408	5,903	6,430	7,000	7,616
	50-54	3,379	3,571	3,737	3,711	4,111	4,477	4,651	4,856	5,145	5,633	6,207	6,835	7,522
	55-59	3,244	3,309	3,465	3,659	3,799	4,289	4,628	4,910	5,165	5,487	5,842	6,216	6,610
	60-64	2,759	3,119	3,193	3,346	3,524	3,689	4,129	4,553	4,867	5,134	5,404	5,685	5,977
	65-69	2,308	2,584	2,910	3,013	3,118	3,299	3,426	3,921	4,358	4,672	4,979	5,302	5,643
	70-74	1,592	2,142	2,376	2,689	2,848	2,994	3,141	3,337	3,855	4,300	4,739	5,219	5,745

	75-79	1,054	1,438	1,895	2,147	2,424	2,588	2,705	2,904	3,116	3,617	4,272	5,042	5,948
	80-84	706	861	1,183	1,626	1,869	2,139	2,270	2,439	2,645	2,859	3,086	3,328	3,588
	85+	601	798	1,005	1,376	1,785	2,167	2,536	2,892	3,239	3,605	4,008	4,453	4,945
		49,388	52,735	55,966	59,395	62,957	67,047	70,568	75,729	81,697	88,136	95,081	102,574	110,658
Woollahra	0-4	3,310	3,368	3,420	3,486	3,582	3,708	3,852	3,993	4,109	4,209	4,306	4,402	4,498
	5-9	2,803	3,040	3,169	3,243	3,298	3,375	3,485	3,626	3,766	3,882	3,993	4,104	4,216
	10-14	2,706	3,020	3,285	3,428	3,503	3,551	3,626	3,752	3,913	4,069	4,225	4,385	4,547
	15-19	2,736	2,982	3,314	3,593	3,755	3,829	3,872	3,961	4,106	4,284	4,473	4,667	4,867
	20-24	3,186	3,204	3,430	3,768	4,007	4,150	4,218	4,273	4,375	4,530	4,698	4,870	5,045
	25-29	4,969	4,710	4,763	4,962	5,279	5,553	5,731	5,836	5,927	6,073	6,234	6,396	6,557
	30-34	5,394	5,404	5,333	5,380	5,500	5,794	6,070	6,275	6,406	6,516	6,623	6,727	6,829
	35-39	4,402	4,613	4,724	4,758	4,806	4,895	5,138	5,391	5,586	5,712	5,824	5,934	6,042
	40-44	3,963	3,995	4,280	4,448	4,558	4,607	4,683	4,924	5,177	5,373	5,559	5,748	5,938
	45-49	3,671	3,783	3,893	4,205	4,470	4,591	4,633	4,721	4,976	5,242	5,508	5,784	6,070
	50-54	3,427	3,542	3,690	3,816	4,234	4,516	4,630	4,685	4,790	5,059	5,377	5,712	6,064
	55-59	3,193	3,349	3,497	3,700	3,814	4,216	4,490	4,617	4,687	4,804	4,934	5,065	5,196
	60-64	2,972	3,117	3,304	3,506	3,663	3,756	4,148	4,433	4,573	4,655	4,727	4,797	4,865
	65-69	2,988	2,731	2,966	3,176	3,284	3,403	3,487	3,867	4,149	4,292	4,412	4,533	4,654
	70-74	2,286	2,673	2,560	2,797	2,935	3,021	3,129	3,221	3,589	3,864	4,108	4,364	4,634
	75-79	1,596	2,026	2,435	2,369	2,564	2,682	2,766	2,877	2,980	3,335	3,800	4,327	4,924
	80-84	1,150	1,341	1,710	2,069	2,307	2,585	2,708	2,819	2,951	3,077	3,204	3,334	3,467
	85+	1,509	1,457	1,642	2,049	2,596	3,086	3,564	3,939	4,258	4,573	4,904	5,256	5,630
		56,259	58,356	61,413	64,755	68,155	71,316	74,230	77,210	80,317	83,548	86,909	90,405	94,042

SGS calculations, 2015

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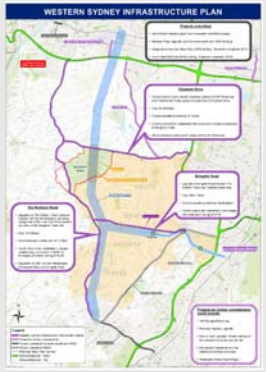
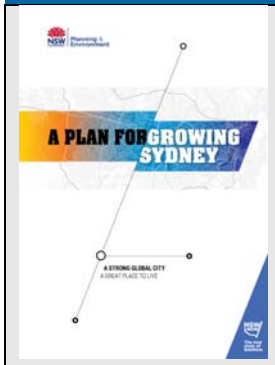
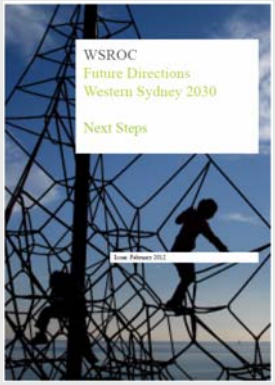
Appendix C – Review of Strategic Planning Documents

Strategy/Policy	Overview	Implications for the SIA for the Western Sydney Airport
Australian Government		
Western Sydney Infrastructure Plan 	The Australian Government has announced plans to invest in a number of infrastructure projects to build a stronger and more prosperous Western Sydney. This includes major road and transport linkages to support the proposed Western Sydney Airport by relieving pressure on existing infrastructure, ease congestion and support the creation of jobs. The plan will deliver significant upgrades to major and local roads connecting to and surrounding the proposed Western Sydney Airport site including: • Bringelly Road – upgrade to four lanes from Camden Valley Way to the Northern Road • The Northern Road – upgrade to a minimum of four lanes from Narellan to M4 Motorway • Elizabeth Drive Corridor – construction of a new four lane motorway from the M7 Motorway to the Northern Road • Construction of the Werrington Arterial Road between the M4 Motorway and the Great Western Highway • Upgrade of Ross Street and Great Western Highway intersection at Glenbrook • Improve interchanges connecting Northern Road and Elizabeth Drive with arterial roads • Local Roads – $200 million for local road upgrades.	The upgrade of these roads will lead to a number of benefits for local and regional communities, including improved travel times and increased access. There may also be socio-economic impacts particularly for local communities during the construction, and together with the construction of the proposed WSA, may lead to cumulative impacts.
New South Wales Government		
NSW Government - A Plan for Growing Sydney	*A Plan for Growing Sydney* is the NSW Government's Metropolitan Strategy for managing the growth of Sydney. The plan sets ambitious housing and employment targets for Sydney to 2031, including: • Sydney will have 1.6 million more people • There is a need for 664,000 additional homes • Employment capacity will increase to 689,000 new jobs across metropolitan Sydney. The NSW Government's vision for Sydney is: *a strong global city, a great place to live*. To deliver on this, a	The WSA would support the directions outlined in The Plan as a major stimulus to the Western Sydney economy, broadening the range of job opportunities available to residents. The WSA will facilitate

Strategy/Policy	Overview	Implications for the SIA for the Western Sydney Airport
	number of goals have been set including: A competitive economy with world-class services and transport A key priority under this goal is to support the development of the Western Sydney Airport as a new hub of intense economic activity and improved new transport connections. This would then support the growth of Liverpool, Penrith, Campbelltown-Macarthur as regional city centres. Supporting actions include: • 1.4.1. Improve transport links and create a new services centre and industrial precinct to support the growth of Western Sydney Airport • 1.4.2. Develop new strategic employment corridors along transport infrastructure investments that will service Western Sydney Airport. The Plan states that the NSW Government will support the timely and efficient delivery of Western Sydney Airport as an aviation and services centre. Over the longer term, Western Sydney Airport will transform and drive future investment and jobs growth in Western Sydney, with Australian Government projections indicating potential for the airport to create 35,000 jobs by 2035, increasing to 60,000 jobs in the longer term. The government commits to: preserving land for the airport, associated infrastructure and transport connections; and facilitate an enterprise corridor from Leppington to the Western Sydney Airport and direct economic growth to this corridor and other adjacent economic areas (e.g. Western Sydney Employment Area). *A Plan for Growing Sydney* identifies a number of subregions across the metropolitan area. The Western Sydney Airport will be particularly important for the West Central, West and South West subregions. The Plan acknowledges the economic benefits for these subregions, and the need to leverage these and strengthen transport connections to the Western Sydney Airport.	development of the Western Sydney Employment Area and other economic corridors/areas. Improved transport connections between the proposed Western Sydney Airport and centres will support economic activity and housing development in these centres, whilst improving access to local employment for Western Sydney communities.

Strategy/Policy	Overview	Implications for the SIA for the Western Sydney Airport
2014 State Infrastructure Strategy Update 	This report outlines Infrastructure NSW's independent advice to the NSW Government on the next round of critical infrastructure priorities for NSW. The growth of Western Sydney is identified as key to the future of NSW and the development of an airport at Badgerys Creek will help to reshape the Western Sydney economy. Investments in road upgrades have already commenced to support a second Sydney airport at Badgerys Creek. Further, the Outer Sydney Orbital (M9) will connect the North West and the South West Growth Centres and provide links to the future Western Sydney Airport. An objective of the report is to maximise the economic potential of Western Sydney Airport including: • Protecting the future operating capacity of the airport • Preserving land for complementary activities • Protecting future transport corridors related to the site. The report notes that to support the development of the Western Sydney Airport, planning should continue to develop the significant landside infrastructure that will be needed to support WSA and connect the proposed new airport to the wider Sydney metropolitan area. Investment and action will be needed across a number of areas to protect the future operating capacity of Western Sydney Airport, preserve land for complementary activities and ensure efficient, reliable access to the airport.	Investment in the development of WSA and supporting infrastructure will lead to significant economic growth for Sydney, and it will be important to consider how these benefits can be delivered to local communities in Western Sydney.
Broader Western Sydney Employment Area – Draft Structure Plan 	The Western Sydney Employment Area (WSEA) is located directly north of the proposed Western Sydney Airport site, and covers more than 10,000 hectares. The draft structure plan sets out a long-term development framework, with the following key priorities relevant to the proposed Western Sydney Airport: • Investigate a potential south west expansion of the Western Sydney Employment Area (WSEA) of up to 10,000 hectares through a structure planning process • Encourage critical industries that support the economy's global functioning and promote employment, such as industrial uses, freight, logistics and research and development functions as well as opportunities for agribusiness and food production	The relationship between the WSEA and the proposed Western Sydney Airport is critical, as each will support the development and growth of the other. As the proposed Western Sydney Airport and WSEA develop, the built form and character of surrounding

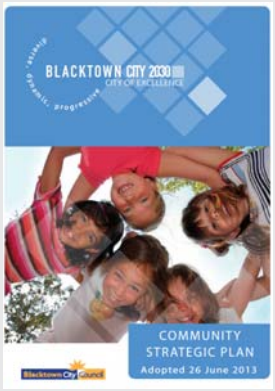
Strategy/Policy	Overview	Implications for the SIA for the Western Sydney Airport
	• Identify opportunities to improve transport connections to the area, including protecting a corridor for the Western Sydney Freight Line and completing the Western Sydney Employment Area arterial network • Identify and protect opportunities for a major intermodal terminal at Eastern Creek • Investigate opportunities for better connections with surrounding centres such as possible transport connections to Mount Druitt, Fairfield and Leppington. The plan identifies the importance of avoiding incompatible development in the vicinity of the potential Western Sydney Airport. An Economic Issues and Drivers study identified that demand within the Broader WSEA is likely to remain directed towards employment uses within the freight and logistics areas. While the potential for higher intensity employment development is not ruled out, other factors such as population growth, transport infrastructure improvements and market conditions will take time to help drive other forms of employment.	communities will change as employers move to the area and transport initiatives are introduced.
Regional organisations		
Regional Plan for Sydney – Regional Development Australia 	Regional Development Australia (RDA) is a nation-wide initiative between the Australian, State and Territory Governments, with RDA Sydney funded to advance sustainable economic development and social equity within Sydney's regions. The Regional Plan for Sydney identifies the need for an integrated long-term vision for the GSM to capitalise on Sydney's opportunities and manage future challenges. It outlines the challenges for an economically, environmentally and socially sustainable Sydney and provides priority solutions to address them, including key place-based solutions. The following key priorities are relevant to the proposed Western Sydney Airport: • Jobs closer to home • Adopting whole of government planning which encompasses utilities, roads, transport, health, employment and education • Expanding and developing Sydney's capacity as a global city attracting investment and sustainable development.	The Western Sydney Airport would support many of the key priorities of this plan, such as provision of job opportunities in Western Sydney. However early and integrated planning will be required to ensure that Western Sydney communities can take advantage of these jobs.

Strategy/Policy	Overview	Implications for the SIA for the Western Sydney Airport
	• Supporting employment growth in the South West and North West Growth areas by developing attractive employment lands and through the development of new strategic centres. The Western Sydney Airport is identified as an opportunity for regional infrastructure. RDA advises that the airport is a priority to ensure a smooth continuation and expansion of Sydney's air travel and air freight tasks. Further, a rail orbital route which links the Western Sydney Employment Area and WSA to the metropolitan rail network is recommended as a priority.	
Future Directions Western Sydney 2030 – WSROC  	The Western Sydney Regional Organisation of Councils (WSROC) represents the councils and communities of Western Sydney, and enables sharing of resources and cooperation between member councils. WSROC member councils include: • Auburn City Council • Bankstown City Council • Blacktown City Council • Blue Mountains City Council • Fairfield City Council • Hawkesbury City Council • Holroyd City Council • Liverpool City Council • Parramatta City Council • Penrith City Council. This document is intended to commence a partnership between the Councils of Western Sydney, the State and Federal Governments, business, education and utility stakeholders and the wider community, to deliver the future of Western Sydney. The document been developed to provide strategic guidance to decision makers and project partners,	The Western Sydney Airport would contribute to the aims of the WSROC plan through jobs creation and diversification, and the facilitation of new public transport connections, including potential high speed rail.

Strategy/Policy	Overview	Implications for the SIA for the Western Sydney Airport
	and acknowledges that the challenges of Western Sydney are greater than any one council or centre. The plan identifies the following ideas for a future direction which are relevant to the proposed Western Sydney Airport: • Western Sydney can become more economically resilient through diversifying businesses, increasing direct interactions between businesses and expanding the skills base of the workforce • Greater diversity of job options, including professional jobs and jobs in the creative sectors will provide greater opportunities for residents to work locally In addition, Parramatta or Badgerys Creek are identified as the potential locations for a terminus for High Speed Rail, which is to be investigated.	
Progressing the NSW Economic Development Framework - WSROC	This document was prepared as a submission to the NSW Government's Economic Development Framework Priority Settings for 2014. It outlines that the future development of Western Sydney is vital within the economic framework of the NSW Government, including the creation of jobs and business opportunities. The lack of public transport is a significant barrier to investment and growth, and needs to be improved if residents and employees are to move freely around the region. Despite this, the economy and development potential of Western Sydney provide a unique opportunity to capitalise on the energy, initiative, innovation and determination of the population. The following suggestions have been provided as Potential Priority Actions for 2014: • Support the needs of major industries • Leverage multicultural assets • Support attraction of international students. • Promote the sustainability and growth of small business • Help industry and business meet skills shortages • Drive jobs and business growth in Western Sydney	WSA would be a key catalyst for the development of Western Sydney. The priorities identified in the plan would all be supported by a major international airport in Western Sydney.

Strategy/Policy	Overview	Implications for the SIA for the Western Sydney Airport
	• Investigate drivers and barriers for business investment in Western Sydney • Increase the availability of alternative workplaces • Rollout of digital initiatives • Raise the global profile of Sydney and NSW.	
South West Rail Link Extension Submission - MACROC	The Macarthur Regional Organisation of Councils (MACROC) includes: • Camden Council • Campbelltown City Council • Wollondilly Shire Council. MACROC has not recently released a strategic policy document, however it has made a number of submissions on NSW Government planning policies and projects. The most recent of these which is related to the proposed Western Sydney Airport is the Submission to the South West Rail Link Extension Public Transport Corridor Protection. The submission notes that South West Sydney is the area targeted to accommodate the major proportion of Sydney's projected growth over the coming years and transport continues to be a considerable challenge in supporting a future population. MACROC supports the extension of the South West Rail Link which would connect Leppington to Bringelly (and the proposed Western Sydney Airport) and then north to St Marys and South to Narellan. However MACROC recommends further extension to include connection from Narellan to Campbelltown to connect future populations within the Macarthur region and employment hubs in Western Sydney.	The WSA will support the expected population growth of South West Sydney and the Macarthur region through provision of employment opportunities, as well as facilitating employment in surrounding areas. The proposed transport links would also support the population growth and ensure future communities of these regions can access these employment benefits, as well as other parts of Sydney.

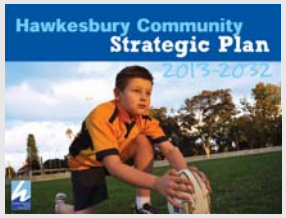
Local government		
Auburn City Community Strategic Plan 2013 – 2023 	Auburn's community strategic plan provides a 10 year vision for the communities of Auburn following consultations with 7,000 community members in 2010, with further consultations in 2012 and 2013. The themes of the vision are: • Our Community – Diverse and Inclusive • Our Places – Attractive and Liveable • Our Environment – Healthy and Green • Our Leadership – Visionary and Responsible Auburn is one of the most culturally diverse LGA's in Australia, which is seen as a key asset for the community.	Auburn is located on the eastern edge of the Western Sydney region. As such there may not be many direct impacts from the proposed Western Sydney Airport, however the community would benefit from improved access to an airport, and potentially from increased employment opportunities in Western Sydney.
Bankstown Community Plan 2030 	The *Bankstown Community Plan* outlines the community's 10 year vision for Bankstown, to address key challenges in Bankstown's future including economic development, protection of the natural environment and continued growth. The key directions for Bankstown include: • Liveable – access to good public transport, services and leisure facilities; clean, safe and attractive; appropriate and affordable housing • Invest – encourage investment and economic growth • Green – balanced development and built environment; green spaces; sustainable growth • Connected – accessible modes of transport; safe commuting. • Lead – positive strategic decision-making and advocacy.	Located on the eastern edge of the Western Sydney region, there may not be significant direct impacts from the proposed Western Sydney Airport for Bankstown LGA, however economic growth and the development of Bankstown would be supported by the proposed Western Sydney Airport and development of Western Sydney overall.

Blacktown City 2030 	This document identifies the main priorities of the Blacktown community and aspirations for the city, which are based on the principles of sustainability and social equity. Council adopted *Blacktown City 2030* in 2013. The community identified the following focus areas for a vibrant and inclusive community: • Coordinate a whole-of-government approach on key social issues and needs in the city • Develop projects, partnerships, festivals and events that build community • Develop Blacktown City as a centre of cultural excellence • Provide and promote libraries, current technology, the history of Blacktown City and the availability and benefits of lifelong learning to the community • Provide and promote community facilities that meet the needs of the community • Ensure the provision of high-quality child care services which meet the needs of children and their families. The plan does not directly reference the Western Sydney Airport however the following aspirations relate to WSA: • Pursue strategic economic opportunities and partnerships to facilitate sustainable growth of the local and regional economy • The community has excellent access to all transport networks, which have expanded to meet the needs of a major growth centre • Facilitate the accessibility of major employment centres in the City through quality transport and communication infrastructure and services • Provide transport networks that connect the City and are functional, accessible and acceptable to the community and support vehicle and non-vehicle users.	The Western Sydney Airport would support the continued economic growth and diversity of the LGA, as well as improved transport networks. The WSA may also support the growth of cultural opportunities through increasing the profile and accessibility of Western Sydney.

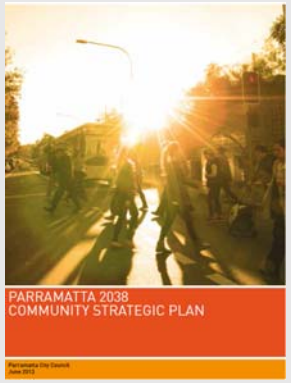
Sustainable Blue Mountains 2025 	The plan presents a community endorsed vision and strategic plan for the City of Blue Mountains, which was prepared in 2000 and updated in 2012 and 2013. The Blue Mountains World Heritage National Park covers 70% of the LGA with only 11% available for development. The plan identifies the following key directions: • Centralising population close to public transport, land and infrastructure • Provide a range of housing choices to meet diverse needs • Promote alternative forms of transport that are safe and accessible • Health and service needs for those without access to transport • Facilitate and support programs that engage community and build social cohesion • Improve access of young people to learning opportunities in the Blue Mountains • Reducing the social and environmental impacts of large numbers of people commuting outside the LGA by increasing local employment opportunities • The ageing population is creating a demand for increased services and a workforce to meet the needs of older people • Implementing economic development strategies in the City that benefit Aboriginal communities • Increasing employment-generating social enterprise initiatives.	The Blue Mountains World Heritage Area is located to the west of the proposed Western Sydney Airport site. There may be impacts on the cultural heritage values of the Blue Mountains for the community. The WSA would also support the development of the Blue Mountains through increasing the accessibility of the Blue Mountains to tourists and to Western Sydney residents.

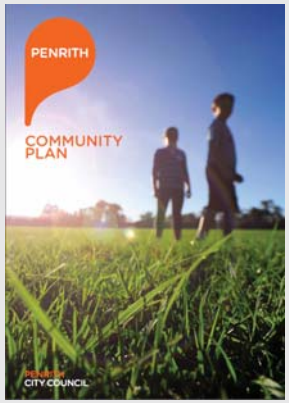
Camden 2040 	*Camden 2040* has been prepared as a strategic response to the large-scale population growth and urban development projected for the future of the LGA and the South West Growth Centre. This document was adopted by council in 2013. The plan identifies a number of relevant targets for the proposed Western Sydney Airport: • A strong local economy would be characterised by vibrant town and commercial centres, thriving local businesses, stable and diverse employment opportunities, skilled local residents, infrastructure that supports economic growth and a thriving tourist/visitor market • A diverse range of business and industry had located and invested in the Camden and Macarthur areas because it is sought-after location, an environment that is known to support and sustain local enterprises • Local small businesses are flourishing, and have access to the information and support that they need to be sustainable over time • More of the community are employed locally because there are enough jobs in the region, and local residents have the necessary skills needed to make up the local workforce • An accessible Camden means that people are able to travel easily within their own local area and are effectively connected to the wider Macarthur and metropolitan area • The road network is well connected, free-flowing and safe • Community is enriched through a diverse array of opportunities, through arts and cultural programs, local libraries, access to information, recreation and sporting pursuits, parks and open spaces.	Camden is identified as an area of high growth with the South West Growth Centre identified as an area for future employment and housing opportunities. The Western Sydney Airport would support this growth and drive further change to the character and amenity of Camden, which as an LGA on the fringe of the Sydney Metropolitan area, has large areas of semi-rural and rural land. This change will be a key issue for the community over time. The WSA would support many of the targets outlined in the plan, particularly: providing more local employment opportunities; increased transport options through supporting the South West Rail Link; increased urban development; and access to larger scale infrastructure and facilities.

Creating our Future Together – Campbelltown's Community Strategic Plan 	Campbelltown's Community Strategic Plan was prepared in 2013. The vision statement is 'a connected community with opportunities to grow in a safe and sustainable environment'. Community identified aspirations included: • A healthy local economy delivers jobs, opportunities and increased prosperity. It is fundamental that there are educational and trade opportunities to continue to contribute towards a productive and growing economy • Attraction of business to the local area to create jobs • Promotion of Campbelltown as a regional City through the growth of the City's major business centres • Improved transport systems will reduce traffic congestion, save people valuable time and provide significant benefits to business, industry and the environment. Government will work together to grow public transport patronage and provide services that are physically and financially accessible • Participation in walking and cycling as active modes of transport will be encouraged and will also help reduce road congestion and promote healthy lifestyles for the community • A strong service sector supports a variety of community needs, including providing a healthy and sage community that has opportunities for involvement to build a strong sense of community spirit. The following strategic directions are associated with WSA: • Attraction of business to the local area to create jobs • The encouragement of the use of alternative transportation in, out and around the City.	Economic growth through the support and attraction of businesses is a clear theme throughout the document. The Western Sydney Airport would support this and Campbelltown's development as a regional city through supporting the development of the South West Growth Centre.

Fairfield City Plan 2012-2022 	This plan outlines the community's priorities for the future and strategies and was adopted by Council in 2012. The plan highlights that Fairfield has a young population however older people over 65 years are the fastest growing age group. Fairfield is also very culturally diverse, and many new migrants choose to live in Fairfield. The following goals of Fairfield's City Plan are related to the proposed Western Sydney Airport: • Encourage an increased range of local employment that cater to both skilled and unskilled workers. • Capitalise on business/industry/government partnerships to promote existing strengths and emerging opportunities to grow the local economy • Market local business and growth opportunities • Provide buildings, infrastructure and facilities to support employment areas.	The WSA site is adjacent to the western edge of the Fairfield LGA, with some residents in these rural residential areas likely to experience some impacts as a result of the proposed Western Sydney Airport.
Hawkesbury Community Strategy Plan 2013 - 2023 	The Community Strategic Plan identifies a number of key challenges including: • Slowing population growth • Supporting local employment • Supporting tourism and the promotion of the Hawkesbury area. The key strategies identified in the plan include: • Looking after people and place – preserving character; well serviced development; connected and safe neighbourhoods • Caring for our environment – minimising ecological footprint; sustainable use of the environment • Linking the Hawkesbury – community facility provision; accessible and integrated transport and communications systems • Supporting business and local jobs – support new and existing industries; range of local employment training options.	Although located a distance from the proposed Western Sydney Airport site, the proposed Western Sydney Airport could support the development of the Hawkesbury through increased employment opportunities in Western Sydney for community members, as well as providing tourism benefits through improved access brought by the airport.

Living Holroyd – Community Strategic Plan 	*Living Holroyd* establishes a long-term vision for the future of the city and was adopted in 2013. The community prioritises a city that is: • Inclusive, healthy and safe • Focused on urban planning and economic development • A place that values its environment, open space and sustainable development • Open and accessible for all • Engaged and innovative.	The growth of Western Sydney supported by the proposed Western Sydney Airport will support the growth and development of Holroyd over time.
Growing Liverpool 2023 	This plan aims to address the key challenges that Liverpool communities face and its unique characteristics over the next 10 years. This plan was adopted in 2013. Relevant directions and strategies for the proposed Western Sydney Airport include: • Vibrant Prosperous City – through attracting investment and business, supporting business growth, improving availability of jobs and workforce participation • Liveable Safe City – create attractive and safe places and facilitate diverse and more affordable housing options • Healthy Inclusive City – strengthen communities and increase participation, support and deliver high quality services, programs and facilities • Proud Engaged City – deliver a range of cultural events, provide first class and iconic facilities, protect Liverpool's heritage • Accessible Connected City – Provide safe and easy travel with a high quality road and traffic management network.	The site of the Western Sydney Airport is within the Liverpool LGA, which will have direct impacts on residents in these rural areas. The plan highlights the importance of supporting vulnerable groups in the community, including older people, Aboriginal people, and people from diverse cultural backgrounds, which will be a key consideration for this SIA. The WSA will also support the directions and strategies to develop Liverpool as a regional city, with increased employment opportunities, improved transport connections, a healthy and supported community, and a centre for cultural activities.

Parramatta 2038 	*Parramatta 2038* makes bold commitments to seeing the revitalisation of the city centre and identifies Parramatta as the driving force and heart of Western Sydney, which it identifies as Australia's most significant economic region; a vibrant home for diverse communities and a centre of excellence in research, education and enterprise. Council adopted *Parramatta 2038* in 2013. The plan identifies that people in Western Sydney spend, on average, more time commuting than anyone else in the country, and they have less access to jobs, high-level education, entertainment and cultural institutions than those who live in other parts of Sydney. The plan notes that the Parramatta railway station is the fourth busiest in NSW and that 82% of people who work in Parramatta live outside the LGA. The plan identifies that an airport in Western Sydney would be a major catalyst for jobs growth and infrastructure. Relevant objectives that relate to the proposed Western Sydney Airport include: • Parramatta's economic growth will help build the City as a centre of high, value-adding employment and the driving force behind the generation of new wealth for Western Sydney • Parramatta will be a city with fast, reliable transport and digital networks that connect people to each other, to the information and services they need and to where they need to go • People and places need to be linked by fast and reliable transport • New housing will be supported by new jobs, especially as Western Sydney employment is particularly vulnerable to declining manufacturing and increased energy costs.	The Western Sydney Airport would support the continued growth and development of Parramatta as a major employment and commercial centre for Sydney.

Penrith Community Plan 	The *Penrith Community Plan* has been developed through extensive engagement and was adopted in 2013. The following objectives are relevant to the proposed Western Sydney Airport: • The population is growing faster than the number of jobs available in the region, so residents will have to travel longer distances, which in turn affects the wellbeing of the community and the health of individuals. Penrith city council aims to support a balanced local economy delivering local jobs • The plan identifies the following key growth areas: health and wellbeing, arts/culture/communication, sustainability, logistics, innovation and manufacturing, finance and business • Improve roads, public transport, footpaths and cycleways to reduce traffic congestion and enhance liveability and access around the City.	The site of the proposed Western Sydney Airport is located on the edge of the Penrith LGA, with a number of communities in this area likely to experience both impacts and benefits. The airport would also support the objectives of the plan to support additional employment in the Western Sydney region to reduce the need to travel long distances for work.
The Hills Future Community Strategic Plan 	The Hills Community Strategic Plan identifies the following outcomes for the shire in the 10 years from 2013 when the plan was adopted: • Proactive leadership • Vibrant communities • Balanced urban growth. • Protected environment. • Modern local economy.	The Hills Shire is located on the edge of the Western Sydney region and there may be few direct impacts for The Hills communities, however transport and economic objectives could be supported by the proposed Western Sydney Airport and associated development.

Wollondilly Community Strategic Plan 2033 	The strategic plan captures the strengths and key issues facing the community and in response it establishes strategies to provide Council and the community with a focus and direction for achieving the identified outcomes. Due to the low and dispersed population, Council has limitations regarding employment opportunities, schools, human services, cultural and recreational opportunities, shopping, and leisure. Key issues that relate to the proposed Western Sydney Airport include: • Limited access to public transport and high reliance on having to travel significant distances • Population growth is needed to support business and employment growth, as well as schools, shops, professional services, cultural activities, community facilities and services. Wollondilly has a shortage of knowledge-based jobs, lacks strategic educational assets such as a university or TAFE presence and key infrastructure to support economic development • Council has insufficient funds to adequately maintain all assets, particularly roads and community facilities, in a suitable condition that meets the needs of the community • Public and alternative transport arrangements are poor, with limited bus services and diesel train services that terminate at Campbelltown • Access to services (e.g. health services) by elderly residents is an issue, with outreach services being poorly targeted to the community.	The airport site is located on the northern edge of Wollondilly Shire, with a number of nearby villages likely to experience impacts as well as benefits from the proposed airport. Population growth is identified as a key strategic need to support the community. The WSA would support this growth through increased development and employment in the region.

Appendix D – Badgerys Creek community profile

Badgerys Creek socio-demographic profile

Community overview

Badgerys Creek can be accessed from the north via Elizabeth Drive or from the south via The Northern Road, both of which are main thoroughfares within the locality. Kemps Creek or Luddenham are the closest service centres for the Badgerys Creek residents.

The Australian Government identified a site located in Badgerys Creek as the preferred location for a second Sydney Airport in 1986 and the site was acquired from property owners between 1986 and 1991.

The following information for the suburb of Badgerys Creek with a comparison to Liverpool LGA is based on ABS Census data 2011 unless otherwise stated. A large portion of Badgerys Creek is Commonwealth owned land (around 1,700 hectares of the total 1,810 hectares). As a result, the following information may not accurately reflect the current community profile. The following information provides an indicative community profile only.

Demographic profile

Population

- The population of Badgerys Creek in 2011 was 455 persons compared with 721 persons in 2006 (ABS 2006).
- Badgerys Creek had a significantly lower population density compared with Liverpool LGA (0.03 persons per hectare compared with 5.89 persons per hectare)
- Aboriginal and Torres Strait Islander people made up 3.7 per cent of the population or 17 persons. This was significantly higher than the Aboriginal and Torres Strait Islander population of Liverpool LGA with 1.5 per cent of the population with 2,676 persons
- 14.9 per cent of the population were born in a non-English speaking country and 63.5 per cent speak only English at home. This is considerably lower than Liverpool with 35.9 per cent of the population born in a non-English speaking country and 49.8 per cent speaking a language other than English at home.
- Slightly higher percentage of people living at the same address 1 and 5 years ago in comparison to Liverpool LGA (81.7 per cent and 56.2 per cent in contrast to 80 per cent and 52.8 per cent respectively).

Age profile

- Largest proportion of people in the 35-49 years age bracket- 19.6 per cent; followed by 60-69 years age group - 13.6 per cent. In Liverpool, the largest proportion of the population was also in the 35-49 years age group (22.3 per cent) followed by the 25-34 years age group (14.7 per cent)
- There were 117 people (25.7 per cent) aged under 18 years and 93 (20.4 per cent) aged 60 years or older. These results showed a slightly larger percentage of the population aged less than 18 years compared to Liverpool LGA (28.1 per cent) and a lower percentage aged 60 years or older compared to the wider area (13.5 per cent)
- A similar median age of 34 compared with 33 in Liverpool LGA.

Gender profile

- In 2011, Badgerys Creek had a female population of 213 (46.9 per cent) and a male population of 241 (52.9 per cent). Liverpool however had a higher proportioned female population of 90,820 (50.4 per cent) and a male population of 89,323 (49.6 per cent).

Badgerys Creek socio-demographic profile

Household structure and family composition

- There were a total of 119 households in Badgerys Creek in 2011. Of the total number of households, family households comprised 78.2 per cent, 16.0 per cent were lone person households and 5.9 per cent were group households. Liverpool LGA had a higher number of family households (82.1 per cent), the same percentage of lone person households and a significantly lower proportion of group households (1.8 per cent)
- Of the 102 families in Badgerys Creek, 49% were couple families with children, 29.4% were couple families without children and 21.6 per cent were one parent families. Liverpool LGA reported more couple families with children (56.7 per cent), less couple families without children (23.7 per cent) and one parent families (18.2 per cent).

Education level

- Badgerys Creek has a significantly lower high school completion rate (18.4 per cent) compared with Liverpool LGA (46.3 per cent). The suburb also recorded a higher proportion of the population without post-school qualifications (58.3 per cent compared with 50.1%).

Housing tenure

- There were a total of 120 private dwellings, of which 97.6 per cent were occupied and 2.4 per cent were unoccupied. Liverpool LGA had a lower percentage of occupied private dwellings (95.8 per cent)
- All of the private dwellings in Badgerys Creek were separate houses, with no flats, units or apartments. Liverpool LGA however had a variety of housing choices including separate houses (72.1 per cent), semi-detached or terrace houses (11.4 per cent), flats, units or apartments (12.1 per cent) and other dwellings (0.2 per cent)
- Of the occupied dwellings in Badgerys Creek, a significant percentage (67.2 per cent) of dwellings were rented, with 25 per cent being fully owned and 7.8 per cent owned with a mortgage. In comparison to Liverpool LGA, there was a higher percentage of rented dwellings (67.2 per cent and 30.4 per cent), similar full ownership rates (25 per cent and 24.1 per cent) and a significantly lower proportion of owned with a mortgage (7.8 per cent and 41.9 per cent)
- Lower proportion of state housing properties being rented in Badgerys Creek (11.5 per cent) compared to Liverpool LGA (25.9 per cent). This represented nine properties of the total 120 private dwellings.

Economic profile

Total employment

- Total employment in Badgerys Creek and Liverpool LGA was above 92 per cent.

Unemployment rate

- The rate of unemployment was slightly lower in Badgerys Creek (6.1 per cent) in comparison to Liverpool LGA (7 per cent).

Total labour force

- Badgerys Creek has lower labour force participation (49.1 per cent) in comparison to Liverpool LGA (58.1 per cent).

Occupations

- Residents of Badgerys Creek were mainly employed as managers (18.5 per cent),

Badgerys Creek socio-demographic profile
labourers (16.8 per cent) and technicians and trades (16.8 per cent). The more common professions in Liverpool were clerical and administrative (17.5 per cent), technicians and trades (15.7 per cent) and professionals (15.4 per cent).
Industries of employment • The most common industries of employment in Badgerys Creek were construction (13.3 per cent), agriculture (9.8 per cent), transport and warehousing (9.2 per cent). Manufacturing (14 per cent) and health care (8.1 per cent) ranked highest in Liverpool LGA.
Travel to work • A significant percentage of the population worked from home in comparison to the Liverpool LGA (14.9 per cent and 2.7 per cent). • The most common form of transport to work is by car (56.9 per cent), however more of the population in the Liverpool LGA used a private vehicle (71.1 per cent). Only a small percentage of residents used public transport (5.1 per cent).
Average income • Lower average weekly household income ($1,172) in comparison to Liverpool LGA ($1,299) • Lower average weekly individual income ($413) compared with Liverpool LGA ($510).
SEIFA rating • The SEIFA Index of Advantage and Disadvantage for Badgerys Creek was 913 indicating that the suburb was more disadvantaged compared to GSM (1025) (ABS 2013).

Appendix E – Western Sydney region - community profiles

Auburn LGA socio-demographic profile

Community overview

Auburn LGA is located 17 kilometres from the Sydney CBD and covers 32 square kilometres. Located close to the geographical centre of the GSM region and at the 'gateway to Western Sydney (Auburn City Council 2013), Auburn is densely populated, and primarily made up of residential and industrial areas.

In 2014 the estimated residential population of Auburn LGA was 85,446 persons (Profile.id 2014). The population is projected to grow by 32 per cent to 113,083 persons by 2030 (SGS Economics and Planning 2015).

The M4 Motorway travels through the LGA, which is proposed for major urban renewal. Sydney Olympic Park, the former site of the 2000 Olympic Games, is a major sport and recreation facility. The University of Sydney has a campus in Auburn (Cumberland Campus), and there is a TAFE campus. Auburn and Lidcombe are the largest town centres of the LGA and are located around train stations. Significant population growth is expected in the established centres and residential suburbs of Wentworth Point, Sydney Olympic Park and Lidcombe which will have increased housing and commercial development (Auburn City Council 2013).

The LGA has one of the largest overseas born populations of any local government in NSW. In 2011, 57 per cent of residents were born overseas, originating from 124 countries. The LGA is the first place of settlement for many newly arrived refugees and migrants; 27 per cent of Auburn LGA's population arrived in Australia within the last five years (Auburn City Council 2013).

Auburn City Council's *Community Strategic Plan 2013-2023* identifies the characteristics that make the LGA unique. Auburn LGA is a community with a sense of pride in its cultural and linguistic diversity. There is a strong network of not-for-profit cultural, civic, and community organisations with over 170 groups. The community has strong social capital, and values social inclusion and intercultural understanding (Auburn City Council 2013).

The following information for the Auburn LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011a and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Auburn LGA as at 30 June 2014 was 85,446 persons (Profile.id. 2014a)
- The population of Auburn LGA in 2011 was 73,738 persons compared with 64,959 persons in 2006 (ABS 2006a), which is equivalent to an increase of 14 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Auburn LGA was considerably more populated than Greater Sydney with a density of 22.81 persons per hectare compared with 3.54 persons per hectare
- Slightly lower percentage of people living at the same address 1 and 5 years ago in comparison to Greater Sydney (75.3 per cent and 45.4 per cent in contrast to 80.0 per cent and 52.8 per cent respectively).
- Aboriginal and Torres Strait Islander people made up 0.6 per cent of the population

Auburn LGA socio-demographic profile
with 448 persons. This was lower than the Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney • Culturally diverse population with 54.2 per cent of the population born in a non-English speaking country and 71.0 per cent speaking a language other than English at home. This was significantly higher than Greater Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home.
Population projections • The population of Auburn LGA is expected to increase to 100,056 persons by 2025, 113,083 persons by 2030 and 193,047 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 93 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[3].
Age profile • Largest proportion of people is in the 35-49 years age bracket- 15,269 persons 20.7 per cent; followed by 25-34 years age group- 15,122 persons 20.5 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent) • There were 17,205 people (23.3 per cent) aged under 18 years and 9,137 (12.4 per cent) aged 60 years or older. Greater Sydney recorded a fairly similar percentage of the population under the age of 18 (22.9 per cent), however the proportion of the population aged 60 years and older was noticeably higher than the LGA at 18.0 per cent • Younger population in Auburn with a median age of 31 years compared with 36 years in Greater Sydney.
Gender profile • In 2011, Auburn had a male population of 38,225 (51.8 per cent) and a female population of 35,513 (48.2 per cent). Greater Sydney reported a larger female population (50.8 per cent) compared to male population (49.2 per cent).
Household structure and family composition • There were a total of approximately 22,079 households in Auburn LGA. Of the total number of households, family households comprised 77.9 per cent, 17.0 per cent were lone person households and 5.1 per cent were group households. Greater Sydney reported a lower percentage of family households (73.1 per cent) and group households (4.3 per cent) and a higher percentage of lone person households (22.6 per cent) • Of the 18,303 families in Auburn LGA, 52.6 per cent were couple families with children, 29.1 per cent were couple families without children, and 15.3 per cent were one parent families. Greater Sydney recorded slightly more couple families without children (33.5 per cent) and one parent families (15.7 per cent) and a lower percentage of couple families with children (48.9 per cent).

[3] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

Auburn LGA socio-demographic profile

Education level

- Auburn LGA had a similar rate of high school completion (55.4 per cent) compared to Greater Sydney (54.5 per cent). The LGA recorded a higher percentage of the population without post-school qualifications with 46.6 per cent compared to 40.5 per cent for Greater Sydney.

Housing tenure

- In Auburn LGA, 94.9 per cent of private dwellings were occupied and 5.1 per cent were unoccupied. There were a total of 23,261 private dwellings. Greater Sydney had a higher number of unoccupied private dwellings with 7.2 per cent
- Of occupied private dwellings in Auburn LGA, 49.8 per cent were separate houses, 37.7 per cent were flats, units or apartments, 12.1 per cent were semi-detached, row or terrace houses, or townhouses, and 0.2 per cent were other dwellings. Greater Sydney recorded a higher percentage of separate houses (60.9 per cent) and a lower number of flats, units or apartments (25.8 per cent)
- Of occupied private dwellings in Auburn LGA, approximately 57.1 per cent of the dwellings were privately owned (32.2 per cent were owned with a mortgage, 24.9 per cent were owned outright) and 38.9 per cent were rented. Greater Sydney recorded a greater percentage of privately owned dwellings with 65.2 per cent and fewer rented properties at 31.6 per cent
- Lower percentage of state housing properties in Auburn LGA (9.7 per cent) compared to Greater Sydney (14.4 per cent)
- The number of dwellings in the Auburn is forecast to grow from 24,986 in 2011 to 51,119 in 2036, with the average household size falling from 3.15 to 2.70 by 2036 (Forecast.id. 2014a).

Economic profile

Total employment

- Total employment in Auburn LGA and Greater Sydney was over 90 per cent.

Unemployment rate

- The rate of unemployment was higher in Auburn LGA (8.6 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- The total labour force in Auburn LGA was 59,245 persons and 80 per cent compared with 81 per cent for Greater Sydney.

Occupations

- The most common occupations in Auburn LGA included professionals (20.8 per cent), clerical and administrative workers (14.3 per cent) and technicians and trades workers (14.2 per cent). These occupations were also dominant in Greater Sydney.

Auburn LGA socio-demographic profile

Industries of employment

- The main industries of employment in Auburn LGA included manufacturing (11.0 per cent), health care and social assistance (10.4 per cent) and retail trade (10.2 per cent). These industries were also dominant employers in Greater Sydney.

Travel to work

- Average trip to work 38 minutes (Bureau of Transport Statistics 2012)
- In 2011, 64.3 per cent of Auburn's working residents travelled outside of the area to work (Profile.id. 2014a)
- 56.3 per cent of the workforce travelled to work by car as driver or passenger while 28.2 per cent of the workforce travelled to work by public transport. A lower percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with more travelling by car (58.4 per cent).

Average income

- Lower average weekly household income ($1,160) in comparison to Greater Sydney ($1,447)
- Lower average weekly individual income ($420) compared with Greater Sydney ($619).

Housing values

- Average sale price of $704,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 17.4 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Auburn was 944 indicating that the LGA was on more disadvantaged compared to Greater Sydney (1025) (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing the Auburn LGA have been identified based on a review of planning and policy documents including:

- Auburn City Council Community Strategic Plan 2013- 2023
- Consultation with Auburn City Council for Western Sydney Airport SIA.

Auburn LGA socio-demographic profile

Opportunities:

- Provision of local employment initiatives which target service gaps and employment barriers for migrants and refugees.
- Cultural and linguistic diversity creates a unique community identity, strong connections and networks.
- Significant urban revitalisation projects including the Parramatta Road Revitalisation Project leading to employment and housing growth, and new infrastructure e.g. potential light rail link to Parramatta.
- Building on strong social networks and developing more partnerships to increase resources into the LGA.
- Building a positive image of the LGA through community education and safety programs and celebrating cultural diversity.
- Engaging young people and providing accessible, youth-specific spaces.
- Health and wellbeing programs which encourage physical activity.

Challenges:

- Fragmented distribution of community services and facilities across the LGA, diversity of languages and a significant socially disadvantaged population makes providing information and services challenging
- Significant population of newly arrived migrants and refugees, many of whom experience multiple disadvantages e.g. poverty, housing stress unemployment
- Rapid population growth and increasing demand for housing, employment and community services
- Perceptions of crime and disparity between actual crime rates and likelihood of victimisation and the community's perception of risk
- Housing affordability is becoming an increasing issue
- Frequency and accessibility of public transport services and links between centres and key destinations. Low car ownership and infrequent public transport options
- Low education levels and high population turnover requires continual delivery and promotion of education programs
- High rates of youth disengagement - 11.1% of people 15 - 24 years neither employed nor studying.
- Chronic diseases and health risk factors are above NSW state averages including type two diabetes, high cholesterol and hyper-intensive diseases, and physical inactivity.

Bankstown LGA socio-demographic profile

Community overview

Bankstown LGA is located 20 kilometres from the Sydney CBD in Sydney's south west on the M5 Motorway, and covers 78 square kilometres (Bankstown City Council 2013) Densely populated, Bankstown has a mix of residential, commercial and industrial areas. Key industries for Bankstown include retail, wholesale, property and business services, construction and manufacturing (Profile.id 2014b).

The Bankstown Airport is a significant business park for south west Sydney, focused on aviation (flying schools, aircraft maintenance, scenic flights, aircraft couriers), aviation related (light aeronautical manufacturing and supply chain industry), and other industries (e.g. food retailers, warehouse distribution, manufacturing) (Bankstown Airport 2015). The University of Western Sydney also has a campus in Bankstown, and there are three TAFE campuses across the LGA.

The population of Bankstown was 200,357 in 2014 (Profile.id. 2014b), and is projected to increase to 233,573 persons by 2030 (SGS Economics and Planning 2015). Bankstown LGA is very culturally diverse, with over 120 different languages spoken across the LGA (Bankstown City Council 2013).

Bankstown City Council's *Community Plan 2030* identifies the community's values and aspirations. Bankstown LGA residents have a strong sense of local identity, and are proud of the diverse population, village atmosphere in the suburbs, and local history. The LGA's residents are active, and value the access they have to a number of parklands, community spaces and bushland (Bankstown City Council 2013).

The following information for the Bankstown LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011b and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Bankstown LGA as at 30 June 2014 was 200,357 persons (Profile.id. 2014b)
- The population of Bankstown LGA in 2011 was 182,352 persons compared with 170,489 persons in 2006 (ABS 2006b). This is equivalent to an increase of 7 per cent. The population of Greater Sydney also increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Bankstown LGA was considerably more populated than Greater Sydney with a density of 23.70 persons per hectare compared with 3.54 persons per hectare
- Higher percentage of people living at the same address 1 and 5 years ago in comparison to Greater Sydney (83.6 per cent and 59.1 per cent in contrast to 80.0 per cent and 52.8 per cent respectively).
- Aboriginal and Torres Strait Islander people made up 0.8 per cent of the population with 1,388 persons. This was slightly lower than the Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney

Bankstown LGA socio-demographic profile
• Culturally diverse population in Bankstown with 34.6 per cent of the population born in a non-English speaking country and 54.7 per cent speaking a language other than English at home. This was higher than Greater Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home.
Population projections • The population of Bankstown LGA is expected to increase to 218,863 persons by 2025, 233,573 persons by 2030 and 335,597 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 53 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[4].
Age profile • Largest proportion of people in the 35-49 years age bracket- 36,608 persons 20.1 per cent; followed by 25-34 years age group- 24,679 persons 13.5 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent) • There were 47,376 people (26.0 per cent) aged under 18 years and 33,954 (18.7 per cent) aged 60 years or older. These results were fairly consistent with those of Greater Sydney which reported 22.9 per cent under the age of 18 years and 18.0 per cent aged 60 years or older • Median age of 35 years in Bankstown compared with 36 years in Greater Sydney.
Gender profile • In 2011, Bankstown had a female population of 92,424 (50.7 per cent) and a male population of 89,928 (49.3 per cent). Greater Sydney reported similar percentages with a female population of 50.8 per cent and a male population of 49.2 per cent.
Household structure and family composition • There were a total of approximately 57,237 households in Bankstown LGA. Of the total number of households, family households comprised 78.0 per cent, 20.0 per cent were lone person households and 2.0 per cent were group households. Greater Sydney reported similar percentages of household composition with 73.1 per cent family households, 22.6 per cent lone person households and 4.3 per cent group households • Of the 47,029 families in Bankstown LGA, 52.6 per cent were couple families with children, 26.4 per cent were couple families without children, and 19.3 per cent were one parent families. Greater Sydney recorded similar percentages with 48.9 per cent couple families with children, 33.5 per cent couple families without children and 15.7 per cent one parent families.

[4] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

Bankstown LGA socio-demographic profile

Education level

- Bankstown LGA had a lower rate of high school completion (45.7 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a higher percentage of the population without post-school qualifications with 51.4 per cent compared to 40.5 per cent for Greater Sydney.

Housing tenure

- In Bankstown LGA, 95.0 per cent of private dwellings were occupied and 5.0 per cent were unoccupied. There were a total of 60,236 private dwellings. Greater Sydney had a higher number of unoccupied private dwellings with 7.2 per cent
- Of occupied private dwellings in Bankstown LGA, 69.2 per cent were separate houses, 16.4 per cent were semi-detached, row or terrace houses, or townhouses, 13.8 per cent were flats, units or apartments, and 0.4 per cent were other dwellings. Greater Sydney recorded a lower percentage of separate houses (60.9 per cent) and a greater number of flats, units or apartments (25.8 per cent)
- Of occupied private dwellings in Bankstown LGA, approximately 67.2 per cent of the dwellings were privately owned (34.0 per cent were owned outright, 33.2 per cent were owned with a mortgage) and 28.9 per cent were rented. Greater Sydney recorded similar percentages of tenure with 65.2 per cent privately owned dwellings and 31.6 per cent rented properties
- Significantly higher percentage of state housing properties in Bankstown LGA (32.0 per cent) compared to Greater Sydney (14.4 per cent)
- The number of dwellings in the Bankstown is forecast to grow from 63,508 in 2011 to 76,584 in 2031, with the average household size falling from 3.01 in 2011 to 2.87 by 2031 (Forecast.id. 2012a).

Economic profile

Total employment

- Total employment in Bankstown LGA and Greater Sydney was over 90 per cent.

Unemployment rate

- The rate of unemployment was higher in Bankstown LGA (7.6 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- The labour force of Bankstown was 142,805 persons in 2011. This equated to 78 per cent of the total population compared with 81 per cent for Greater Sydney.

Occupations

- The most common occupations in both Bankstown LGA and Greater Sydney included clerical and administrative workers (18.0 per cent and 16.2 per cent) and professionals (17.3 per cent and 25.5 per cent respectively).

Bankstown LGA socio-demographic profile

Industries of employment

- The main industries of employment in Bankstown LGA included manufacturing (11.4 per cent), retail trade (11.1 per cent) and health care and social assistance (9.7 per cent). These industries were also dominant employers in Greater Sydney.

Travel to work

- Average trip to work 36 minutes (Bureau of Transport Statistics 2012)
- In 2011, 58.3 per cent of Bankstown's working residents travelled outside of the area to work (Profile.id. 2014b)
- 66.6 per cent of the workforce travelled to work by car as driver or passenger while 16.3 per cent of the workforce travelled to work by public transport. A slightly higher percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with less travelling by car (58.4 per cent).

Average income

- Lower average weekly household income ($1,091) in comparison to Greater Sydney ($1,447)
- Lower average weekly individual income ($428) compared with Greater Sydney ($619).

Housing values

- Average sale price of $696,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 15.3 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Bankstown was 946 indicating that the LGA was more disadvantaged compared to Greater Sydney (1025) (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing the Bankstown LGA have been identified based on a review of planning and policy documents including:

- Bankstown City Council, Bankstown Community Plan 2030
- Consultation with Bankstown City Council for Western Sydney Airport SIA.

Opportunities:

- Culturally diverse communities
- Potential for renewal of employment lands focusing on with intensification in some precincts and possible conversion to mixed use or residential in other precincts
- Bankstown Airport is an important transport hub that supports a range of associated industries
- Increasingly educated population
- Investment in economic and educational opportunities

Bankstown LGA socio-demographic profile
• Safe and accessible public transport with designated pedestrian and bike paths • Young adults and young families are drawn to the area by medium density housing options • Increase in service based industries including health care and food, and small business opportunities Challenges: • High proportion of unskilled or semi-skilled occupations particularly for new migrants and refugees who have low English levels, low skill levels, or skills are not recognised in Australia. • Ageing population and large proportion of young children require higher quality and supply of health services • Decline of manufacturing and trade industries • Concerns around safety in public areas. Resources to improve town centres, clean parks and facilities • Provision of affordable housing for increasing population • Car dependency and residents choosing cars over other forms of transport leading to congested roads. Traffic management and limited parking near businesses

Blacktown LGA socio-demographic profile

Community overview

Blacktown is located in central Western Sydney, 35 kilometres from the Sydney CBD and covers 47 square kilometres (Blacktown City Council 2013). Major commercial centres of the LGA are Blacktown and Mount Druitt. There are 16 industrial estates across the LGA. The Blacktown LGA is supported by major transport infrastructure including the Western Motorway (M4), Westlink (M7), the Hills Motorway (M2), and 10 railway stations. The LGA has significant recreation and open space attractions including part of the Western Sydney Parklands and Prospect Reservoir, as well as major education institutions including the Blacktown Campus of the University of Western Sydney. Hospitals include the Blacktown District Hospital and Mount Druitt Hospital (Profile.id. 2014 (c)).

The LGA's population in 2014 was 332,424 (Profile.id 2014). This is projected to grow by 32 per cent to 439,663 persons by 2030 (SGS Economics and Planning 2015).

The Blacktown LGA is made up of residential areas, with substantial industrial and commercial land. Significant rural areas in the north of the LGA are primarily used for farming but are proposed for development as part of the North West Growth Centre in coming years. The Blacktown LGA makes up the largest proportion of the North West Growth Centre (Blacktown City Council 2013).

The Blacktown City Council's long term community strategic plan, *Blacktown City 2030* adopted in June 2013 outlines the community identified key issues and values for the LGA. Blacktown communities have a strong sense of pride in their city, and value the friendliness of the residents, and the varied backgrounds and life experiences of its members (Blacktown City Council 2013).

The following information for the Blacktown LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011c and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Blacktown LGA as at 30 June 2014 was 332,424 persons (Profile.id. 2014c)
- The population of Blacktown LGA in 2011 was 301,099 persons compared with 271,709 persons in 2006 (ABS 2006c). This is equivalent to an increase of 11 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Blacktown LGA had a higher population density (12.49 persons per hectare) compared with Greater Sydney (3.54 persons per hectare)
- Aboriginal and Torres Strait Islander people made up 2.7 per cent of the population with 8,199 persons. This was higher than the Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney
- Culturally diverse population in Blacktown with 31.6 per cent of the population born in a non-English speaking country and 36.9 per cent speaking a language other than English at home. This was higher than Greater Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than

Blacktown LGA socio-demographic profile

English at home.

Population projections

- The population of Blacktown LGA is expected to increase to 397,512 persons by 2025, 439,663 persons by 2030 and 741,664 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 87 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[5]

Age profile

- Largest proportion of people in the 35-49 years age bracket- 65,591 persons 21.8 per cent; followed by 25-34 years age group- 46,569 persons 15.5 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent)
- Large percentage of the population aged under 18 years with 84,759 persons (28.1 per cent) and 40,792 (13.5 per cent) aged 60 years or older. Greater Sydney trends indicated an older population with 22.9 per cent under the age of 18 years and 18.0 per cent aged 60 years or older
- Younger population in Blacktown with a median age of 32 years compared with 36 years in Greater Sydney.

Gender profile

- In 2011, Blacktown had a female population of 151,552 (50.3 per cent) and a male population of 149,547 (49.7 per cent). Greater Sydney reported a female population of 50.8 per cent and a male population of 49.2 per cent.

Household structure and family composition

- There were a total of approximately 93,657 households in Blacktown LGA. Of the total number of households, family households comprised 81.7 per cent, 16.1 per cent were lone person households and 2.2 per cent were group households. Greater Sydney reported fewer family households (73.1 per cent), and a higher percentage of lone person households (22.6 per cent) and group households (4.3 per cent) compared to the LGA
- Of the 80,467 families in Blacktown LGA, 53.5 per cent were couple families with children, 25.4 per cent were couple families without children, and 19.5 per cent were one parent families. Greater Sydney recorded fewer couple families with children (48.9 per cent) and one parent families (15.7 per cent) and a greater number of couple families without children (33.5 per cent).

Education level

- Blacktown LGA had a lower rate of high school completion (48.2 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a higher percentage of the population without post-school qualifications with 47.6 per cent compared to 40.5 per cent for Greater Sydney.

Housing tenure

- In Blacktown LGA, 95.5 per cent of private dwellings were occupied and 4.5 per cent

[5] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

were unoccupied. There were a total of 98,034 private dwellings. Greater Sydney had a higher number of unoccupied private dwellings with 7.2 per cent

- Of occupied private dwellings in Blacktown LGA, the majority were separate houses (82.9 per cent), 11.4 per cent were semi-detached, row or terrace houses, or townhouses, 5.1 per cent were flats, units or apartments, and 0.4 per cent were other dwellings. Greater Sydney recorded a significantly lower percentage of separate houses (60.9 per cent) and a higher number of flats, units or apartments (25.8 per cent)
- Of occupied private dwellings in Blacktown LGA, approximately 66.8 per cent of the dwellings were privately owned (43.6 per cent were owned with a mortgage, 23.2 per cent were owned outright) and 30.1 per cent were rented. Greater Sydney recorded similar percentages with 65.2 per cent privately owned dwellings and 31.6 per cent rented properties
- Blacktown LGA had double the percentage of state housing properties (28.9 per cent) compared to Greater Sydney (14.4 per cent)
- The number of dwellings in the Blacktown is forecast to grow from 102,074 in 2011 to 153,100 in 2036, with the average household size falling from 3.09 to 2.96 by 2036 (Forecast.id. 2011).

Economic profile

Total employment

- Total employment in Blacktown LGA and Greater Sydney was over 90 per cent.

Unemployment rate

- The rate of unemployment was higher in Blacktown LGA (7.2 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- The labour force of Blacktown in 2011 comprised 229,640 persons which equated to 76 per cent of the population. Greater Sydney had a greater percentage of total labour force with 81 per cent.

Occupations

- The most common occupations in Blacktown LGA included clerical and administrative workers (18.3 per cent) and professionals (17.4 per cent). These were also the dominant occupations in Greater Sydney.

Industries of employment

- The main industries of employment in Blacktown LGA included manufacturing (12.7 per cent), health care and social assistance (11.4 per cent) and retail trade (10.8 per cent). Health care and social assistance and retail trade were also dominant employers in Greater Sydney.

Travel to work

- Average trip to work 36 minutes (Bureau of Transport Statistics 2012)
- In 2011, 59.0 per cent of Blacktown's working residents travelled outside of the area to work (Profile.id. 2014c)

Blacktown LGA socio-demographic profile

- 66.6 per cent of the workforce travelled to work by car as driver or passenger while 17.6 per cent of the workforce travelled to work by public transport. A slightly higher percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with less people travelling by car (58.4 per cent).

Average income

- Lower average weekly household income ($1,388) in comparison to Greater Sydney ($1,447)
- Lower average weekly individual income ($565) compared with Greater Sydney ($619).

Housing values

- Average sale price of $575,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 17.6 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Blacktown was 974 indicating that the LGA was more disadvantaged compared to Greater Sydney (1025) (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing the Blacktown LGA have been identified based on a review of planning and policy documents including:

- Blacktown City Council, adopted June 2013. Blacktown City 2030
- Consultation with Blacktown City Council in June 2015 for Western Sydney Airport SIA.

Opportunities:

- Continued development of the North West Growth Centre, with Blacktown making up the largest proportion, leading to significant residential development and population growth.
- Provision and promotion of high quality community facilities including libraries which encourage lifelong learning and childcare facilities which meet the needs of families.
- Culturally and linguistically diverse population and the celebration and promotion of this e.g. through public artworks and festivals.
- Provision of transport networks that connect the LGA and are functional, accessible and acceptable to the community and support vehicle and non-vehicle users.

Challenges:

- Decreasing housing affordability.
- Rapid population growth, particularly resulting from recent high migration to the LGA.
- High rates of unemployment and limited job opportunities.
- Pockets of significant socio-economic disadvantage e.g. large social housing

Blacktown LGA socio-demographic profile

areas.

- Provision of services and information and social inclusion for emerging migrant populations.

Blue Mountains LGA profile

Blue Mountains LGA socio-demographic profile

Community overview

The Blue Mountains LGA is located on the western fringe of Metropolitan Sydney covering an area of 1,431 square kilometres (Blue Mountains City Council 2013). The LGA comprises 27 separate towns and villages each with a distinctive identity and character reflecting the varied climate, terrain and heritage of the area (Blue Mountains City Council 2013).

The Blue Mountains makes up 70 per cent of the LGA and is a World Heritage National Park, resulting in only 11 per cent of the LGA available for settlement (Blue Mountains City Council 2013). As the LGA contains the national and internationally significant Greater Blue Mountains World Heritage Area, tourism is a major contributor to the economy (Blue Mountains City Council 2013).

The Great Western Highway and Blue Mountains railway line traverse the LGA transporting goods, services and commuters between Sydney and the Central West of NSW, and within the LGA itself (Blue Mountains City Council 2013). There two hospitals in the including the Blue Mountains Hospital at Katoomba and the Springwood Hospital. TAFE NSW Western Sydney Institute has a campus in the LGA.

The estimated resident population of the LGA was 79,688 persons in 2014. The LGA has had the lowest population growth across all LGAs in the Greater Sydney region over the last decade (Blue Mountains City Council 2013). The population is projected to increase by 14 per cent to 90,741 persons by 2030 (SGS Economics and Planning 2015).

The following information for the Blue Mountains LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011d and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Blue Mountains LGA as at 30 June 2014 was 79,688 persons (Profile.id. 2014d)
- The population of Blue Mountains LGA in 2011 was 75,942 persons compared with 74,067 persons in 2006 (ABS 2006d). This is equivalent to an increase of 3 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Blue Mountains LGA had a significantly lower population density of 0.52 persons per hectare compared with 3.54 persons per hectare in Greater Sydney
- Aboriginal and Torres Strait Islander people made up 1.7 per cent of the population with 1,318 persons. This was slightly higher than the Aboriginal and Torres Strait Islander

Blue Mountains LGA socio-demographic profile

population of 1.2 per cent recorded for Greater Sydney

- Blue Mountains displays less cultural diversity, with only 6.3 per cent of the population born in a non-English speaking country and 5.1 per cent speaking a language other than English at home. This was significantly lower than Greater Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home.

Population projections

- The population of Blue Mountains LGA is expected to increase to 85,741 persons by 2025, 90,741 persons by 2030 and 129,172 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 51 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[6].

Age profile

- Older population in Blue Mountains with a median age of 42 years compared with 36 years in Greater Sydney.
- Largest proportion of people in the 50-54 year age bracket at 8.0 per cent (6,050 persons); followed by 55-59 years age group at 7.9 per cent (5,971 persons). In Greater Sydney, the largest proportion of the population was in the 35-49 year age group (21.9 per cent) followed by the 25-34 year age group (15.4 per cent)
- There were 17,922 people (23.6 per cent) aged under 18 years and 17,390 (22.8 per cent) aged 60 years or older. These results were fairly similar to the Greater Sydney region which reported 22.9 per cent under the age of 18 years and 18.0 per cent aged 60 years or older

Gender profile

- In 2011, Blue Mountains had a female population of 39,231 (51.7 per cent) and a male population of 36,711 (48.3 per cent). Greater Sydney also reported a larger female population (50.8 per cent) compared to male population (49.2 per cent).

Household structure and family composition

- There were a total of approximately 28,030 households in Blue Mountains LGA. Of the total households, family households comprised 71.5 per cent, followed by 25.6 per cent lone person households and 2.8 per cent group households. This was similar to Greater Sydney which had 73.1 per cent family households, 22.6 per cent lone person households and 4.3 per cent group households
- Of the 20,386 families in Blue Mountains LGA, 45.2 per cent were couple families with children, 38.3 per cent were couple families without children, and 15.6 per cent were one parent families. Greater Sydney recorded similar percentages with 48.9 per cent couple families with children, 33.5 per cent couple families without children and 15.7 per cent one parent families.

[6] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

Blue Mountains LGA socio-demographic profile

Education level

- Blue Mountains LGA had a slightly lower rate of high school completion (50.2 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a lower percentage of the population without post-school qualifications with 34.9 per cent compared to 40.5 per cent for Greater Sydney.

Housing tenure

- In Blue Mountains LGA, 87.8 per cent of private dwellings were occupied and 12.2 per cent were unoccupied. There were a total of 31,910 private dwellings. Greater Sydney had a higher number of occupied private dwellings with 92.8 per cent
- Of occupied private dwellings in Blue Mountains LGA, the majority were separation houses with 92.7 per cent. 5.1 per cent were semi-detached, row or terrace houses, or townhouses, 2.0 per cent were flats, units or apartments, and 0.2 per cent were other dwellings. Greater Sydney recorded a lower percentage of separate houses (60.9 per cent) and a higher number of flats, units or apartments (25.8 per cent) and semi-detached, row or terrace houses or townhouses (12.8 per cent)
- Of occupied private dwellings in Blue Mountains LGA, approximately 78.0 per cent of the dwellings were privately owned (40.6 per cent were owned with a mortgage, 37.4 per cent were owned outright) and 19.2 per cent were rented. Greater Sydney recorded less privately owned dwellings with 65.2 per cent and more rented properties at 31.6 per cent
- Lower percentage of state housing properties in Blue Mountains LGA (6.5 per cent) compared to Greater Sydney (14.4 per cent)
- The number of dwellings in the Blue Mountains LGA is forecast to grow from 33,574 in 2011 to 36,771 in 2031, with the average household size falling from 2.51 to 2.38 by 2031 (Forecast.id. 2010).

Economic profile

Total employment

- Total employment in Blue Mountains LGA and Greater Sydney was around 95 per cent.

Unemployment rate

- The rate of unemployment was lower in Blue Mountains LGA (4.9 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- Both Blue Mountains LGA and Greater Sydney had a total labour force of 81 per cent. The labour force of Blue Mountains in 2011 comprised 61,144 persons.

Occupations

- The most common occupations in both Blue Mountains LGA and Greater Sydney included professionals (28.8 per cent and 25.5 per cent respectively) and clerical and administrative workers (14.3 per cent and 16.2 per cent).

Blue Mountains LGA socio-demographic profile

Industries of employment

- The main industries of employment in Blue Mountains LGA included health care and social assistance (14.7 per cent), education and training (14.6 per cent), and retail trade (9.2 per cent). Greater Sydney differed slightly with heath care and social assistance, retail trade and professional, scientific and technical services being the dominant industries of employment.

Travel to work

- Average trip to work 41 minutes (Bureau of Transport Statistics 2012)
- In 2011, 50.3 per cent of Blue Mountain's working residents travelled outside of the area to work (Profile.id. 2014d)
- 62.7 per cent of the workforce travelled to work by car as driver or passenger while 11.5 per cent of the workforce travelled to work by public transport. A higher percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with less travelling by car (58.4 per cent).

Average income

- Lower average weekly household income ($1,270) in comparison to Greater Sydney ($1,447)
- Lower average weekly individual income ($590) compared with Greater Sydney ($619).

Housing values

- Average sale price of $499,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 15.9 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Blue Mountains was 1038 indicating that the LGA was above average and reported lower levels of disadvantage compared to Greater Sydney (1025) (ABS 2013).

Tourism

- In 2011, there were 2.3 million day trip visitors to the Blue Mountains, with expenditure of $233 million (Blue Mountains City Council 2013). The City also received an estimated 80,000 international overnight visitors (Blue Mountains City Council 2013).

Blue Mountains LGA socio-demographic profile

Key opportunities and challenges

Existing opportunities and challenges facing the Blue Mountains LGA have been identified based on a review of planning and policy documents including:

- *Sustainable Blue Mountains 2025* (Blue Mountains City Council 2013)
- Consultation with Blue Mountains City Council for Western Sydney Airport SIA.

Opportunities

- LGA contains the Greater Blue Mountains World Heritage Area which is highly valued by the community for its environmental, cultural and recreational significance and is a major tourism destination.
- Close-knit communities with distinct character and identity.
- Rich cultural and built heritage.
- Creative and spiritual LGA and attractive place for artists. The city was designated the inaugural ‘City of the Arts’ in NSW.

Challenges

- Conserving natural, built and cultural heritage in the context of limited resources and increased pressures for change and growth.
- Encouraging appropriate development, settlement patterns and urban forms, which accommodate some population growth, while minimising impacts on the environment.
- Very limited capacity for increased supply of housing in the LGA has resulted in housing demand not matched by supply – this has flow on effects including increased housing prices.
- Natural disasters particularly bushfire risk.
- Provision of utilities and infrastructure given the mountainous topography, heritage features, low population densities and dispersed settlement patterns.
- Some difficulty accessing services and facilities for some members of the community due to dispersed villages.
- Ageing of town centre infrastructure and vandalism have impacts on local amenity, vitality and viability
- Many young people leave once they’ve completed schooling, attracted by educational and employment opportunities outside the area
- Ageing population placing pressures on health and aged care services and accommodation
- Difference in socio-economic wellbeing and health status between the Upper and Lower Mountains.

Camden LGA socio-demographic profile

Community overview

Camden LGA is located in Sydney's south-western suburbs, 60 kilometres from the Sydney CBD (Profile.id 2014 (e)). The area covers 201 square kilometres. The Camden LGA contains a mix of agricultural land, country towns and villages, and new residential areas with associated commercial and industrial development (Camden Council 2013). Camden is located within the South West Growth Centre.

The estimated population of Camden LGA in 2014 was 67,000 persons. This is projected to increase by 96 per cent to 131,265 persons by 2030 (SGS Economics and Planning 2015).

Camden's Community Strategic Plan, *Camden 2040* adopted in May 2013 was prepared in response to the large scale population growth and development projected for the future of the LGA and the South West Growth Centre. Camden 2040 identifies opportunities presented by urban development and population growth including at Oran Park and Gregory Hills. Other precincts are in planning and rezoning process, such as Leppington Precinct which will house a major centre, railway station with the extension of South West Rail Link, and residential development. (Camden Council 2013).

The LGA's residents value open space and the quiet setting. Camden's community have a strong sense of pride in the 'country feel', and agricultural heritage. (Camden Council 2013).

The following information for the Camden LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011e and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Camden LGA as at 30 June 2014 was 67,084 persons (Profile.id. 2014e)
- The population of Camden LGA in 2011 was 56,720 persons compared with 49,645 persons in 2006 (ABS 2006e). This is equivalent to an increase of 14 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Camden LGA had a lower population density (2.79 persons per hectare) compared with Greater Sydney (3.54 persons per hectare)
- Aboriginal and Torres Strait Islander people made up 2.0 per cent of the population with 1,117 persons. This was slightly higher than the Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney
- Not a highly culturally diverse population in Camden with 8.5 per cent of the population born in a non-English speaking country and 10.2 per cent speaking a language other than English at home. This was considerably lower than Greater Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home.

Camden LGA socio-demographic profile

Population projections

- The population of Camden LGA is expected to increase to 106,074 persons by 2025, 131,265 persons by 2030 and 267,281 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 152 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[7].

Age profile

- Largest proportion of people in the 35-49 years age bracket- 13,109 persons 23.1 per cent; followed by 25-34 years age group- 7,471 persons 13.2 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent)
- There were 16,386 people (28.9 per cent) aged under 18 years and 8,133 (14.4 per cent) aged 60 years or older. These results showed a larger percentage of the population aged less than 18 years compared to Greater Sydney (22.9 per cent) and a lower percentage aged 60 years or older compared to the wider area (18.0 per cent)
- Younger population in Camden with a median age of 34 years compared with 36 years in Greater Sydney.

Gender profile

- In 2011, Camden had a female population of 28,840 (50.8 per cent) and a male population of 27,880 (49.2 per cent). Greater Sydney reported the same percentages of male and female populations.

Household structure and family composition

- There were a total of approximately 17,875 households in Camden LGA. Of the total number of households, family households comprised 83.7 per cent, 14.5 per cent were lone person households and 1.8 per cent were group households. Greater Sydney reported a smaller percentage of family households with 73.1 per cent and a larger percentage of lone person households (22.6 per cent) and group households (4.3 per cent)
- Of the 15,462 families in Camden LGA, 54.9 per cent were couple families with children, 30.0 per cent were couple families without children, and 14.1 per cent were one parent families. Greater Sydney also recorded more couple families with children at 48.9 per cent, 33.5 per cent couple families without children and 15.7 per cent one parent families.

Education level

- Camden LGA had a lower rate of high school completion (40.7 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a higher percentage of the population without post-school qualifications with 45.6 per cent compared to 40.5 per cent for Greater Sydney.

[7] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

Camden LGA socio-demographic profile

Housing tenure

- In Camden LGA, 95.0 per cent of private dwellings were occupied and 5.0 per cent were unoccupied. There were a total of 18,806 private dwellings. Greater Sydney had a higher number of unoccupied private dwellings with 7.2 per cent
- Of occupied private dwellings in Camden LGA, the majority were separate houses (91.7 per cent), with only 5.7 per cent semi-detached, row or terrace houses, or townhouses, 1.6 per cent flats, units or apartments, and 0.9 per cent other dwellings. Greater Sydney recorded a significantly lower percentage of separate houses (60.9 per cent) and a higher number of flats, units or apartments (25.8 per cent)
- Of occupied private dwellings in Camden LGA, a significant percentage (78.7 per cent) of the dwellings were privately owned (52.7 per cent were owned with a mortgage, 26.0 per cent were owned outright) and 18.7 per cent were rented. Greater Sydney recorded a lower percentage of privately owned dwellings with 65.2 per cent and more rented properties at 31.6 per cent
- Smaller percentage of state housing properties in Camden LGA (9.7 per cent) compared to Greater Sydney (14.4 per cent)
- The number of dwellings in the Camden Council is forecast to grow from 19,588 in 2011 to 74,138 in 2036, with the average household size falling from 3.07 to 3.03 by 2036 (Forecast.id. 2014b).

Economic profile

Total employment

- Total employment in Camden LGA and Greater Sydney was around 95 per cent.

Unemployment rate

- The rate of unemployment was lower in Camden LGA (4.0 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- Camden LGA and Greater Sydney had similar percentages of total labour force of 76 per cent and 81 per cent respectively. The labour force of Camden in 2011 comprised 42,955 persons.

Occupations

- The most common occupations in both Camden LGA and Greater Sydney included professionals (17.5 per cent and 25.5 per cent respectively) and clerical and administrative workers (17.5 per cent and 16.2 per cent).

Industries of employment

- The main industries of employment in Camden LGA included manufacturing (11.1 per cent), retail trade (11.0 per cent), construction (9.9 per cent) and education and training (9.3 per cent). These industries also ranked highly in Greater Sydney; however health care and social assistance and retail trade were the most dominant.

Camden LGA socio-demographic profile

Travel to work

- Average trip to work 34 minutes (Bureau of Transport Statistics 2012)
- In 2011, 60.5 per cent of Camden's working residents travelled outside of the area to work (Profile.id. 2014e)
- 73.8 per cent of the workforce travelled to work by car as driver or passenger while 6.8 per cent of the workforce travelled to work by public transport. A higher percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with less travelling by car (58.4 per cent).

Average income

- Higher average weekly household income ($1,727) in comparison to Greater Sydney ($1,447)
- Higher average weekly individual income ($690) compared with Greater Sydney ($619).

Housing values

- Average sale price of $584,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 15.4 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Camden was 1056 indicating that the LGA was just above average with lower levels of disadvantage compared to Greater Sydney (1025) (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing the Camden LGA have been identified based on a review of planning and policy documents including:

- Camden Council, Adopted May 2013. Camden 2040
- Consultation with Camden Council in June 2015 for Western Sydney Airport SIA.

Opportunities:

- Increasingly culturally diverse population
- Rapid population growth due to development of the South West Growth Centre bringing new infrastructure to the area
- Retaining valued heritage and characteristics within Camden
- Timely funding and delivery of infrastructure and services

Challenges:

- Managing population growth effectively and ensuring the LGA is supported by transport infrastructure, delivery of services to meet community, health, education, economic and recreational needs
- Loss of agricultural land and associated industries as a result of development of South West Growth Centre

Camden LGA socio-demographic profile

- Retaining natural heritage and the 'country feel', and managing the impacts resulting from development
- Resourcing management of growth given the Council's current financial restraints
- Lack of employment opportunities in the LGA, and of those available, limited to a few occupations
- Providing services and support to the increasingly culturally diverse community e.g. translation services, support networks
- Currently community service provision and public transport is lacking, resulting in socially disadvantaged groups moving out of the LGA

Campbelltown LGA profile

Campbelltown LGA socio-demographic profile

Community overview

Campbelltown LGA is recognised as a regional centre located approximately 53 kilometres south west of Sydney CBD (Campbelltown City Council 2013). The LGA covers an area of 312 square kilometres and includes 33 suburbs (Campbelltown City Council 2013).

The LGA has significant environmental assets including large areas of bushland and waterways, as well as large residential and industrial areas, and some agricultural lands (Campbelltown City Council 2013). Key features include the University of Western Sydney (UWS) Campbelltown Campus including the School of Medicine, two TAFE colleges and Campbelltown Hospital (Campbelltown City Council 2013).

The estimated resident population of Campbelltown LGA as at 30 June 2014 was 156,572 persons (Profile.id. 2014f). This is projected to increase by 30 per cent to 203,220 by 2030 (SGS Economics and Planning 2015).

Campbelltown is one of the ten largest local government authorities in NSW (Campbelltown City Council 2013). Future population growth will largely be attributed to urban renewal, medium density and smaller scale master-planned estates (Campbelltown City Council 2013).

The Strategic Plan (2013) identifies the City as providing a *unique combination of city opportunities in a natural setting*. Campbelltown also has a rich cultural heritage and has one of the largest populations of people identifying as Aboriginal and Torres Strait Islanders in NSW (Campbelltown City Council 2013).

The following information for the Campbelltown LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011f and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Campbelltown LGA as at 30 June 2014 was 156,572 persons (Profile.id. 2014f)
- The population of Campbelltown LGA in 2011 was 145,967 persons compared with

Campbelltown LGA socio-demographic profile

143,076 persons in 2006 (ABS 2006f). This is equivalent to an increase of 2 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)

- Campbelltown LGA had a higher population density (4.67 persons per hectare) compared with Greater Sydney (3.54 persons per hectare)
- Aboriginal and Torres Strait Islander people made up 3.2 per cent of the population with 4,729 persons. This was double the percentage of Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney
- Culturally diverse population in Campbelltown with 20.5 per cent of the population born in a non-English speaking country and 25.2 per cent speaking a language other than English at home. This was slightly lower than Greater Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home. The most common languages spoken after English are Arabic and Filipino (Campbelltown City Council 2013).

Population projections

- The population of Campbelltown LGA is expected to increase to 185,900 persons by 2025, 203,220 persons by 2030 and 320,041 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 72 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[8].

Age profile

- Largest proportion of people in the 35-49 years age bracket- 29,203 persons 20.0 per cent; followed by 25-34 years age group- 20,676 persons 14.2 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent)
- There were 39,033 people (26.7 per cent) aged under 18 years and 21,756 (14.9 per cent) aged 60 years or older. Data for the Greater Sydney region indicated a greater percentage of the population aged 60 years or older (18.0 per cent) compared with the LGA and less of the population under the age of 18 years (22.9 per cent)
- Younger population in Campbelltown with a median age of 33 years compared with 36 years in Greater Sydney.

Gender profile

- In 2011, Campbelltown had a female population of 74,628 (51.1 per cent) and a male population of 71,339 (48.9 per cent). Greater Sydney also reported a larger female population (50.8 per cent) compared to male population (49.2 per cent).

Household structure and family composition

- There were a total of approximately 47,286 households in Campbelltown LGA. Of the total number of households, family households comprised 79.1 per cent, 18.7 per cent were lone person households and 2.2 per cent were group households. Greater Sydney reported similar percentages of household composition with 73.1 per cent family households, 22.6 per cent lone person households and 4.3 per cent group households

[8] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

Campbelltown LGA socio-demographic profile

- Of the 39,123 families in Campbelltown LGA, 48.6 per cent were couple families with children, 27.5 per cent were couple families without children, and 22.3 per cent were one parent families. Greater Sydney recorded similar percentages with 48.9 per cent couple families with children, 33.5 per cent couple families without children and less one parent families with 15.7 per cent.

Education level

- Campbelltown LGA had a lower rate of high school completion (40.5 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a higher percentage of the population without post-school qualifications with 50.2 per cent compared to 40.5 per cent for Greater Sydney.

Housing tenure

- In Campbelltown LGA, 95.6 per cent of private dwellings were occupied and 4.4 per cent were unoccupied. There were a total of 49,486 private dwellings. Greater Sydney had a higher number of unoccupied private dwellings with 7.2 per cent
- Of occupied private dwellings in Campbelltown LGA, 80.5 per cent were separate houses, 15.4 per cent were semi-detached, row or terrace houses, or townhouses, 3.8 per cent were flats, units or apartments, and 0.3 per cent were other dwellings. Greater Sydney recorded a lower percentage of separate houses (60.9 per cent) and a higher number of flats, units or apartments (25.8 per cent)
- Of occupied private dwellings in Campbelltown LGA, approximately 66.5 per cent of the dwellings were privately owned (42.3 per cent were owned with a mortgage, 24.2 per cent were owned outright) and 30.4 per cent were rented. Greater Sydney recorded similar percentages with 65.2 per cent privately owned dwellings 65.2 per cent and 31.6 per cent rented properties
- Considerably larger percentage of state housing properties in Campbelltown LGA (36.7 per cent) compared to Greater Sydney (14.4 per cent)
- The number of dwellings in the Campbelltown City is forecast to grow from 51,903 in 2011 to 77,050 in 2036, with the average household size falling from 2.98 to 2.83 by 2036 (Forecast.id. 2015).

Economic profile

Total employment

- Total employment in Campbelltown LGA and Greater Sydney was over 90 per cent.

Unemployment rate

- The rate of unemployment was higher in Campbelltown LGA (7.4 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- Campbelltown LGA and Greater Sydney had similar percentages of total labour force with 78 per cent and 81 per cent respectively. The labour force of Campbelltown in 2011 comprised 113,953 persons.

Campbelltown LGA socio-demographic profile

Occupations

- The most common occupations in Campbelltown LGA included clerical and administrative workers (18.1 per cent), technicians and trades workers (14.9 per cent) and professionals (14.3 per cent). Professionals and clerical and administrative workers were the dominant occupations in Greater Sydney.

Industries of employment

- The main industries of employment in Campbelltown LGA included manufacturing (13.9 per cent), health care and social assistance (10.8 per cent) and retail trade (10.8 per cent). Health care and social assistance and retail trade were the dominant employers in Greater Sydney.

Travel to work

- Average trip to work 35 minutes (Bureau of Transport Statistics 2012)
- In 2011, 54.1 per cent of Campbelltown's working residents travelled outside of the area to work (Profile.id. 2014f)
- 66.1 per cent of the workforce travelled to work by car as driver or passenger while 17.1 per cent of the workforce travelled to work by public transport. A higher percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with less travelling by car (58.4 per cent).

Average income

- Lower average weekly household income ($1,251) in comparison to Greater Sydney ($1,447)
- Lower average weekly individual income ($549) compared with Greater Sydney ($619).

Housing values

- Average sale price of $470,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 17.4 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Campbelltown was 1003 indicating that the LGA was just below average with similar levels of disadvantage compared to Greater Sydney (1025) (ABS 2013).

Campbelltown LGA socio-demographic profile

Key opportunities and challenges

Existing opportunities and challenges facing the Campbelltown LGA have been identified based on a review of planning and policy documents including:

- Campbelltown's Community Strategic Plan 2013-2023 (Campbelltown City Council 2013)
- Consultation with Campbelltown City Council for Western Sydney Airport SIA.

Opportunities:

- Environmental assets and attractiveness of the area i.e. bushland, waterways
- Cultural heritage and culturally diverse population
- The emergence of the City as a regional centre will provide a wide range of education and employment opportunities, particularly for young people
- Diverse and resilient economy
- Growth of the health sector with the University of Western Sydney, Campbelltown Hospital and new aged care services creating new job opportunities for professional roles. The retail and community sectors are also growing.

Challenges:

- Ageing population
- Pressure on infrastructure and services due to population growth in the South West Growth Centre
- Management of assets is critical to ensure their preservation
- Decreasing housing affordability for an area that has previously been known as affordable
- The changing population and demographics will have a significant impact on transport corridors and infrastructure needs within the LGA.

Fairfield LGA socio-demographic profile

Community overview

Fairfield LGA is located 32 kilometres south-west of Sydney CBD (Fairfield City Council 2015). The LGA consists of 27 suburbs encompassing an area of approximately 104 square kilometres (Fairfield City Council 2015). Key features include part of the Western Sydney Parklands and Chipping Norton Lakes.

The land within the LGA is predominately residential, with substantial industrial and commercial areas, and some rural residential areas in the west (Fairfield City Council 2012). Housing in the LGA consists of mainly detached housing with apartments and residential flat development surrounding the town centres of Fairfield and Cabramatta (Fairfield City Council 2015).

The estimated resident population of Fairfield LGA as at 30 June 2014 was 203,109 persons (Profile.id. 2014g). This is projected to increase by 15 per cent to 234,202 persons by 2030 (SGS Economics and Planning 2015).

The population of Fairfield LGA is highly diverse and made up of many different cultures. This is a key focus of the LGA and reflected in the City motto of Celebrating Diversity (Fairfield City Council 2015).

The following information for the Fairfield LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011g and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Fairfield LGA as at 30 June 2014 was 203,109 persons (Profile.id. 2014g)
- The population of Fairfield LGA in 2011 was 187,766 persons compared with 179,893 persons in 2006 (ABS 2006g). This is equivalent to an increase of 4 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Fairfield LGA was considerably more populated than Greater Sydney with a density of 18.43 persons per hectare compared with 3.54 persons per hectare
- Aboriginal and Torres Strait Islander people made up 0.7 per cent of the population with 1,322 persons. This was lower than the Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney
- Culturally diverse population in Fairfield with 50.1 per cent of the population born in a non-English speaking country and 69.9 per cent speaking a language other than English at home. This was double the percentages recorded for Greater Sydney of 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home. The most common other languages spoken are Vietnamese, Arabic, Assyrian, Cantonese and Spanish (Fairfield City Council 2015).

Fairfield LGA socio-demographic profile

Population projections

- The population of Fairfield LGA is expected to increase to 221,317 persons by 2025, 234,202 persons by 2030 and 328,864 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 49 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[9].

Age profile

- Largest proportion of people in the 35-49 years age bracket- 38,858 persons 20.7 per cent; followed by 50-59 years age group- 25,277 persons 13.5 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent)
- There were 46,904 people (25.0 per cent) aged under 18 years and 32,185 (17.1 per cent) aged 60 years or older. These results showed a larger percentage of the population aged less than 18 years compared to Greater Sydney (22.9 per cent) and a slightly lower percentage aged 60 years or older compared to the wider area (18.0 per cent)
- Both Fairfield LGA and Greater Sydney had a median age of 36 years.

Gender profile

- In 2011, Fairfield had a female population of 95,245 (50.7 per cent) and a male population of 92,521 (49.3 per cent). Greater Sydney also reported a larger female population (50.8 per cent) compared to male population (49.2 per cent).

Household structure and family composition

- There were a total of approximately 55,835 households in Fairfield LGA. Of the total number of households, family households comprised 82.3 per cent, 15.6 per cent were lone person households and 2.0 per cent were group households. Greater Sydney reported a smaller percentage of family households with 73.1 per cent and a larger percentage of lone person households (22.6 per cent) and group households (4.3 per cent)
- Of the 49,714 families in Fairfield LGA, 52.0 per cent were couple families with children, 23.3 per cent were couple families without children, and 22.6 per cent were one parent families. This represents a higher Greater Sydney also recorded more couple families with children at 48.9 per cent, 33.5 per cent couple families without children and 15.7 per cent one parent families.

Education level

- Fairfield LGA had a lower rate of high school completion (43.0 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a considerably higher percentage of the population without post-school qualifications with 60.3 per cent compared to 40.5 per cent for Greater Sydney.

[9] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

Fairfield LGA socio-demographic profile

Housing tenure

- In Fairfield LGA, 95.7 per cent of private dwellings were occupied and 4.3 per cent were unoccupied. There were a total of 58,369 private dwellings. Greater Sydney had a higher number of unoccupied private dwellings with 7.2 per cent
- Of occupied private dwellings in Fairfield LGA, the majority were separate houses (74.0 per cent), 13.6 per cent semi-detached, row or terrace houses, or townhouses, 12.0 per cent flats, units or apartments, and 0.3 per cent other dwellings. Greater Sydney recorded a lower percentage of separate houses (60.9 per cent) and a higher number of flats, units or apartments (25.8 per cent)
- Fairfield LGA demonstrated equal percentages of housing tenure 32.5 per cent of dwellings owned outright, 32.3 per cent owned with a mortgage, and 30.8 per cent rented. Greater Sydney also recorded a fairly equal split with 34.8 per cent owned with a mortgage, 31.6 per cent rented and 30.4 per cent owned outright
- Higher percentage of state housing properties in Fairfield LGA (24.2 per cent) compared to Greater Sydney (14.4 per cent)
- The number of dwellings in Fairfield City is forecast to grow from 61,195 in 2011 to 71,948 in 2031, with the average household size falling from 3.23 to 3.03 by 2031 (Forecast.id. 2014c).

Economic profile

Total employment

- Total employment in Fairfield LGA and Greater Sydney was above 90 per cent.

Unemployment rate

- The rate of unemployment was higher in Fairfield LGA (9.7 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- Fairfield LGA and Greater Sydney had similar percentages of total labour force of 80 per cent and 81 per cent respectively. The labour force of Fairfield in 2011 comprised 149,548 persons.

Occupations

- The most common occupations in Fairfield LGA included technicians and trades workers (15.8 per cent) clerical and administrative workers (15.2 per cent) and labourers (14.8 per cent). The percentage of labourers in the LGA was double the percentage recorded for Greater Sydney (7.3 per cent). Greater Sydney had a significantly higher percentage of professionals (25.5 per cent) compared to Fairfield.

Industries of employment

- The main industries of employment in Fairfield LGA included manufacturing (17.8 per cent), retail trade (11.5 per cent), health care and social assistance (8.6 per cent) and construction (8.6 per cent). These industries also ranked highly in Greater Sydney; however health care and social assistance and retail trade were the most dominant.

Fairfield LGA socio-demographic profile

Travel to work

- Average trip to work 37 minutes (Bureau of Transport Statistics 2012)
- In 2011, 55.9 per cent of Fairfield's working residents travelled outside of the area to work (Profile.id. 2014g)
- 70.7 per cent of the workforce travelled to work by car as driver or passenger while 13.7 per cent of the workforce travelled to work by public transport. A higher percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with less travelling by car (58.4 per cent).

Average income

- Lower average weekly household income ($1,022) in comparison to Greater Sydney ($1,447)
- Significantly lower average weekly individual income ($369) compared with Greater Sydney ($619).

Housing values

- Average sale price of $585,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 18.2 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Fairfield was 886 indicating that the LGA was below average and more disadvantaged compared to Greater Sydney (1025). This was the lowest SEIFA index in Greater Sydney (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing the Fairfield LGA have been identified based on a review of planning and policy documents including:

- Fairfield City Plan 2012-2022- Community Strategic Plan (Fairfield City Council 2012)
- Consultation with Fairfield City Council in June 2015 for Western Sydney Airport SIA.

Opportunities:

- Culturally diverse population with strong community networks and community resilience
- Diverse LGA with both urban and rural areas
- Variety of cuisines, cafes, and local businesses that reflect the diverse population

Challenges:

- High levels of socio-economic disadvantage including poverty
- High rates of physical and mental disability
- Decreasing housing affordability with high levels of housing stress
- Need for improved health services and access to education
- Gaps in skilled labour in population
- Environmental issues- community would like to see a cleaner environment with less

Fairfield LGA socio-demographic profile

rubbish dumping

- Need for better public transport, improved roads and more parking
- Need more activities for children and youth

Hawkesbury LGA profile

Hawkesbury LGA socio-demographic profile

Community overview

The Hawkesbury LGA is located approximately 50 kilometres from Sydney towards the outer northwest of the metropolitan area (Hawkesbury City Council 2006). It is the largest local government area in metropolitan NSW covering an area of 2,793 square kilometres (Hawkesbury City Council 2006). Key features include the University of Western Sydney Hawkesbury Campus, a TAFE campus, and the Richmond RAAF base.

The landscape is characterised by four river valleys with the Hawkesbury River being a key focus, fertile floodplains and wetlands, undulating hills, timbered ridges, steep gorges and towering escarpments (Hawkesbury City Council 2006). As well as the Hawkesbury River, around 70 per cent of the LGA is National Parks and Wilderness Areas, including part of the world heritage listed Blue Mountains (Hawkesbury City Council 2006). The area also has a rich Indigenous and post-settlement history (Hawkesbury City Council 2006).

The Hawkesbury is made up of many small townships and localities within a rural and natural setting (Hawkesbury City Council 2006). Despite almost 94 per cent of The Hawkesbury's total population living within the most south easterly portion of the LGA, no single township or locality contains more than 11 per cent of the total population (Hawkesbury City Council 2006). The remaining 6 per cent live in small and isolated hamlets on the rural periphery (Hawkesbury City Council 2006). Part of the LGA is located in the North West Growth Centre.

The estimated resident population of Hawkesbury LGA as at 30 June 2014 was 65,527 persons (Profile.id. 2014i). This is projected to increase by 20 per cent to 78,676 persons by 2030 (SGS Economics and Planning 2015).

The following information for the Hawkesbury LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011i and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Hawkesbury LGA as at 30 June 2014 was 65,527 persons (Profile.id. 2014i)
- The population of Hawkesbury LGA in 2011 was 62,353 persons compared with 60,561 persons in 2006 (ABS 2006h). This is equivalent to an increase of 3 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Hawkesbury LGA had a significantly lower population density of 0.22 persons per hectare compared with 3.54 persons per hectare in Greater Sydney

Hawkesbury LGA socio-demographic profile

- Aboriginal and Torres Strait Islander people made up 2.6 per cent of the population with 1,610 persons. This was double the percentage of the Aboriginal and Torres Strait Islander population recorded for Greater Sydney of 1.2 per cent
- Not a highly culturally diverse population in Hawkesbury with 5.5 per cent of the population born in a non-English speaking country and 5.3 per cent speaking a language other than English at home. This was significantly lower than Greater Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home.

Population projections

- The population of Hawkesbury LGA is expected to increase to 74,189 persons by 2025, 78,676 persons by 2030 and 101,213 persons by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 36 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[10].

Age profile

- Largest proportion of people in the 35-49 years age bracket- 13,629 persons 21.9 per cent; followed by 50-59 years age group- 8,173 persons 13.1 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent)
- There were 16,238 people (26.0 per cent) aged under 18 years and 10,684 (17.1 per cent) aged 60 years or older. Greater Sydney reported a smaller population under the age of 18 (22.9 per cent) and a slightly larger percentage of the population aged 60 years or older (18.0 per cent)
- Both Hawkesbury LGA and Greater Sydney had the same median age of 36 years.
- The population of The Hawkesbury is ageing. Over the last two decades the proportion of children and young people aged 0 to 24 has been declining and this trend is set to continue. However the Hawkesbury still has a relatively young population compared with national trends. The Hawkesbury's lower than national average age reflects the area's sustained population growth – primarily as a result of natural population increases. (Hawkesbury City Council 2006)

Gender profile

- In 2011, Hawkesbury had a female population of 31,297 (50.2 per cent) and a male population of 31,056 (49.8 per cent). Greater Sydney also reported a larger female population (50.8 per cent) compared to male population (49.2 per cent).

Household structure and family composition

- There were a total of approximately 20,845 households in Hawkesbury LGA. Of the total number of households, family households comprised 77.2 per cent, 20.4 per cent were lone person households and 2.4 per cent were group households. Greater Sydney reported generally similar percentages of household composition with 73.1 per cent family households, 22.6 per cent lone person households and 4.3 per cent group households
- Of the 16,621 families in Hawkesbury LGA, 49.4 per cent were couple families with

[10] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

children, 32.5 per cent were couple families without children, and 17.0 per cent were one parent families. Greater Sydney recorded similar percentages with 48.9 per cent couple families with children, 33.5 per cent couple families without children and 15.7 per cent one parent families.

Education level

- Hawkesbury LGA had a lower rate of high school completion (36.4 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a higher percentage of the population without post-school qualifications with 44.7 per cent compared to 40.5 per cent for Greater Sydney.

Housing tenure

- In Hawkesbury LGA, 92.8 per cent of private dwellings were occupied and 7.2 per cent were unoccupied. There were a total of 22,462 private dwellings. Greater Sydney had the same distribution of private dwellings
- Of occupied private dwellings in Hawkesbury LGA, the majority were separate houses with 85.8 per cent, 9.3 per cent were semi-detached, row or terrace houses, or townhouses, 3.7 per cent were flats, units or apartments, and 1.2 per cent were other dwellings. Greater Sydney recorded a lower percentage of separate houses (60.9 per cent) and a higher number of flats, units or apartments (25.8 per cent)
- Of occupied private dwellings in Hawkesbury LGA, approximately 72.4 per cent of the dwellings were privately owned (42.5 per cent were owned with a mortgage, 29.9 per cent were owned outright) and 24.9 per cent were rented. Greater Sydney recorded a smaller percentage of privately owned dwellings with 65.2 per cent and more rented properties at 31.6 per cent
- Similar percentage of state housing properties in Hawkesbury LGA (13.7 per cent) compared to Greater Sydney (14.4 per cent).

Economic profile

Total employment

- Total employment in Hawkesbury LGA and Greater Sydney was around 95 per cent.

Unemployment rate

- The rate of unemployment was lower in Hawkesbury LGA (4.6 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- The labour force of Hawkesbury in 2011 was 24,784 persons equating to 40 per cent of the population. Greater Sydney reported almost double this percentage with a total labour workforce of 81 per cent.

Occupations

- The most common occupations in Hawkesbury LGA included technicians and trades workers (18.8 per cent), clerical and administrative workers (15.4 per cent) and professionals (15.2 per cent). Professionals and clerical and administrative workers were dominant in Greater Sydney.

Hawkesbury LGA socio-demographic profile

Industries of employment

- The main industries of employment in Hawkesbury LGA included construction (12.6 per cent); manufacturing (10.8 per cent) and retail trade (10.4 per cent). Health care and social assistance, retail trade, and professional, scientific and technical services were the dominant industries in Greater Sydney.

Travel to work

- Average trip to work 31 minutes (Bureau of Transport Statistics 2012)
- In 2011, 42.6 per cent of Hawkesbury's working residents travelled outside of the area to work (Profile.id. 2014i)
- 71.8 per cent of the workforce travelled to work by car as driver or passenger while 4.7 per cent of the workforce travelled to work by public transport. A considerably higher percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with less travelling by car (58.4 per cent).

Average income

- Lower average weekly household income ($1,385) in comparison to Greater Sydney ($1,447)
- Higher average weekly individual income ($622) compared with Greater Sydney ($619).

Housing values

- Average sale price of $600,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 11.2 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Hawkesbury was 1017 indicating that the LGA was just below average and reported similar levels of disadvantage compared to Greater Sydney (1025) (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing the Hawkesbury LGA have been identified based on a review of planning and policy documents including:

- Hawkesbury Community Strategic Plan 2013-2032 (Hawkesbury City Council 2013)
- Hawkesbury Cultural Plan 2006-2011 (Hawkesbury City Council 2006)
- Consultation with Hawkesbury City Council for Western Sydney Airport SIA.

Opportunities:

- Cultural and built heritage including significant Indigenous heritage
- Community values the relaxed lifestyle and close-knit community
- Promotion of the Hawkesbury area as a tourist destination
- The LGA has a balance of rural / agricultural and city/urban areas. The agricultural and farming sector is complemented by the area's relatively close proximity to the Sydney

Hawkesbury LGA socio-demographic profile

CBD

- The Hawkesbury is a regional centre in a natural setting with a large amount of bushland including part of the Blue Mountains
- The shifting economy from a more agricultural model to an economy based on diversity of services and products can provide opportunities whilst still recognising the need to retain the area's natural and rural/agricultural environment and heritage in order to preserve local quality of life.

Challenges:

- Population growth slowing and population ageing
- Agriculture and farming threatened by urban development. The LGA is on the fringe of Western Sydney, close to rapidly growing urban centres such as Parramatta, Castle Hill and Blacktown
- Lack of effective public transport network which links to regional centres e.g. Parramatta, Sydney CBD
- Shortfalls in some community infrastructure particularly telecommunications infrastructure- lack of mobile phone access
- Lack of opportunities for young people.

Holroyd LGA socio-demographic profile

Community overview

The Holroyd LGA is located in Sydney's western suburbs, about 25 kilometres from the Sydney CBD (Holroyd City Council 2012). The LGA covers nearly 40 square kilometres and is bounded by Parramatta in the north and east, Fairfield in the south and Blacktown in the west (Holroyd City Council 2012).

Holroyd is a predominately residential area, with substantial industrial areas, and some commercial areas (Holroyd City Council 2011). The LGA is serviced by major transport infrastructure including the M4 Motorway, Cumberland and Great Western Highway (Holroyd City Council 2011).

Holroyd had a population of around 111,100 persons in 2014 which is expected to increase primarily due to changes to planning controls permitting higher density development in the town centres (Holroyd City Council 2013). The population is projected to increase by 11 per cent to 123,482 persons by 2030 (SGS Economics and Planning 2015).

The Holroyd City Council's *Living Holroyd: Vision and Options Paper* identifies what residents value most about living in the LGA; the top responses including central and convenient location, good amenities / infrastructure, well-kept parks and gardens and good shopping (Holroyd City Council 2010b).

The following information for the Holroyd LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011j and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Holroyd LGA as at 30 June 2014 was 111,100 persons (Profile.id. 2014j)
- The population of Holroyd LGA in 2011 was 99,163 persons compared with 89,766 persons in 2006 (ABS 2006i). This is equivalent to an increase of 10 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Holroyd LGA was considerably more population than Greater Sydney with a density of 24.54 persons per hectare compared with 3.54 persons per hectare
- Aboriginal and Torres Strait Islander people made up 0.8 per cent of the population with 816 persons. This was slightly lower than the Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney
- Culturally diverse population in Holroyd LGA with over half the population speaking a language other than English at home (51 per cent). This was significantly higher than Greater Sydney which recorded 32.5 per cent speaking a language other than English at home. The most common birth countries were India, Lebanon, China and Sri Lanka (Holroyd City Council 2011).

Population projections

- The population of Holroyd LGA is expected to increase to 116,135 persons by 2025, 123,482 persons by 2030 and 169,247 by 2065 (SGS Economics and Planning 2015).

Holroyd LGA socio-demographic profile

This is equivalent to an increase of 46 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[11].

Age profile

- Largest proportion of people in the 35-49 years age bracket- 20,662 persons 20.8 per cent; followed by 25-34 years age group- 17,602 persons 17.8 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent)
- There were 24,327 people (24.5 per cent) aged under 18 years and 16,797 (17.0 per cent) aged 60 years or older. These results were fairly similar to the Greater Sydney region which reported 22.9 per cent under the age of 18 years and 18.0 per cent aged 60 years or older
- Younger population in Holroyd with a median age of 34 years compared with 36 years in Greater Sydney.

Gender profile

- In 2011, Holroyd had a female population of 50,059 (50.5 per cent) and a male population of 49,104 (49.5 per cent). Greater Sydney also reported a larger female population (50.8 per cent) compared to male population (49.2 per cent).

Household structure and family composition

- There were a total of approximately 33,011 households in Holroyd LGA. Of the total number of households, family households comprised 76.4 per cent, 20.9 per cent were lone person households and 2.7 per cent were group households. Greater Sydney reported similar percentages of household composition with 73.1 per cent family households, 22.6 per cent lone person households and 4.3 per cent group households
- Of the 26,388 families in Holroyd LGA, 50.7 per cent were couple families with children, 29.5 per cent were couple families without children, and 17.6 per cent were one parent families. Greater Sydney recorded the same family characteristics with 48.9 per cent couple families with children, 33.5 per cent couple families without children and 15.7 per cent one parent families.

Education level

- Holroyd LGA had a slightly lower rate of high school completion (50.4 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a higher percentage of the population without post-school qualifications with 45.2 per cent compared to 40.5 per cent for Greater Sydney.

House tenure

- In Holroyd LGA, 94.7 per cent of private dwellings were occupied and 5.3 per cent were unoccupied. There were a total of 34,864 private dwellings. Greater Sydney had a higher number of unoccupied private dwellings with 7.2 per cent
- Of occupied private dwellings in Holroyd LGA, 61.6 per cent were separate houses, 23.8 per cent were flats, units or apartments, 14.3 per cent were semi-detached, row or terrace houses, or townhouses, and 0.2 per cent were other dwellings. Greater Sydney

[11] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

Holroyd LGA socio-demographic profile

recorded similar percentages with a slightly higher percentage of flats, units or apartments (25.8 per cent)

- Of occupied private dwellings in Holroyd LGA, approximately 61.7 per cent of the dwellings were privately owned (32.7 per cent were owned with a mortgage, 29.0 per cent were owned outright) and 34.8 per cent were rented. Greater Sydney recorded a greater percentage of privately owned dwellings with 65.2 per cent and fewer rented properties at 31.6 per cent
- Greater percentage of state housing properties in Holroyd LGA (18.9 per cent) compared to Greater Sydney (14.4 per cent)
- Holroyd will have over 15,000 new dwellings over the next 20 years (Holroyd City Council 2014).

Economic profile

Total employment

- Holroyd City is seen as a major employment hub for Western Sydney (Holroyd City Council 2011)
- Total employment in Holroyd LGA and Greater Sydney was over 90 per cent.

Unemployment rate

- The rate of unemployment was higher in Holroyd LGA (7.2 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- Holroyd LGA and Greater Sydney had similar percentages of total labour force of 79 per cent and 81 per cent respectively. The labour force of Holroyd in 2011 comprised 78,412 persons
- An additional 8,000 jobs are projected to be created by 2031 (Holroyd City Council 2011).

Occupations

- The most common occupations in both Holroyd LGA and Greater Sydney included professionals (20.0 per cent and 25.5 per cent respectively) and clerical and administrative workers (18.7 per cent and 16.2 per cent).

Industries of employment

- The main industries of employment in Holroyd LGA included manufacturing (11.1 per cent), health care and social assistance (11.0 per cent) and retail trade (10.6 per cent). Retail trade and health care and social assistance were also dominant in Greater Sydney.

Travel to work

- Average trip to work 36 minutes (Bureau of Transport Statistics 2012)
- In 2011, 70.7 per cent of Holroyd's working residents travelled outside of the area to work (Profile.id. 2014j)
- 63.2 per cent of the workforce travelled to work by car as driver or passenger while

Holroyd LGA socio-demographic profile
20.4 per cent of the workforce travelled to work by public transport. This was fairly consistent with the travel to work data for Greater Sydney which indicated that 20.0 per cent travelled to work by public transport and 58.4 per cent travelled by car.
Average income • Lower average weekly household income ($1,209) in comparison to Greater Sydney ($1,447) • Lower average weekly individual income ($517) compared with Greater Sydney ($619).
Housing values • Average sale price of $624,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 17.7 per cent in median price annually (Housing NSW 2014).
SEIFA rating • The SEIFA Index of Advantage and Disadvantage for Holroyd was 972 indicating that the LGA was more disadvantaged compared to Greater Sydney (1025) (ABS 2013).
Key opportunities and challenges Existing opportunities and challenges facing the Holroyd LGA have been identified based on a review of planning and policy documents including: • Living Holroyd Community Strategic Plan 2011 (Holroyd City Council 2011) • Holroyd City Social Plan 2010-2012 (Holroyd City Council 2010a) • Consultation with Holroyd City Council for Western Sydney Airport SIA.
Opportunities: • The strong cultural diversity in the LGA provides the opportunity to build a more inclusive and harmonious community • Holroyd is identified as a family-oriented city • Large number of volunteer and social groups within the LGA • Opportunity to revitalise centres and improve vibrancy of community through local events, community markets, art projects and street furniture • Encourage wider variety of businesses to locate in the area to improve access to services • Large skilled migrant and refugees in some area in the LGA however there is a relatively high rate of unemployment in these areas. There are opportunities to provide increased employment for these groups but they rely on good public transport • Diversity of skills across the community. Challenges: • Relatively high unemployment rates in migrant and refugee communities. • Community identified issues with transport infrastructure (need to improve public transport, roads, parking, accessibility, access afterhours including lighting, pedestrian and cycle facilities and footpaths).

Holroyd LGA socio-demographic profile

- Time taken to travel to CBD due to traffic on roads.
- Lack of understanding of differences and cultural practices by some community members has raised concerns of anti-social behaviour
- Disadvantage affects many residents through low income, housing stress, mental health and homelessness
- Information is not accessible to the whole community due to the range of languages spoken in the community, differing education levels and relatively low level of access to the Internet
- Shortfalls in some community facilities which community identify as run down, under serviced and under-used(e.g. child and family services, health and aged care options)
- Decreasing housing affordability.

Liverpool LGA profile

Liverpool LGA socio-demographic profile

Community overview

Liverpool LGA is identified as a regional city within south west Sydney (Liverpool City Council 2014). The LGA consists of 42 suburbs covering an area of 305 square kilometres (Liverpool City Council 2013). Liverpool City is a rapidly growing residential area with substantial industrial and commercial areas. Liverpool features both highly urbanised and rural areas. Part of the Western Sydney Parklands is located in the LGA, as well as Chipping Norton Lakes, Liverpool Hospital, Casula Powerhouse, the Holsworthy Military Camp, and a TAFE campus.

The area has undergone significant infrastructure upgrades with the launch of the largest hospital in Australia, high-end retail facilities, schools and tertiary education facilities including TAFE and a teaching hospital (Liverpool City Council 2014).

The estimated resident population of Liverpool LGA as at 30 June 2014 was 199,928 persons (Profile.id. 2014k). This is projected to increase by 34 per cent to 268,208 persons by 2030 (SGS Economics and Planning 2015).

Liverpool is a young city with almost 40 per cent of the population under 24 years of age at the time of the 2011 Census (Liverpool City Council 2013). It is also a culturally diverse population with people from a diverse range of backgrounds (Liverpool City Council 2014).

The following information for the Liverpool LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011k and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Liverpool LGA as at 30 June 2014 was 199,928 persons (Profile.id. 2014k)
- The population of Liverpool LGA in 2011 was 180,143 persons compared with 164,603 persons in 2006 (ABS 2006j). This is equivalent to an increase of 9 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from

Liverpool LGA socio-demographic profile

4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)

- Liverpool LGA had a higher population density (5.89 persons per hectare) compared with Greater Sydney (3.54 persons per hectare)
- Aboriginal and Torres Strait Islander people made up 1.5 per cent of the population with 2,676 persons. This was slightly higher than the Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney
- Culturally diverse population in Liverpool with 35.9 per cent of the population born in a non-English speaking country and 49.8 per cent speaking a language other than English at home. This was considerably higher than Greater Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home.

Population projections

- The population of Liverpool LGA is expected to increase to 237,874 persons by 2025, 268,208 persons by 2030 and 534,517 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 125 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[12].

Age profile

- Largest proportion of people in the 35-49 years age bracket- 40,158 persons 22.3 per cent; followed by 25-34 years age group- 26,391 persons 14.7 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent)
- There were 50,568 people (28.1 per cent) aged under 18 years and 24,219 (13.5 per cent) aged 60 years or older. These results showed a larger percentage of the population aged less than 18 years compared to Greater Sydney (22.9 per cent) and a lower percentage aged 60 years or older compared to the wider area (18.0 per cent)
- Younger population in Liverpool with a median age of 33 years compared with 36 years in Greater Sydney.

Gender profile

- In 2011, Liverpool had a female population of 90,820 (50.4 per cent) and a male population of 89,323 (49.6 per cent). Greater Sydney also reported a larger female population (50.8 per cent) compared to male population (49.2 per cent).

Household structure and family composition

- There were a total of approximately 53,594 households in Liverpool LGA. Of the total number of households, family households comprised 82.1 per cent, 16.0 per cent were lone person households and 1.8 per cent were group households. Greater Sydney reported a smaller percentage of family households with 73.1 per cent and a larger percentage of lone person households (22.6 per cent) and group households (4.3 per cent)
- Of the 46,563 families in Liverpool LGA, 56.7 per cent were couple families with children, 23.7 per cent were couple families without children, and 18.2 per cent were one parent families. Greater Sydney recorded less couple families with children at 48.9

[12] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

Liverpool LGA socio-demographic profile
per cent, more couple families without children (33.5 per cent) and less one parent families (15.7 per cent).
Education level • Liverpool LGA had a lower rate of high school completion (46.3 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a higher percentage of the population without post-school qualifications with 50.1 per cent compared to 40.5 per cent for Greater Sydney.
Housing tenure • In Liverpool LGA, 95.8 per cent of private dwellings were occupied and 4.2 per cent were unoccupied. There were a total of 55,958 private dwellings. Greater Sydney had a higher number of unoccupied private dwellings with 7.2 per cent • Of occupied private dwellings in Liverpool LGA, 75.3 per cent were separate houses, 12.6 per cent were flats, units or apartments, 11.9 per cent were semi-detached, row or terrace houses, or townhouses, and 0.2 per cent other dwellings. Greater Sydney recorded a lower percentage of separate houses (60.9 per cent) and a higher number of flats, units or apartments (25.8 per cent) • Of occupied private dwellings in Liverpool LGA, a significant percentage (66.0 per cent) of the dwellings were privately owned (41.9 per cent were owned with a mortgage, 24.1 per cent were owned outright) and 30.4 per cent were rented. Greater Sydney recorded similar percentages with 65.2 per cent privately owned dwellings and 31.6 per cent rented properties • Higher proportion of state housing properties in Liverpool LGA (25.9 per cent) compared to Greater Sydney (14.4 per cent).
Economic profile
Total employment • Total employment in Liverpool LGA and Greater Sydney was above 90 per cent.
Unemployment rate • The rate of unemployment was higher in Liverpool LGA (7.0 per cent) compared to Greater Sydney (5.7 per cent).
Total labour force • Liverpool LGA and Greater Sydney had similar percentages of total labour force of 77 per cent and 81 per cent respectively. The labour force of Liverpool in 2011 comprised 137,897 persons.
Occupations • The most common occupations in Liverpool LGA included clerical and administrative workers (17.5 per cent) technicians and trades workers (15.7 per cent) and professionals (15.4 per cent). Professional (25.5 per cent) and clerical and administrative workers (16.2 per cent) ranked the highest in Greater Sydney.

Liverpool LGA socio-demographic profile

Industries of employment

- The main industries of employment in Liverpool LGA included manufacturing (14.0 per cent), retail trade (10.4 per cent) and health care and social assistance (10.1 per cent). Health care and social assistance and retail trade were the most dominant industries in Greater Sydney.

Travel to work

- Average trip to work 37 minutes (Bureau of Transport Statistics 2012)
- In 2011, 57.0 per cent of Liverpool's working residents travelled outside of the area to work (Profile.id. 2014k)
- 70.0 per cent of the workforce travelled to work by car as driver or passenger while 12.4 per cent of the workforce travelled to work by public transport. A higher percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with less travelling by car (58.4 per cent).

Average income

- Lower average weekly household income ($1,299) in comparison to Greater Sydney ($1,447)
- Lower average weekly individual income ($510) compared with Greater Sydney ($619).

Housing values

- Average sale price of $575,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 20.4 per cent in the median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Liverpool was 968 indicating that the LGA was more disadvantaged compared to Greater Sydney (1025) (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing the Liverpool LGA have been identified based on a review of planning and policy documents including:

- *Growing Liverpool 2023* (Liverpool City Council 2013)
- Consultation with Liverpool City Council for Western Sydney Airport SIA.

Opportunities:

- Regional city within south west Sydney
- Culturally diverse population
- Large population of children and young people, with increasing levels of education
- Growth in the health and education sectors
- Providing more jobs to keep up with population growth and that are closer to homes and keep up with population growth.

Liverpool LGA socio-demographic profile

Challenges:

- Providing affordable housing and a mix of housing types so residents can still live in the area when circumstances change
- Maintenance of assets and facilities
- Providing more accessible recreation and entertainment options
- Opportunities for a healthier lifestyle including improved open space areas
- Traffic congestion, public transport and lack of parking
- Provide services and programs for all groups and interests
- Areas of significant socio-economic disadvantage
- High rates of commuting outside of the LGA for work which has a significant impact on health and wellbeing.

Parramatta LGA profile

Parramatta LGA socio-demographic profile

Community overview

Parramatta LGA is located in Sydney's western suburbs, 24 kilometres from Sydney CBD and covers 61 square kilometres (Parramatta City Council 2013). The LGA is home to Sydney's second CBD and is the geographical, commercial and cultural centre for Western Sydney (Parramatta City Council 2013).

Parramatta is a major economic hub, playing a key role in the wider regional area (Parramatta City Council 2013). The central location of the LGA makes it an important core for medical, legal, financial, educational and professional services (Parramatta City Council 2013). Key features include Westmead Hospital and Westmead Children's Hospital, University of Western Sydney (Parramatta and Westmead Campuses), and a TAFE campus.

The population of Parramatta LGA was 189,932 persons in 2014. This is forecast to increase by 28 per cent to 243,784 persons by 2030 (SGS Economics and Planning 2015).

The following information for the Parramatta LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011l and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Parramatta LGA as at 30 June 2014 was 189,932 persons (Profile.id. 2014l)
- The population of Parramatta LGA in 2011 was 166,858 persons compared with 148,323 persons in 2006 (ABS 2006k). This is equivalent to an increase of 12 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Parramatta LGA was considerably more populated than Greater Sydney with a density

Parramatta LGA socio-demographic profile

of 27.36 persons per hectare compared with 3.54 persons per hectare

- Aboriginal and Torres Strait Islander people made up 0.8 per cent of the population with 1,404 persons. This was slightly lower than the Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney
- Culturally diverse population in Parramatta with 40.4 per cent of the population born in a non-English speaking country and 50.2 per cent speaking a language other than English at home. This was significantly higher than Greater Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home.

Population projections

- The population of Parramatta LGA is expected to increase to220,736 persons by 2025, 243,784 persons by 2030 and 377,388 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 71 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[13].

Age profile

- Largest proportion of people in the 35-49 years age bracket- 34,797 persons 20.9 per cent; followed by 25-34 years age group- 33,165 persons 19.9 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent)
- There were 37,170 people (22.3 per cent) aged under 18 years and 26,811 (16.0 per cent) aged 60 years or older. These results were fairly similar to the Greater Sydney region which reported 22.9 per cent under the age of 18 years and 18.0 per cent aged 60 years or older
- Younger population in Parramatta with a median age of 33 years compared with 36 years in Greater Sydney.

Gender profile

- In 2011, Parramatta had a male population of 83,560 (50.1 per cent) and a female population of 83,298 (49.9 per cent). Greater Sydney reported a larger female population (50.8 per cent) compared to male population (49.2 per cent).

Household structure and family composition

- There were a total of approximately 56,703 households in Parramatta LGA. Of the total number of households, family households comprised 72.6 per cent, 23.2 per cent were lone person households and 4.2 per cent were group households. Greater Sydney reported similar percentages of household composition with 73.1 per cent family households, 22.6 per cent lone person households and 4.3 per cent group households
- Of the 42,967 families in Parramatta LGA, 49.7 per cent were couple families with children, 32.7 per cent were couple families without children, and 15.3 per cent were one parent families. Greater Sydney recorded similar percentages with 48.9 per cent couple families with children, 33.5 per cent couple families without children and 15.7 per cent one parent families.

[13] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

Parramatta LGA socio-demographic profile

Education level

- Parramatta LGA had a slightly higher rate of high school completion (57.5 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a marginally lower percentage of the population without post-school qualifications with 39.8 per cent compared to 40.5 per cent for Greater Sydney.

Housing tenure

- In Parramatta LGA, 93.9 per cent of private dwellings were occupied and 6.1 per cent were unoccupied. There were a total of 60,418 private dwellings. Greater Sydney had a higher number of unoccupied private dwellings with 7.2 per cent
- Of occupied private dwellings in Parramatta LGA, 52.8 per cent were separate houses, 33.5 per cent were flats, units or apartments, 13.4 per cent were semi-detached, row or terrace houses, or townhouses, and 0.2 per cent were other dwellings. Greater Sydney recorded a higher percentage of separate houses (60.9 per cent) and a lower number of flats, units or apartments (25.8 per cent)
- Of occupied private dwellings in Parramatta LGA, approximately 57.0 per cent of the dwellings were privately owned (31.9 per cent were owned with a mortgage, 25.1 per cent were owned outright) and 39.3 per cent were rented. Greater Sydney recorded a greater percentage of privately owned dwellings with 65.2 per cent and fewer rented properties at 31.6 per cent
- Greater percentage of state housing properties in Parramatta LGA (20.0 per cent) compared to Greater Sydney (14.4 per cent)
- The number of dwellings in the Parramatta City is forecast to grow from 64,291 in 2011 to 90,766 in 2036, with the average household size falling from 2.76 to 2.66 by 2026 (Forecast.id. 2014d).

Economic profile

Total employment

- Total employment in Parramatta LGA and Greater Sydney was over 90 per cent.

Unemployment rate

- The rate of unemployment was higher in Parramatta LGA (7.0 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- Both Parramatta LGA and Greater Sydney had a total labour force of 81 per cent. The labour force of Parramatta in 2011 comprised 135,301 persons.

Occupations

- The most common occupations in both Parramatta LGA and Greater Sydney included professionals (25.9 per cent and 25.5 per cent respectively) and clerical and administrative workers (17.3 per cent and 16.2 per cent).

Industries of employment

- The main industries of employment in Parramatta LGA included health care and social assistance (11.9 per cent), retail trade (10.1 per cent), manufacturing (9.2 per cent) and

Parramatta LGA socio-demographic profile

professional, scientific and technical services (8.6 per cent). These industries were also the dominant employers in Greater Sydney.

Travel to work

- Average trip to work 36 minutes (Bureau of Transport Statistics 2012)
- In 2011, 64.2 per cent of Parramatta's working residents travelled outside of the area to work (Profile.id. 2014l)
- 57.5 per cent of the workforce travelled to work by car as driver or passenger while 24.1 per cent of the workforce travelled to work by public transport. A slightly lower percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with more travelling by car (58.4 per cent).

Average income

- Lower average weekly household income ($1,288) in comparison to Greater Sydney ($1,447)
- Lower average weekly individual income ($544) compared with Greater Sydney ($619).

Housing values

- Average sale price of $687,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 20.4 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Parramatta was 996 indicating that the LGA was slightly more disadvantaged compared to Greater Sydney (1025) (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing the Parramatta LGA have been identified based on a review of planning and policy documents including:

- Parramatta 2038 - Community Strategic Plan
- Consultation with Parramatta City Council for Western Sydney Airport SIA.

Opportunities:

- Geographical, commercial and cultural hub of Western Sydney – Sydney's second CBD
- Growth of Westmead health precinct and new University of Western Sydney campus in CBD leading to new jobs and education opportunities.
- Diverse and multicultural community which could be capitalised on for community enrichment and economic growth
- Growing workforce and population particularly increased density
- Celebration of cultural and built heritage
- Increasing rates of education

Parramatta LGA socio-demographic profile

Challenges:

- Growing workforce and population may cause major impacts on health and wellbeing and result in unsustainable demands on infrastructure.
- High rates of youth unemployment
- Need to encourage job growth close to people's place of residence
- Ageing of the population

Penrith LGA profile

Penrith LGA socio-demographic profile

Community overview

Penrith is a regional city on the western fringe of Sydney (Penrith City Council 2013). The LGA covers an area of 404 square kilometres and 34 suburbs and is approximately 54 kilometres from Sydney CBD (Penrith City Council 2013). The LGA is located on the Nepean River flats of the Cumberland Plain, and the majority of the population lives in residential areas along the Great Western Highway. Around 80 per cent of the LGA consists of rural areas and rural residential development, with agriculture a strong contributor to the local economy of Penrith (Penrith City Council 2013).

Key featuers include the University of Western Sydney Penrith Campus, a TAFE campus, Nepean Hospital, and the eastern part of Blue Mountains National Park.

The population of Penrith LGA was 194,134 persons in 2014. This is projected to increase by 23 per cent to 238,090 persons by 2030 (SGS Economics and Planning 2015).

The following information for the Penrith LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011m and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Penrith LGA as at 30 June 2014 was 194,134 persons (Profile.id. 2014m)
- The population of Penrith LGA in 2011 was 178,467 persons compared with 172,140 persons in 2006 (ABS 2006l). This is equivalent to an increase of 4 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Penrith LGA had a higher population density (4.41 persons per hectare) compared with Greater Sydney (3.54 persons per hectare)
- Aboriginal and Torres Strait Islander people made up 3.0 per cent of the population with 5,388 persons. This was double the Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney
- Not a highly culturally diverse population in Penrith LGA with 13.3 per cent of the population born in a non-English speaking country and 14.6 per cent speaking a language other than English at home. This was considerably lower than Greater

Penrith LGA socio-demographic profile

Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home.

Population projections

- The population of Penrith LGA is expected to increase to 219,766 persons by 2025, 238,090 persons by 2030 and 363,251 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 65 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[14].

Age profile

- Largest proportion of people in the 35-49 years age bracket- 37,294 persons 20.9 per cent; followed by 25-34 years age group- 26,315 persons 14.7 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent)
- There were 46,581 people (26.1 per cent) aged under 18 years and 26,757 (15.0 per cent) aged 60 years or older. Greater Sydney trends indicated an older population with 22.9 per cent under the age of 18 years and 18.0 per cent aged 60 years or older
- Slightly younger population in Penrith with a median age of 34 years compared with 36 years in Greater Sydney.

Gender profile

- In 2011, Penrith had a female population of 90,378 (50.6 per cent) and a male population of 88,089 (49.4 per cent). Greater Sydney also reported a larger female population (50.8 per cent) compared to male population (49.2 per cent).

Household structure and family composition

- There were a total of approximately 59,390 households in Penrith LGA. Of the total number of households, family households comprised 78.3 per cent, 19.2 per cent were lone person households and 2.5 per cent were group households. Greater Sydney reported generally similar percentages of household composition with 73.1 per cent family households, 22.6 per cent lone person households and 4.3 per cent group households
- Of the 48,360 families in Penrith LGA, 49.7 per cent were couple families with children, 29.6 per cent were couple families without children, and 19.2 per cent were one parent families. Greater Sydney recorded similar percentages with 48.9 per cent couple families with children, 33.5 per cent couple families without children and 15.7 per cent one parent families.

Education level

- Penrith LGA had a considerably lower rate of high school completion (37.7 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a higher percentage of the population without post-school qualifications with 49.7 per cent compared to 40.5 per cent for Greater Sydney.

Housing tenure

- In Penrith LGA, 94.8 per cent of private dwellings were occupied and 5.2 per cent were

[14] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

Penrith LGA socio-demographic profile
unoccupied. There were a total of 62,632 private dwellings. Greater Sydney had a higher number of unoccupied private dwellings with 7.2 per cent • Of occupied private dwellings in Penrith LGA, 81.5 per cent were separate houses, 10.8 per cent were semi-detached, row or terrace houses, or townhouses, 7.1 per cent were flats, units or apartments, and 0.4 per cent were other dwellings. Greater Sydney recorded a smaller percentage of separate houses (60.9 per cent) and a higher number of flats, units or apartments (25.8 per cent) • Of occupied private dwellings in Penrith LGA, approximately 70.6 per cent of the dwellings were privately owned (43.8 per cent were owned with a mortgage, 26.8 per cent were owned outright) and 26.7 per cent were rented. Greater Sydney recorded a lesser percentage of privately owned dwellings with 65.2 per cent and more rented properties at 31.6 per cent • Slightly larger percentage of state housing properties in Penrith LGA (16.6 per cent) compared to Greater Sydney (14.4 per cent) • The number of dwellings in the Penrith is forecast to grow from 65,444 in 2011 to 84,631 in 2031, with the average household size falling from 2.85 to 2.69 by 2031 (Forecast.id. 2012b).
Economic profile
Total employment • Total employment in Penrith LGA and Greater Sydney was around 95 per cent.
Unemployment rate • The rate of unemployment was slightly lower in Penrith LGA (5.5 per cent) compared to Greater Sydney (5.7 per cent).
Total labour force • The labour force of Penrith in 2011 was 139,757 persons comprising 78 per cent of the population. This was slightly lower than the 81 per cent total labour workforce recorded for Greater Sydney.
Occupations • The most common occupations in Penrith LGA included clerical and administrative workers (19.1 per cent) and technicians and trades workers (15.2 per cent). Professionals and clerical and administrative workers were the dominant employers in Greater Sydney.
Industries of employment • The main industries of employment in Penrith LGA included manufacturing (11.8 per cent), retail trade (11.4 per cent) and health care and social assistance (10.2 per cent). These industries were also dominant employers in Greater Sydney.
Travel to work • Average trip to work 35 minutes (Bureau of Transport Statistics 2012) • In 2011, 51.1 per cent of Penrith's working residents travelled outside of the area to work (Profile.id. 2014m)

Penrith LGA socio-demographic profile

- 70.4 per cent of the workforce travelled to work by car as driver or passenger while 10.7 per cent of the workforce travelled to work by public transport. A higher percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with less travelling by car (58.4 per cent).

Average income

- Lower average weekly household income ($1,398) in comparison to Greater Sydney ($1,447)
- Higher average weekly individual income ($623) compared with Greater Sydney ($619).

Housing values

- Average sale price of $505,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 15.3 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Penrith was 989 indicating that the LGA was more disadvantaged compared to Greater Sydney (1025) (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing the Penrith LGA have been identified based on a review of planning and policy documents *including:*

- *Penrith Community Plan* (Penrith City Council 2013)
- Consultation with Penrith City Council for Western Sydney Airport SIA.

Opportunities:

- Housing and land more affordable than other areas of Sydney leading to new population growth and high numbers of young families
- Diversified economy
- Strong agricultural industry and large rural area
- Identified as a regional city within western Sydney.

Challenges:

- Shortfall of jobs in the LGA leading to people leaving the area and travelling long distances for work, ususally by car due to a lack of public transport
- Ensuring sufficient jobs, services and facilities and infrastructure are provided in time to meet the needs of a growing population
- The population is ageing, although the LGA still has a higher proportion of pre-school aged children and a lower proportion of people of post-retirement age than Sydney overall

The Hills LGA socio-demographic profile

Community overview

The Hills Shire LGA is located north west of Sydney, and stretches over 401 square kilometres. The LGA covers a large area from Wiseman's Ferry at the Hawkesbury River in the north to North Parramatta in the south (The Hills Shire Council 2013)

The Hills LGA is predominantly residential with rural areas in northern areas, agriculture, national parks, as well as semi-rural and rural residential living. Southern areas of the LGA include established residential and commercial areas as well as new release areas of residential and employment development land. Key features include two TAFE campuses and the Norwest Business Park. The North West Rail Link is a major project currently under construction which will connect the Hills communities, including the future North West Growth Centre, to the Sydney CBD by a new metro service (The Hills Shire Council 2013).

The Hills Shire LGA's estimated residential population in 2014 was 187,703 persons. This is projected to increase by 48 per cent to 277,183 persons by 2030 (SGS Economics and Planning 2015).

Many people are drawn to The Hills LGA by the large properties and open space. The LGA has many parks, and high participation in recreation activities (The Hills Shire Council 2013).There are many families with young children, relative to Greater Sydney (The Hills Shire Council 2013).

The following information for The Hills LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011n and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of The Hills LGA as at 30 June 2014 was 187,703 persons (Profile.id. 2014n)
- The population of The Hills LGA in 2011 was 169,872 persons compared with 159,391 persons in 2006 (Profile.id. 2014n). This is equivalent to an increase of 7 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- The Hills LGA had a higher population density (4.20 persons per hectare) compared with Greater Sydney (3.54 persons per hectare)
- Aboriginal and Torres Strait Islander people made up 0.4 per cent of the population with 634 persons. This was lower than the Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney
- In The Hills, 24.4 per cent of the population were born in a non-English speaking country and 28.5 per cent spoke a language other than English at home. While Greater Sydney recorded higher percentages with 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home, both areas indicate culturally diverse populations.

The Hills LGA socio-demographic profile

Population projections

- The population of The Hills LGA is expected to increase to 248,206 persons by 2025, 277,183 persons by 2030 and 406,999 by 2065 (SGS Economics and Planning 2015) This is equivalent to an increase of 64 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[15].

Age profile

- Largest proportion of people in the 35-49 years age bracket- 38,866 persons 22.9 per cent; followed by 50-59 years age group- 23,306 persons 13.7 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) this was followed by the 25-34 years age group (15.4 per cent)
- There were 44,101 people (26.0 per cent) aged under 18 years and 29,974 (17.7 per cent) aged 60 years or older. These results were fairly similar to the Greater Sydney region which reported 22.9 per cent under the age of 18 years and 18.0 per cent aged 60 years or older
- Slightly older population in The Hills with a median age of 38 years compared with 36 years in Greater Sydney.

Gender profile

- The Hills has a female population of 85,886 (50.6 per cent) and a male population of 83,986 (49.4 per cent). Greater Sydney reported the similar percentages of male (49.2 per cent) and female (50.8 per cent) populations.

Household structure and family composition

- There were a total of approximately 53,295 households in The Hills LGA. Of the total number of households, family households comprised 86.4 per cent, 12.0 per cent were lone person households and 1.6 per cent were group households. Greater Sydney reported fewer family households with 73.1 per cent, a higher number of lone person households (22.6 per cent) and group households (4.3 per cent)
- Of the 47,642 families in The Hills LGA, 58.7 per cent were couple families with children, 29.9 per cent were couple families without children, and 10.4 per cent were one parent families. Greater Sydney recorded a lower number of couple families with children (48.9 per cent) and higher numbers of couple families without children (33.5 per cent) and one parent families (15.7 per cent).

Education level

- The Hills LGA had a higher rate of high school completion (61.2 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a lower percentage of the population without post-school qualifications with 36.6 per cent compared to 40.5 per cent for Greater Sydney.

Housing tenure

- In The Hills LGA, 95.2 per cent of private dwellings were occupied and 4.8 per cent were unoccupied. There were a total of 55,962 private dwellings. Greater Sydney had a slightly higher number of unoccupied private dwellings with 7.2 per cent

[15] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

The Hills LGA socio-demographic profile

- Of occupied private dwellings in The Hills LGA, 84.1 per cent were separate houses, 10.7 per cent were semi-detached, row or terrace houses, or townhouses, 5.0 per cent were flats, units or apartments, and 0.1 per cent were other dwellings. Greater Sydney recorded a considerably lower percentage of separate houses (60.9 per cent) and a higher number of flats, units or apartments (25.8 per cent)
- Of occupied private dwellings in The Hills LGA, approximately 82.4 per cent of the dwellings were privately owned (46.6 per cent were owned with a mortgage, 36.0 per cent were owned outright) and 15.6 per cent were rented. Greater Sydney recorded around double the percentage of dwellings being rented with 31.6 per cent and fewer privately owned properties (65.2 per cent)
- Lower percentage of state housing properties in The Hills LGA (4.4 per cent) compared to Greater Sydney (14.4 per cent)
- The number of dwellings in The Hills is forecast to grow from 57,784 in 2011 to 85,770 in 2031, with the average household size falling from 3.09 to 2.94 by 2031 (Forecast.id. 2012c).

Economic profile

Total employment

- Total employment in The Hills LGA and Greater Sydney was around 95 per cent.

Unemployment rate

- The rate of unemployment was slightly higher in Greater Sydney (5.7 per cent) compared to The Hills LGA (4.2 per cent).

Total labour force

- The Hills had a slightly lower total labour force at 79 per cent compared to 81 per cent for Greater Sydney. The labour force of The Hills was 133,579 persons in 2011.

Occupations

- The most common occupations in both The Hills LGA and Greater Sydney included professionals (28.1 per cent and 25.5 per cent respectively), clerical and administrative workers (17.4 per cent and 16.2 per cent) and managers (17.3 per cent and 13.3 per cent).

Industries of employment

- The main industries of employment in The Hills LGA included retail trade (10.9 per cent), health care and social assistance (10.9 per cent) and professional, scientific and technical services (10.1 per cent). These industries were also the dominant employers in Greater Sydney.

Travel to work

- Average trip to work 40 minutes (Bureau of Transport Statistics 2012)
- In 2011, 60.9 per cent of The Hill's working residents travelled outside of the area to work (Profile.id. 2014n)
- 68.1 per cent of the workforce travelled to work by car as driver or passenger while 12.7 per cent of the workforce travelled to work by public transport. A higher

The Hills LGA socio-demographic profile

percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with fewer travelling by car (58.4 per cent).

Average income

- Higher average weekly household income ($2,044) in comparison to Greater Sydney ($1,447)
- Higher average weekly individual income ($719) compared with Greater Sydney ($619).

Housing values

- Average sale price of $1,022,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 19.5 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for The Hills was 1128 indicating that the LGA was above average and reported lower levels of disadvantage compared to Greater Sydney (1025) (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing The Hills LGA have been identified based on a review of planning and policy documents including:

- *The Hills Shire Plan 2013-2017*
- Consultation with the Hills Shire Council in June 2015 for Western Sydney Airport SIA.

Opportunities:

- Highly educated population
- Increasing cultural and linguistically diverse community
- The North West Rail Corridor is expected to change the community dynamic as more young people will remain in the LGA and commute elsewhere for work
- North West Rail Corridor expected to provide 50,000 new jobs. Development of industries in new release areas near train stations.
- Urban activation zones identified at Bella Vista, Castle Hill, Kellyville and Box Hill
- Support for arts and culture.

Challenges

- High rates of youth unemployment
- Housing affordability and employment opportunities. Many young people move out of the LGA to pursue educational and employment opportunities
- Provision of information, resources, and support services to an increasingly cultural and linguistically diverse community
- Some opposition within the community to high density development, and changes to character of housing and properties in the LGA
- Community safety and wellbeing issues e.g. domestic violence

The Hills LGA socio-demographic profile

- High car ownership and dependency
- Pressure on existing community services e.g. Library at Castle Hill and community centres already at capacity.
- Support community based cultural experiences across the LGA.

Wollondilly LGA profile

Wollondilly LGA socio-demographic profile

Community overview

The Wollondilly LGA is located on the south western outskirts of Sydney and at the foothills of the Southern Highlands, and covers 2,560 square kilometres. The majority of the LGA's residents live in or near Picton, Tahmoor and Thirlmere (Wollondilly Shire Council 2012).

Wollondilly is predominantly a national park and rural area, with urban areas in fifteen towns and villages. Two-thirds of the population live in the urban centres, and one-third in the rural areas. Most of the rural land is used for agricultural purposes, including market gardens, orchards, dairy farms, poultry farms and grazing. Coal mining is also a major industry. Key features include the Blue Mountains National Park and a range of other national parks, Warragamba Dam, and Queen Victoria Memorial Hospital (Profile.id. 2014h).

In 2014 the estimated residential population was 47,084 persons. This is projected to increase by 26 per cent to 59,395 persons by 2030 (SGS Economics and Planning 2015).

Wollondilly LGA residents value the rural and community lifestyle, and town and village atmosphere (Wollondilly Shire Council 2012). The LGA appeals to families due to the large open spaces, and family-oriented housing. Wollondilly properties are typically large, and many have horses and other livestock (Wollondilly Shire Council 2012).

The population is dispersed and 60 per cent of Wollondilly's population commute, often large distances, to surrounding LGAs for work, education and commercial opportunities (Wollondilly Shire Council 2012). There are fewer 18-24 year olds in the LGA compared to Greater Sydney, as they tend to move out of the area for education and employment opportunities.

The following information for the Wollondilly LGA with a comparison to Greater Sydney is based on ABS Census data 2011 (ABS 2011o and ABS 2011h) unless otherwise stated.

Demographic profile

Population

- The estimated resident population of Wollondilly LGA as at 30 June 2014 was 47,084 persons (Profile.id. 2014o)
- The population of Wollondilly LGA in 2011 was 43,259 persons compared with 40,344 persons in 2006 (ABS 2006m). This is equivalent to an increase of 7 per cent. The population of Greater Sydney increased by 7 per cent across the same period (from 4,118,041 persons in 2006 to 4,391,674 persons in 2011) (Profile.id. 2014h)
- Wollondilly LGA had a significantly lower population density of 0.17 persons per hectare compared with 3.54 persons per hectare in Greater Sydney
- Aboriginal and Torres Strait Islander people made up 2.4 per cent of the population with

Wollondilly LGA socio-demographic profile

1,036 persons. This was double the percentage of Aboriginal and Torres Strait Islander population of 1.2 per cent recorded for Greater Sydney

- Not a highly culturally diverse population in Wollondilly with 5.2 per cent of the population born in a non-English speaking country and 5.1 per cent speaking a language other than English at home. This was significantly lower than Greater Sydney which recorded 26.3 per cent of the population born overseas and 32.5 per cent speaking a language other than English at home.

Population projections

- The population of Wollondilly LGA is expected to increase to 55,966 persons by 2025, 59,395 persons by 2030 and 95,081 by 2065 (SGS Economics and Planning 2015). This is equivalent to an increase of 70 per cent between 2025 and 2065, with Greater Sydney expected to grow by 55 per cent over the same period.[16].

Age profile

- Largest proportion of people in the 35-49 years age bracket- 9,707 persons 22.4 per cent; followed by the 50-59 years age group- 5,905 persons 13.7 per cent. In Greater Sydney, the largest proportion of the population was also in the 35-49 years age group (21.9 per cent) followed by the 25-34 years age group (15.4 per cent)
- There were 11,961 people (27.6 per cent) aged under 18 years and 7,139 (16.5 per cent) aged 60 years or older. Data for the Greater Sydney region indicated a greater percentage of the population aged 60 years or older (18.0 per cent) compared with the LGA and less of the population under the age of 18 years (22.9 per cent)
- Both Wollondilly LGA and Greater Sydney had a median age of 36 years.

Gender profile

- In 2011, Wollondilly had an equal distribution of male and female populations with a male population of 21,609 and a female population of 21,650. Greater Sydney reported a larger female population (50.8 per cent) compared to male population (49.2 per cent).

Household structure and family composition

- There were a total of approximately 13,953 households in Wollondilly LGA. Of the total number of households, family households comprised 82.2 per cent, 16.1 per cent were lone person households and 1.7 per cent were group households. Greater Sydney reported less family households with 73.1 per cent, and more lone person households (22.6 per cent) and group households (4.3 per cent)
- Of the 11,877 families in Wollondilly LGA, 52.6 per cent were couple families with children, 32.9 per cent were couple families without children, and 13.6 per cent were one parent families. Greater Sydney recorded similar percentages with 48.9 per cent couple families with children, 33.5 per cent couple families without children and 15.7 per cent one parent families.

Education level

- Wollondilly LGA had a lower rate of high school completion (34.6 per cent) compared to Greater Sydney (54.5 per cent). The LGA also recorded a higher percentage of the

[16] The population projections provided by SGS do not always align with the project milestones, therefore a year close to the milestone has been selected, such as 2025 for 2024, and 2063 for 2065.

population without post-school qualifications with 45.5 per cent compared to 40.5 per cent for Greater Sydney.

Housing tenure

- In Wollondilly LGA, 92.8 per cent of private dwellings were occupied and 7.2 per cent were unoccupied. There were a total of 15,038 private dwellings. Greater Sydney had the same distribution of private dwellings
- Of occupied private dwellings in Wollondilly LGA, 94.5 per cent were separate houses, 3.0 per cent were semi-detached, row or terrace houses, or townhouses, 1.6 per cent were flats, units or apartments, and 0.8 per cent were other dwellings. Greater Sydney recorded a significantly lower percentage of separate houses (60.9 per cent) and a higher number of flats, units or apartments (25.8 per cent)
- Of occupied private dwellings in Wollondilly LGA, a high number of dwellings were privately owned with 80.4 per cent (49.6 per cent were owned with a mortgage, 30.8 per cent were owned outright) compared with 65.2 per cent in Greater Sydney. Greater Sydney recorded a higher percentage of rented properties at 31.6 per cent compared with 16.3 per cent for the LGA
- Lower percentage of state housing properties in Wollondilly LGA (5.8 per cent) compared to Greater Sydney (14.4 per cent)
- The number of dwellings in Wollondilly is forecast to grow from 15,609 in 2011 to 20,779 in 2031, with the average household size falling from 2.95 to 2.83 by 2031 (Forecast.id. 2012d).

Economic profile

Total employment

- Total employment in Wollondilly LGA and Greater Sydney was around 95 per cent.

Unemployment rate

- The rate of unemployment was lower in Wollondilly LGA (4.2 per cent) compared to Greater Sydney (5.7 per cent).

Total labour force

- Wollondilly LGA and Greater Sydney had similar percentages of total labour force with 77 per cent and 81 per cent respectively. The labour force of Wollondilly in 2011 comprised 33,271 persons.

Occupations

- The most common occupations in Wollondilly LGA included technicians and trades workers (18.3 per cent), clerical and administrative workers (15.4 per cent) and professionals (15.2 per cent). Professionals and clerical and administrative workers were the most common occupations in Greater Sydney.

Industries of employment

- The main industries of employment in Wollondilly LGA included manufacturing (12.5 per cent), construction (12.0 per cent), health care and social assistance (9.9 per cent) and retail trade (9.8 per cent). Health care and social assistance and retail trade were

Wollondilly LGA socio-demographic profile

the dominant employers in Greater Sydney.

Travel to work

- Average trip to work 44 minutes (Bureau of Transport Statistics 2012)
- In 2011, 58.4 per cent of Wollondilly's working residents travelled outside of the area to work (Profile.id. 2014o)
- 73.0 per cent of the workforce travelled to work by car as driver or passenger while only 4.2 per cent of the workforce travelled to work by public transport. A significantly higher percentage of the workforce of Greater Sydney travelled to work by public transport (20.0 per cent) with less travelling by car (58.4 per cent).

Average income

- Slightly higher average weekly household income ($1,478) in comparison to Greater Sydney ($1,447)
- Marginally lower average weekly individual income ($617) compared with Greater Sydney ($619).

Housing values

- Average sale price of $609,000 for all dwellings for the December quarter of 2014 (Housing NSW 2014). There was an increase of 20.8 per cent in median price annually (Housing NSW 2014).

SEIFA rating

- The SEIFA Index of Advantage and Disadvantage for Wollondilly was 1033 indicating that the LGA was just above average with similar levels of disadvantage compared to Greater Sydney (1025) (ABS 2013).

Key opportunities and challenges

Existing opportunities and challenges facing the Wollondilly LGA have been identified based on a review of planning and policy documents including:

- *Wollondilly Community Strategic Plan 2033*
- Consultation with Wollondilly City Council in June 2015 for Western Sydney Airport SIA.

Opportunities:

- The LGA is attractive due to 'rural living' and lifestyle, more affordable housing than other parts of Sydney, and more open space.
- High number of people with vocational and trade qualifications
- Significant growth expected in the LGA in the future e.g. Wilton Junction, Silverdale/Warragamba
- Aboriginal and European heritage is highly valued
- Agriculture and associated industries

Challenges:

- Resident workers experience significant travel times because Wollondilly is relatively isolated and lacks public transport connections. This limits 'spare time' and results in

Wollondilly LGA socio-demographic profile

significant economic, social, health and environmental costs

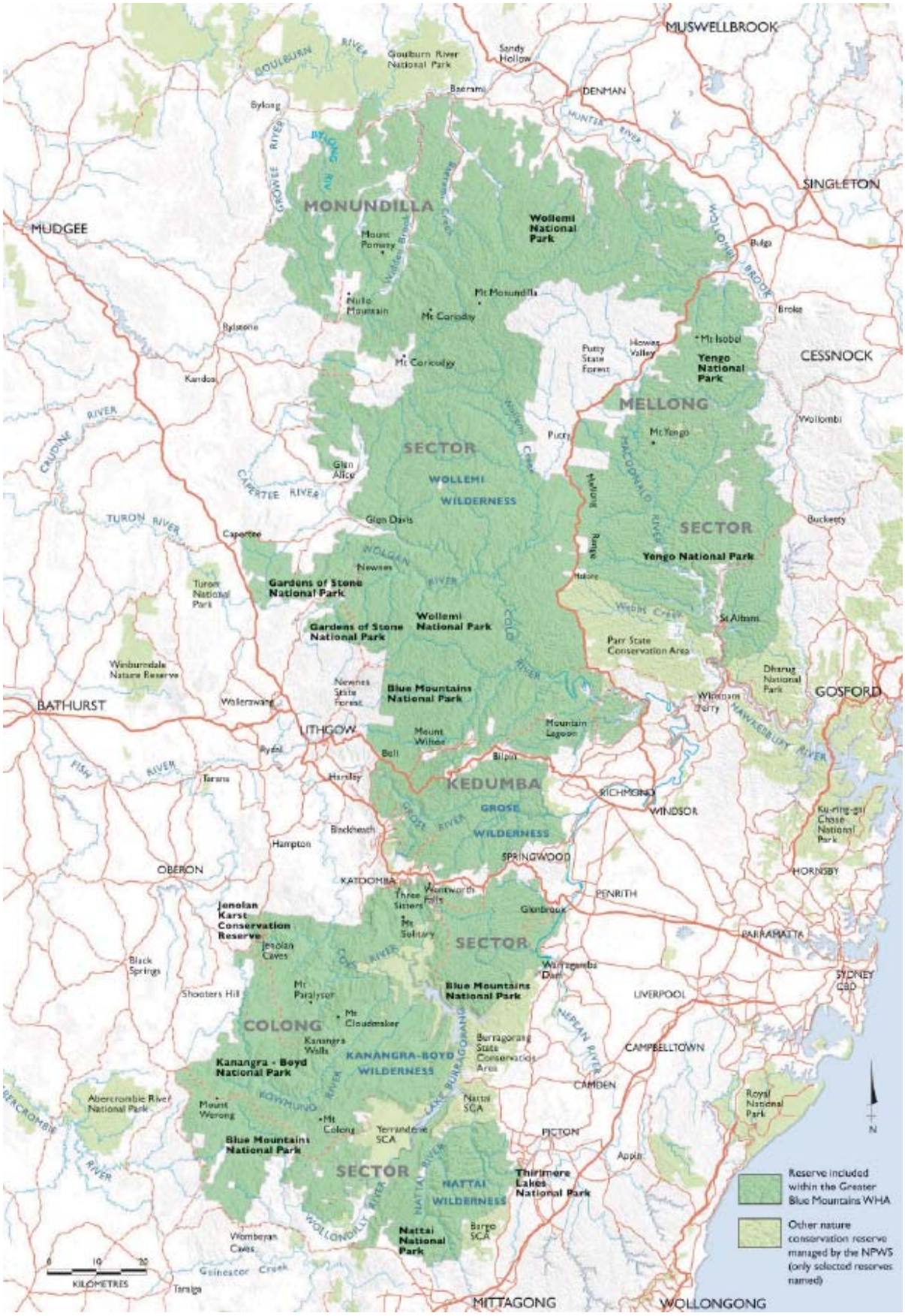
- Dispersed population and large LGA leading to difficulties in servicing the population, and a high level of expenditure outside of the LGA
- Limited education options, with children travelling to schools outside the LGA, often travelling long distances which has an impact on health and wellbeing for children
- Knowledge based jobs and educational assets lacking, and insufficient supply to meet demands of growing population
- Community services and facilities provision to a dispersed population.
- High rate of youth disengagement
- Lacking broadband infrastructure meaning limits to innovation and growth of home-based businesses
- High cost of maintaining assets such as roads and community facilities, relative to small population
- Lack of public transport provision.

Appendix F – Summary of regional open space and recreation areas

Blue Mountains National Park and World Heritage Area

The Greater Blue Mountains World Heritage Area (GBMWHA) covers over 10,000 km^2 extending 60 to 180 kilometres inland from central Sydney. Figure 9-1 below shows the location of the GBMWHA.

The GBMWHA was listed on the World Heritage register due to its outstanding natural values of the major stages of the Earth's ongoing biological processes and biological diversity. A wide range of plant and animals have survived from the Gondwana period, many of which are restricted to the GBMWHA. The GBMWHA also provides the principal habitat for many threatened species of plants and animals. The GBMWHA is an important recreational resource, providing the setting for a range of nature-based activities. Large numbers of local and overseas visitors visit the region, contributing significantly to the economy of local communities (Department of Environment and Climate Change, 2009).



(Source: Department of Environment and Climate Change, 2009)

Figure 9-1 Greater Blue Mountains World Heritage Area

The Blue Mountains National Park covers an area of 247,000 hectares of the GBMWHA. The value of the Blue Mountains National Park is due to both the natural and cultural features and its geographic setting. Outstanding natural features include dominating cliff lines, narrow canyons, forested ridges and gorges, along with a range of vegetation communities including rainforests, tall open forests and heathlands. There are also many sites of Aboriginal significance.

The upper Blue Mountains section of the park has an extensive system of scenic lookouts and walking tracks, and is one of the major nature-based tourism destinations in Australia. The National Park features 140km of walking trails, camping grounds, picnic and BBQ facilities throughout the area. It also caters for a range of recreational activities, including bushwalking, 4WD, horseriding, mountain biking, canyoning, caving, abseiling, rock climbing and canoeing (NSW National Parks and Wildlife Service, 2001).

Bents Basin State Conservation Area

Bents Basin is a deep waterhole that forms part of a gorge on the Nepean River, around eight kilometres south west from the proposed airport site. The Bents Basin State Conservation Area is located on the edges of the Liverpool and Wollondilly LGA's, and is surrounded by cleared agricultural and residential land and remnant native vegetation. The Conservation Area includes a campground, a number of picnic areas and a walking track and lookout, making the area popular for recreational activities including swimming, canoeing, fishing, bushwalking and camping. The Conservation Area also features the Bents Basin Education Centre which can be hired out for events (NSW National Parks and Wildlife Service, 2014).

Burragorang State Conservation Area

The Burragorang State Conservation Area covers over 17,500ha, located around 15 kilometres south west of the proposed airport site. The conservation area is primarily made up of water forming the Warragamba Dam catchment area, and surrounding thick bushland. One of the only publically accessible areas is the Burragorang lookout and picnic area. The traditional owners are the D'harawal and Gundangarra Aboriginal people, and the northern part is also home to the Darug people. A number of threatened species are found in the area (National Parks and Wildlife Service, 2014).

Gulguer Nature Reserve

Gulguer Nature Reserve is located near Greendale and adjacent to the Bents Basin State Conservation Area. It covers 359 hectares and parts of the Liverpool and Wollondilly Shire LGAs and is surrounded by cleared agricultural and residential land and remnant native vegetation. The reserve includes a four kilometre section of the Nepean River and protects diverse native vegetation. It has cultural value being located within the area of the Darug, Dharawal and Gundungurra language groups, and is believed to have been a traditional meeting and trading place between Aboriginal groups. It also has environmental value as a habitat for a range of threatened flora and fauna communities. While there are no facilities, there are tracks and trails through the reserve for visitors' use when accessing the area (NSW Office of Environment and Heritage, 2014b).

Mulgoa Nature Reserve

Mulgoa Nature Reserve is located in the Penrith LGA and is 213 hectares in size. The reserve was established to protect the remnant Cumberland Plain vegetation and shale cliffs in the area, and is home to a number of threatened animals. The reserve is within the traditional lands of the Darug people, and there are four known Aboriginal sites in the reserve (NSW National Parks and Wildlife Service, 2008).

Warragamba Dam

Located on the Nepean River in the Wollondilly LGA, Warragamba Dam is Sydney's major domestic water supply dam. The dam attracts a range of visitors to the recreation areas with picnic shelters, barbecues and viewing areas and a visitors centre (Sydney Catchment Authority, 2015).

Western Sydney Parklands

The Western Sydney Parklands is a regional open space and recreational area encompassing a 27km corridor from Quakers Hill in the north to Leppington in the south, running through the three LGA's of Blacktown, Fairfield and Liverpool. Located to the east of the proposed WSA site, the Parklands cover 5,280 hectares, making them the largest urban parkland system in Australia, and one of the largest in the world.

Picnic grounds and extensive walking and cycling areas are located throughout the Parklands. Large areas are leased for a variety of uses including agriculture, waste processing, motor sports and rural residential purposes. Part of the corridor is still to be acquired from private owners.

The *Western Sydney Parklands Plan of Management (*adopted in 2011 with a Supplement adopted in 2014) highlights the value of the Parklands as regional open space for the growing population of Western Sydney. The Parklands include a range of different open space areas and recreational facilities.

Major recreation facilities located within the Parklands include:

- Blacktown Olympic Park.
- Eastern Creek International Raceway.
- Western Sydney International Dragway.
- Sydney International Equestrian Centre.
- Sydney International Shooting Centre.

Significant nature reserves within the Parklands include:

- **Nurragingy Reserve** - The Nurragingy Reserve covers 90 hectares in the suburbs of Doonside and Rooty Hill in the Blacktown LGA. The reserve contains historically significant areas, including areas of Aboriginal significance. It also contains the largest and least disturbed area of bushland in Blacktown LGA along Eastern Creek, which forms an important north-south flora and fauna corridor (Blacktown City Council, 2013a).

  Facilities within Nurragingy Reserve include picnic areas, playgrounds, walking tracks, gardens, pavilions, toilets and the Colebee Centre function venue. The Reserve attracts over a million local, district and regional visitors each year as a recreational destination (Blacktown City Council, 2013b).

- **Prospect Reservoir and Nature Reserv**e - Prospect Reservoir and Nature Reserve covers 325 hectares on the northern shore of Prospect Reservoir, within the Blacktown LGA. Prospect Reservoir plays an important role as part of Sydney's water supply and is protected under the *Sydney Water Catchment Management Act 1998*. The nature reserve also attracts visitors with a viewing area, barbeques, playgrounds and amenities. The area has cultural value to the Darug people as well as environmental value, containing one of the largest remaining remnants of the critically endangered Cumberland Plain Woodland community (NSW Office of Environment and Heritage, 2012).

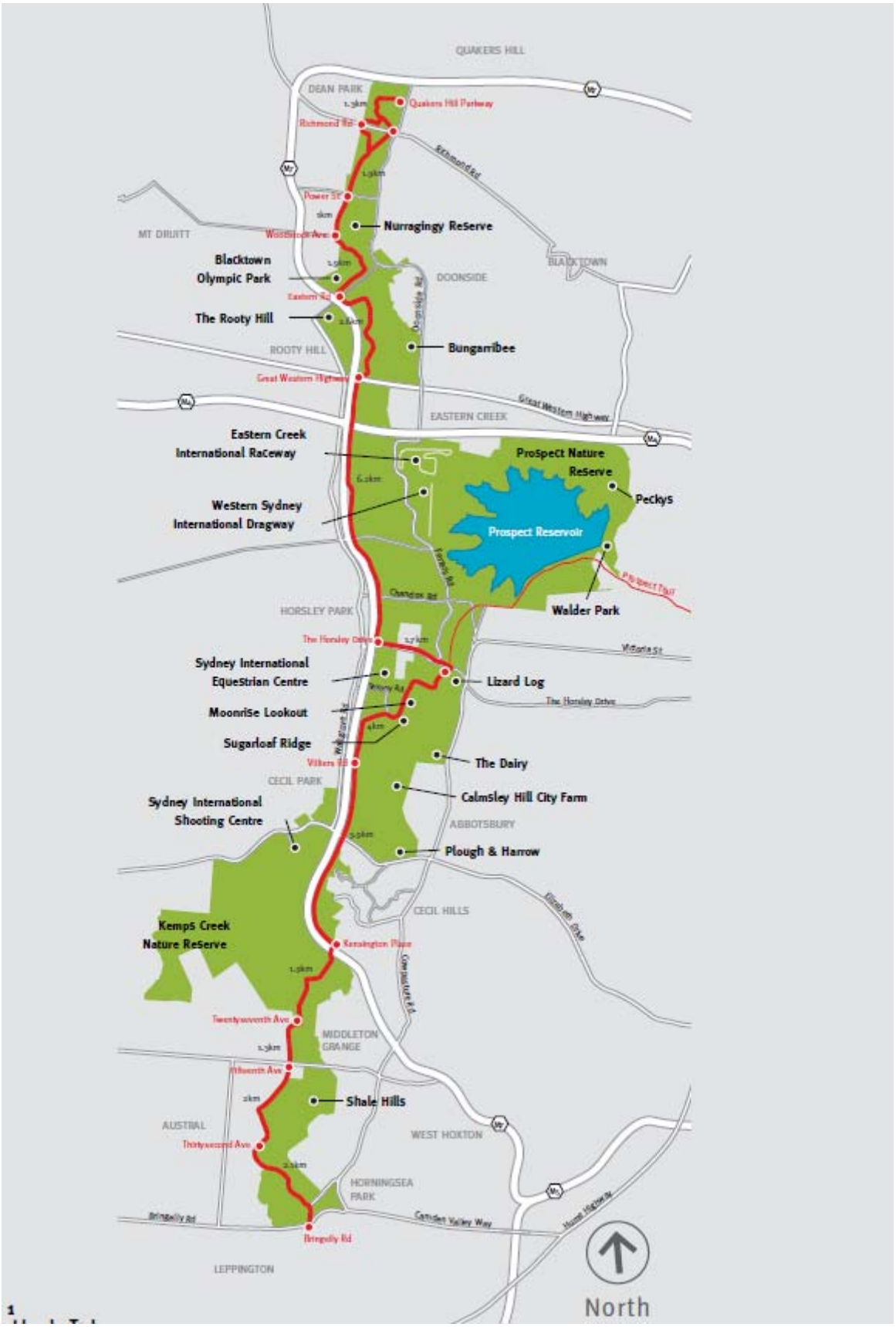
- **Kemps Creek Nature Reserve** - Kemps Creek Nature Reserve covers 197 hectares and is located approximately within the Liverpool LGA, to the south west of the Sydney International Shooting Centre within the Western Sydney Parklands. While the reserve does not have any facilities, it may be used for passive recreation by surrounding residents. The reserve contains a large area of Cumberland Plain (NSW Office of Environment and Heritage, 2014a).

The Parklands also include some agricultural lands near Horsley Park, with the Plan of Management identifying the potential to extend this and create over 500 hectares of urban farm lands. A masterplan has been prepared to:

- Deliver over 11 farming lots ranging in size from 5 to 31 ha.
- Provide for glasshouses, poly/greenhouses, market gardens, orchards and grove farming enterprises.
- Preserve and enhance over 34 ha of bushland.
- Create a tourism destination through a farm gate trail.

Other business and tourism related uses of the Parklands include proposed business hubs, event spaces for hire, and permits for filming and photography (Western Sydney Parklands Trust, 2015).

Figure 9-2 below shows the Western Sydney Parklands and the various areas and features.



(Source: Western Sydney Parklands Trust, 2011)

Figure 9-2 Western Sydney Parklands

Appendix G – Social profiles of representative local communities/villages

1. Badgerys Creek

Although the suburb of Badgerys Creek does not have any services or shops, there was a small centre which focused around Badgerys Creek Primary School and an oval. In 2014, the Badgerys Creek Primary School closed.

The Federal Government identified this site as the preferred location for a second Sydney Airport in 1986 and the site was acquired from property owners between 1986 and 1991. The Federal Government has maintained ownership of the site and leases properties to residents, some of which have been living in Badgerys Creek for over 30 years.

Generally, the houses are on large rural allotments and include some form of agricultural pursuit.

Badgerys Creek can be accessed from the north via Elizabeth Drive or from the south via The Northern Road, both of which are main thoroughfares within the locality. Kemps Creek or Luddenham are the closest service centres for the Badgerys Creek residents.

Community Infrastructure

- 1x Primary School
- 1x Oval

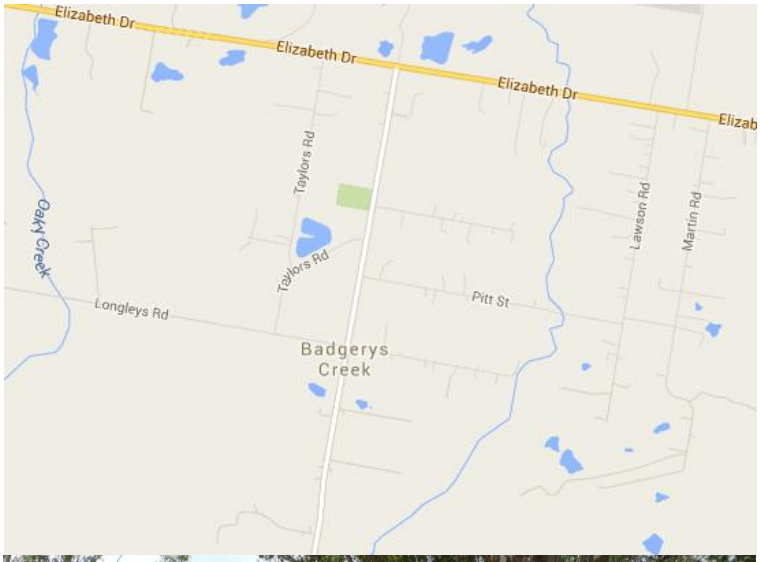




Figure – Badgerys Creek Public School



Figure – Badgerys Creek Oval

Badgerys Creek population snapshot

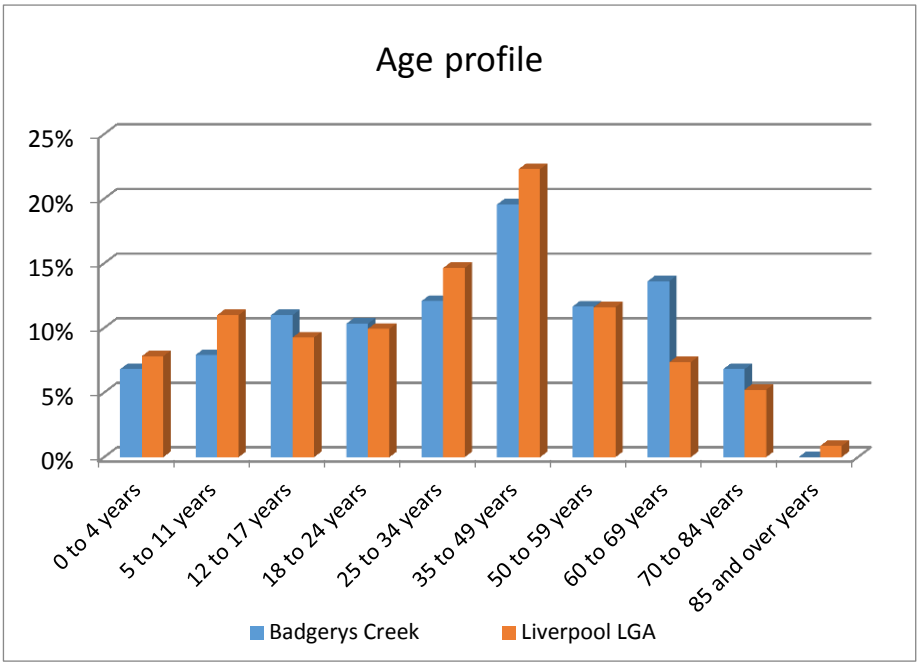
In 2011, the population of Badgerys Creek was 455 persons. Overall, the age profile of Badgerys Creek was similar Liverpool LGA however there was a significantly higher proportion of adults aged 60 to 69 years. The most prevalent household type was families comprised of couples with school aged children (between 5 to 17 years) although this was lower than the LGA.

In Badgerys Creek, 15% of residents were born in a non-English speaking country and 22% spoke another language other than English at home. Although cultural diversity was higher in the LGA, these figures still represent a culturally diverse community.

Badgerys Creek showed indications that there may be vulnerable and disadvantaged residents due to a higher proportion of single parent families, significant proportion of lone person households and lower income households compared to the LGA averages. In terms of SEIFA Index of Disadvantage scores, Badgerys Creek had the lowest score (914) indicating a higher proportion of relatively disadvantaged people, compared to other areas within the study area (between 914 to 1,080).

Workforce participation was lower than the LGA average although the unemployment rate was lower (6.1% compared to 7% in the LGA). This reflects the older demographic of the area, characterised by more people at retirement age than the LGA. The most common occupations of residents were managers, technicians and trades, and labourers.

Almost all households owned a motor vehicle, reflecting a high dependency on cars among residents.



	Badgerys Creek	Liverpool LGA
Median age	34	33
Born in a Non English speaking country	15%	36%
Speaks another language other than English at home	22%	50%
Family households	78%	82%
Couple family with children	49%	57%
Single parent families	22%	18%
Average household size	3.5	3.2
Lone person household	16%	16%
Median weekly household income	$1,172	$1,299
Workforce participation	49%	58%
Unemployed persons	6.1%	7%
Households without a motor vehicle	3%	10%

2. Bringelly

The centre of Bringelly is on the intersection of Greendale Road from the west, Bringelly Road from the east and The Northern Road from the north and south. Due to The Northern Road acting as a main connection between South West Sydney and North West Sydney there are traffic lights at this intersection.

A small convenience centre including a small supermarket, real estate, post office and pharmacy are located within Bringelly Village. The Bringelly Public School is also situated in the main centre, whilst the Bringelly Recreation Reserve and Bringelly Community Centre are situated in close proximity at the rear of the school site. These facilities appear to be well maintained and utilised for a variety of purposes.

The main residential area of Bringelly consists of large rural lots, some with agricultural pursuits, located out of the main town. To the north west of the centre a number of rural residential streets are clustered, which is where the Bringelly Child Care Centre is located.





Figure – Bringelly Recreation Reserve



Figure – Bringelly Recreation Reserve

Community Infrastructure

- 1x Primary School
- 1x Oval
- 1x Netball court
- 1x Community Centre
- 1x Open space reserve
- 1x Child care centre
- 1x Church



Figure – Bringelly Community Centre

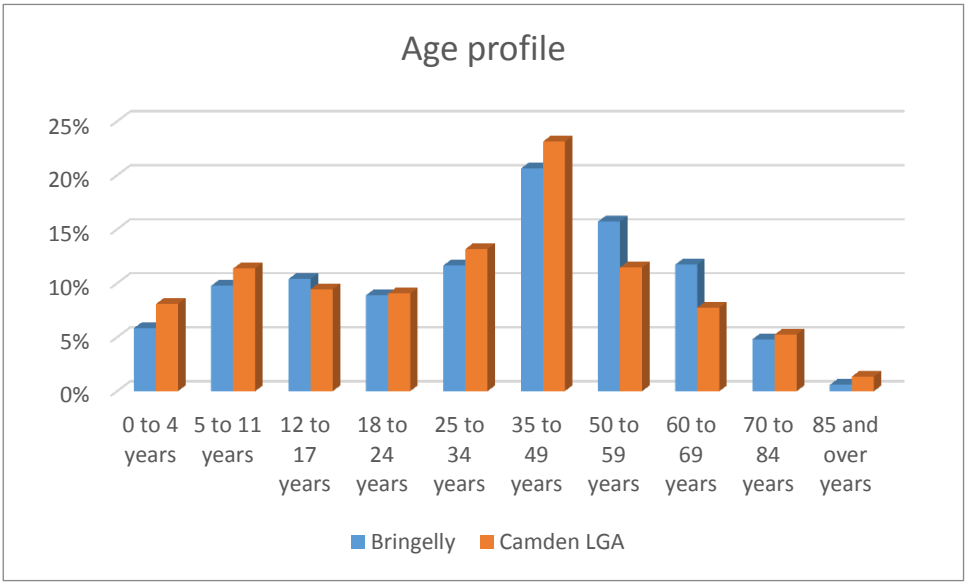
Bringelly population snapshot

In 2011, the population of Bringelly was 2,387 persons. Bringelly had a generally older age profile compared to Camden LGA, with a smaller proportion of adults aged 25 to 49 years and higher proportion of adults aged 50 to 69 years. Bringelly had a higher proportion of families than Camden LGA, with most of these being couples with school aged children (between 5 to 17 years). There were also a significant proportion of single parent families although this was lower than the LGA average.

The Bringelly community was culturally diverse, with 17% of residents born in a non-English speaking country and a quarter of residents speaking a language other than English at home.

Households in Bringelly earned a higher income ($1,540) than Camden LGA ($1,022). There was a smaller proportion of residents who participated in the workforce, reinforcing the older demographic of the area, characterised by more people close to or at retirement age than the LGA. The most common occupation of residents was technicians and trades, clerical and administrative, and machinery operators and drivers.

Motor vehicle ownership was consistent with Camden LGA. Almost all households owned a motor vehicle, reflecting a high dependency on cars among residents.



	Bringelly	Camden LGA
Median age	37	34
Born in a Non English speaking country	17%	9%
Speaks another language other than English at home	25%	10%
Family households	89%	84%
Couple family with children	56%	55%
Single parent families	12%	14%
Average household size	3.3	3
Median weekly household income	$1,540	$1,022
Lone person household	10%	14%
Workforce participation	61%	70%
Unemployed persons	3.7%	4%
Households without a motor vehicle	3%	3%

3. Cecil Hills

Prior to being developed as a residential suburb in 1992, Cecil Hills was a farming property. The original farm property has been retained for its heritage values at the Cecil Hills Farm. Liverpool City Council has co-located the Cecil Hills Community Centre and Cecil Hills Children's Centre at the farm site.

The Western Sydney Parklands is located to the north and west of the suburb, with the Elizabeth Drive exit from the M7 being the main point of access from the north and south. Cowpasture Road also acts as a local entry point from the north and south, whilst Elizabeth Drive connects Cecil Hills to the east and west.

The terrain is relatively undulating with views to the adjacent parkland and consists of traditional suburban housing mainly constructed out of brick. However, the south eastern pocket of the suburb is characterised by a number of new residential development areas.

A reserve for power lines crosses the suburb from the north to south with Pye Hill Reserve in the middle. The suburb is also characterised by a number of open space reserves and lakes, which are well serviced by footpaths.

In addition to the Council run Children's Centre, the Head Start Long Day Care Centre provides a child care service. The Cecil Hills Public School and Cecil Hills High School are both well attended.

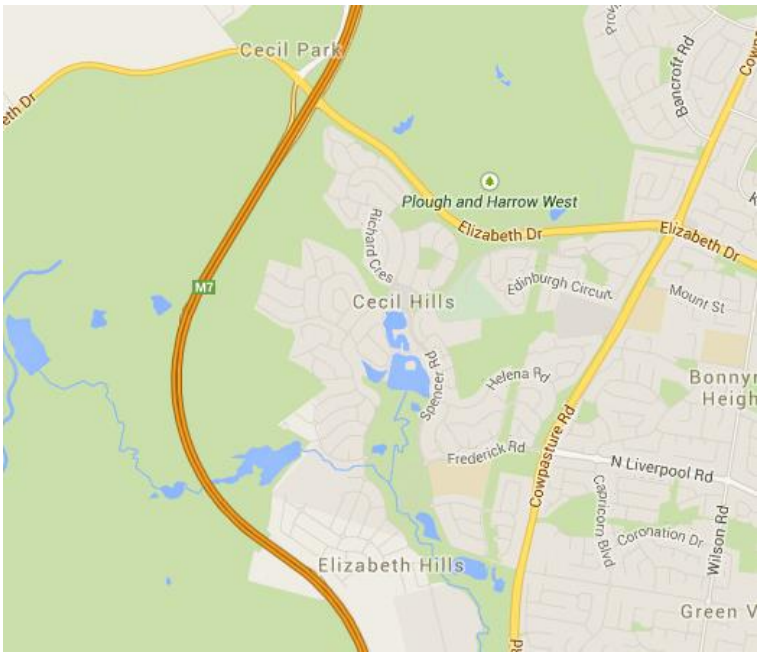




Figure – Cecil Hills Farm

Community Infrastructure

- 1x primary schools
- 1x high school
- 2x long day care centres
- 1x afterhours care
- 1x historical site
- 1x community centre
- 1x major parklands
- 2x parks/reserves



Figure – Cecil Hills Community Centre

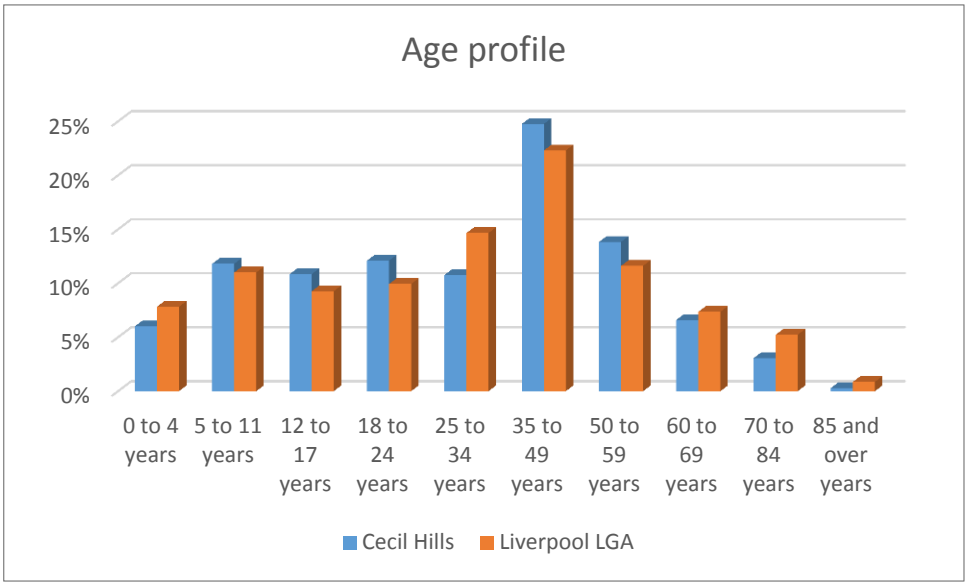
Cecil Hills population snapshot

In 2011, the population of Cecil Hills was 6,865 persons. The age profile of Cecil Hills was fairly consistent with Liverpool LGA, with a lower proportion of adults aged 25 to 34 years and older residents aged over 59 years. Cecil Hills had a high proportion of families (93% compared to 82% in Liverpool LGA), with most of these being couples with school aged children (between 5 to 17 years). Cecil Hills also had the highest average household size (3.7 persons) of the areas within the study area.

The Cecil Hills community was culturally diverse, with 39% born in a non-English speaking country (including Iraq, Vietnam and Philippines) and over half of residents speaking a language other than English at home (58%). This was higher than the LGA averages (36% and 50% respectively). The most common languages other than English were Arabic, Vietnamese and Italian.

Households in Cecil Hills generally earned a higher income ($1, 832) than Liverpool LGA ($1, 299). Participation in the workforce was higher, with a lower unemployment rate (5.8% compared to 7% in the LGA). The most common occupations of residents were clerical and administrative, professional, and technicians and trades roles.

Almost all households owned a motor vehicle, reflecting a high dependency on cars among residents.



	Cecil Hills	Liverpool LGA
Median age	33	33
Born in a Non English speaking country	39%	36%
Speaks another language other than English at home	58%	50%
Family households	93%	82%
Couple family with children	69%	57%
Single parent families	13%	18%
Average household size	3.7	3.2
Median weekly household income	$1,832	$1,299
Workforce participation	68%	58%
Unemployed persons	5.8%	7%
Households without a motor vehicle	1%	10%

4. Greendale

The district of Greendale was a thriving wheat-growing district for many years from about 1815 to 1861. At this time a wheat rust struck the crops, which caused the population to move elsewhere. By 1925 the post office, school and bakery had shut down.



Greendale now has no definable centre and is characterised by large rural lots with a number of agricultural activities occurring. There are two churches in the locality, the Free Church of Tonga appears to be on a private property whilst St Francis Xavier Church is on Greendale Road and includes a cemetery.

Greendale is accessed via Greendale Road through Wallacia village from the north and through Bringelly village from the south east.

The University of Sydney Camden Farms network is located in the south eastern corner of the suburb. These farms that are essential to supporting the present core teaching and research activities of the Faculties of Veterinary Science and Faculty of Agriculture and Environment and vital to securing new initiatives arising from government and Industry priorities in education, bioscience and food chain research occasioned by climate change, peak oil, urbanization, food and water security[1].



Figure – St Francis Xavier Church

Bents Basin State Conservation area is also located in Greendale, which includes a camp ground, picnic area and education centre. A deep waterhole called Bents Basin forms part of a gorge on the Nepean River and is a great location for recreational activities[2].



Figure – Bents Basin State Conservation area (Sourced: NSW National Parks website)

Community Infrastructure

- 2x religious facilities
- 1x regional recreation facility
- 1x university facility

[1] The University of Sydney Camden Farms Network, Accessed 11 March 2015 - http://sydney.edu.au/agriculture/plant_breeding_institute/locations/camden_farms.shtml last updated 17 June 2013

[2] National Parks, Bents Basin State Conservation Area, accessed 11 March 2015, http://www.nationalparks.nsw.gov.au/bents-basin-state-conservation-area

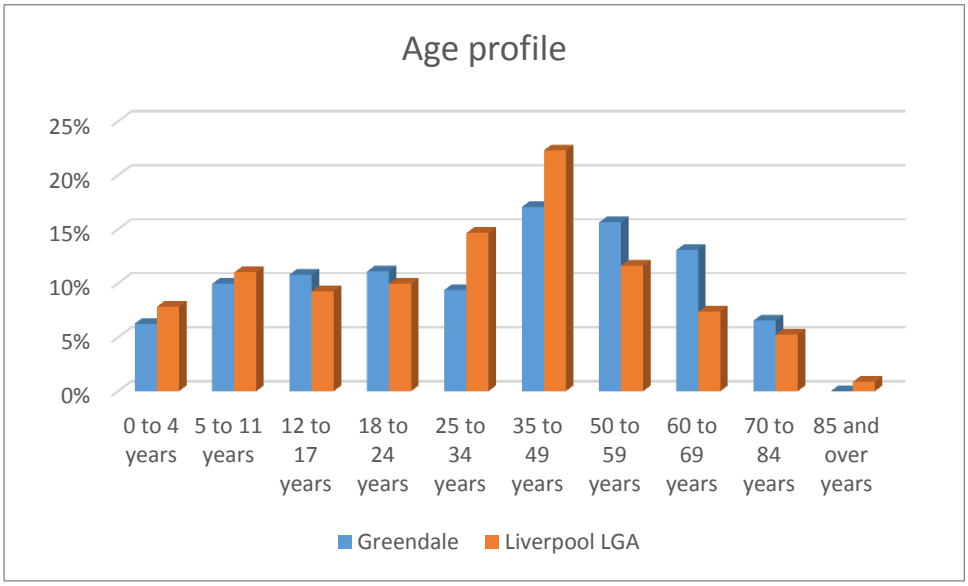
Greendale population snapshot

In 2011, the population of Greendale was 352 persons. Greendale had a generally older age profile compared to Liverpool LGA, with a smaller proportion of adults aged 25 to 49 years and higher proportion of adults aged 50 to 84 years. Although the most prevalent household type was families, there were a smaller proportion of couples with children, compared to Liverpool LGA. There were a significant proportion of single parent families.

In Greendale, 14% of residents were born in a non-English speaking country and one in five residents spoke a language other than English at home. These figures represent a fairly culturally diverse community in Greendale.

Households in Greendale earned a slightly lower income ($1,275) than Liverpool LGA ($1,299). This is despite workforce participation being higher and a lower unemployment rate (3.6% compared to 7% in the LGA). The most common occupations of residents were clerical and administrative, technicians and trades, and professional jobs.

Almost all households owned a motor vehicle, reflecting a high dependency on cars among residents.



	Greendale	Liverpool LGA
Median age	37	33
Born in a Non English speaking country	14%	36%
Speaks another language other than English at home	20%	50%
Family households	84%	82%
Couple family with children	52%	57%
Single parent families	18%	18%
Average household size	3.3	3.2
Lone person household	12%	16%
Median weekly household income	$1,275	$1,299
Workforce participation	61%	58%
Unemployed persons	3.6%	7%
Households without a motor vehicle	4%	10%

5. Horsley Park

Horsley Park's village centre is located around the intersection of Horsley Drive and Horsley Road, west of Wallgrove Road and the M7 entrance. It includes two supermarkets, retail shops, a community hall, Horsley Park Reserve and rural fire brigade.

Other community facilities to the east of the village centre along Horsley Drive include two primary schools, a church and a large conference centre. Horsley Kids is a private child care centre in the residential area along Horsley Road. Horsley Park's services and facilities are likely to serve neighbouring Mount Vernon residents, which currently has no defined centre.

The suburb's residential development is concentrated on the western side of the M7, characterised by large lots and some agricultural uses. Development on the eastern side is constrained by the Western Sydney Parklands, Sydney International Equestrian Centre, Sharks Golf Driving Range and some large commercial and industrial uses located here. The Western Sydney Parklands and major sporting facilities attract high numbers of visitors from surrounding areas.

Community Infrastructure

- 2x primary schools
- 2x sport and recreation facilities
- 1x long day care centre
- 1x church
- 1x conference centre
- 1x community hall
- 1x major parklands
- 1x park/reserve

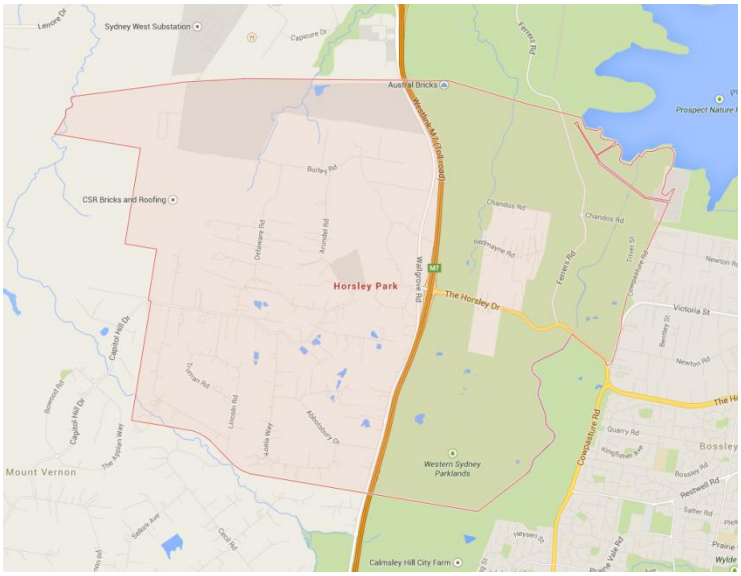




Figure – Horsley Park Community Hall



Figure – Horsley Park village centre

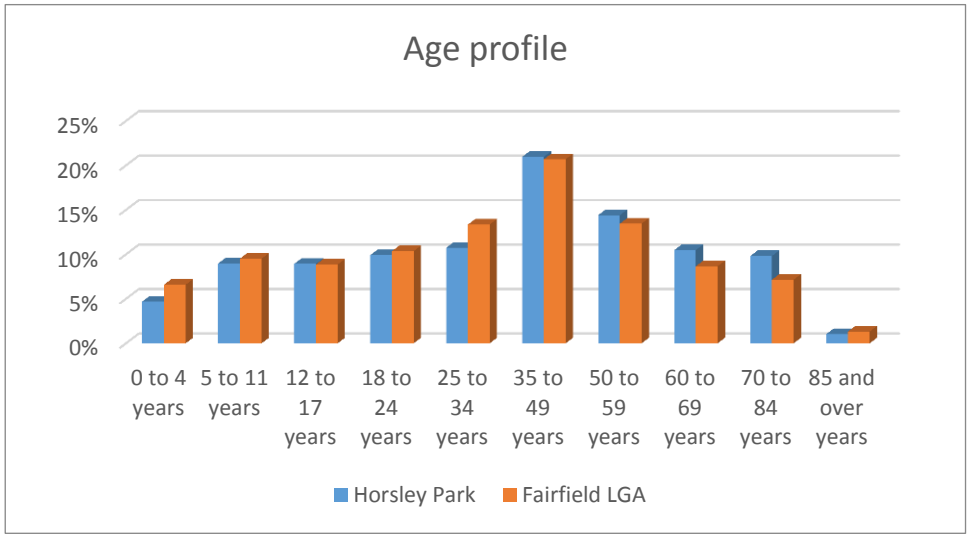
Horsley Park population snapshot

In 2011, 1,936 persons lived in Horsley Park. The population's age distribution was broadly consistent with Fairfield LGA although there was a slightly higher proportion of 50 to 84 year olds. A high proportion of families lived in Horsley Park (84% compared to 82% in Fairfield LGA). Most families were couples with children (57% compared to 52% in Fairfield LGA). Although lower than the LGA averages, lone person households and single parent families were still significant in Horsley Park (both 14%).

The community was culturally diverse, with a quarter of residents born in non-English speaking countries (including Italy and Malta) and 37% speaking a language other than English at home. The most spoken languages other than English were Italian, Maltese and Assyrian.

The median weekly household income in Horsley Park ($1,361) was higher than Fairfield LGA ($1,022). Labour force participation was also higher (56% compared to 51% in Fairfield LGA), while the unemployment rate was lower (3.4% compared to 9.7% in the LGA). The most common occupations among residents were clerical and administrative, technicians and trades, and managers.

Almost all households owned a motor vehicle, reflecting a high dependency on cars among residents.



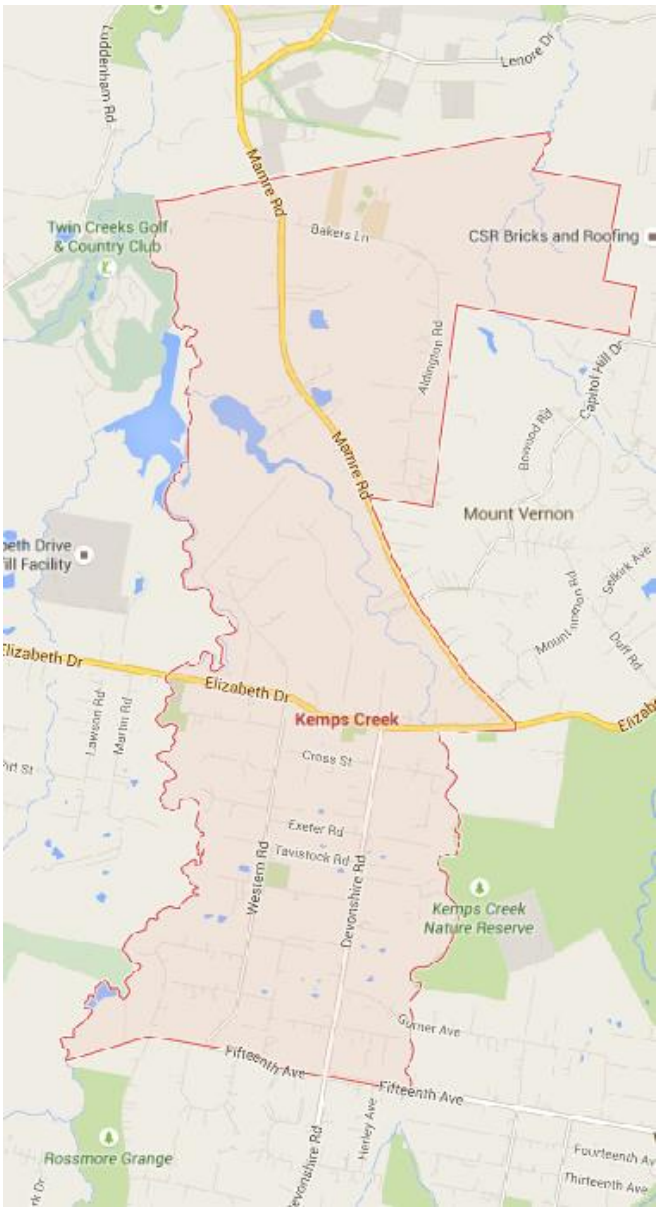
	Horsley Park	Fairfield LGA
Median age	39	36
Born in a Non English speaking country	25%	50%
Speaks another language other than English at home	37%	70%
Family households	84%	82%
Couple family with children	57%	52%
Single parent families	14%	23%
Average household size	3.3	3.2
Lone person household	14%	16%
Median weekly household income	$1,361	$1,022
Workforce participation	56%	51%
Unemployed persons	3.4%	9.7%
Households without a motor vehicle	6%	13%

6. Kemps Creek

The Kemps Creek town centre is spread along Elizabeth Drive with small shops and service stations. Access to Kemps Creek is via Elizabeth Drive from the east and from the M7 to the west and Mamre Road from the north.

Two primary schools, sport and bowling club, and two reserves (one with sporting facilities and amenities) are close to the centre. Three private schools and the Emmaus Residential Aged Care facility are located to the north near St Clair. Although not a large centre, Badgerys Creek residents are likely to access services and facilities in Kemps Creek, being the closest centre other than Luddenham. There is also an Animal Welfare League facility in Kemps Creek.

The main residential area to the south of Elizabeth Drive features houses on large rural lots and some agricultural uses. Some facilities within the residential area include The Grove Academy (long day care centre) and Sydney Catholic Garden Cemetery. Kemps Creek Nature Reserve to the east of the residential area gives residents direct access to the Western Sydney Parklands.



Community Infrastructure

- 3x parks/reserves
- 2x primary schools
- 1x high school
- 2x combined school
- 1x aged care facility
- 2x child care centres
- 1x church
- 1x cemetery and crematorium
- 1x sport and bowling club

Kemps Creek population snapshot

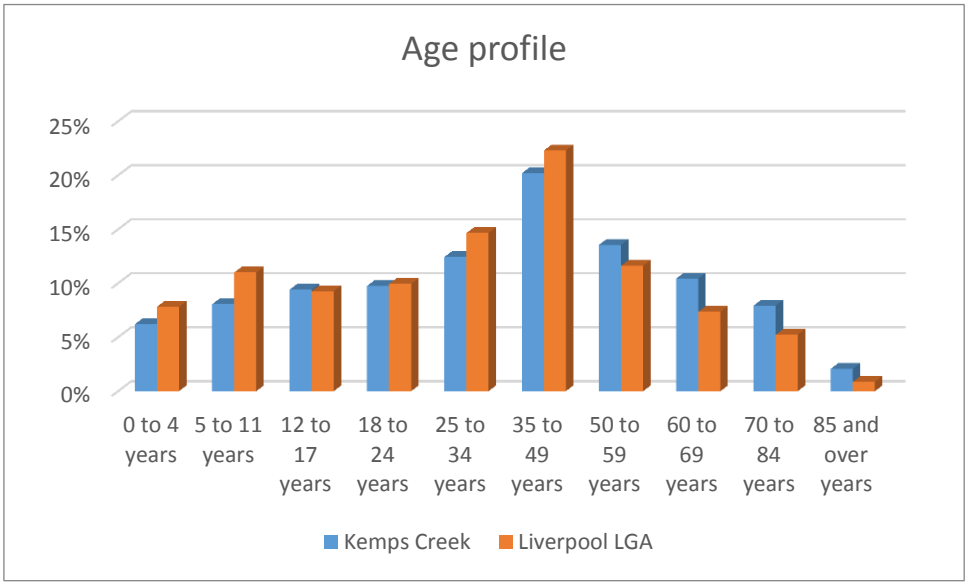
In 2011, 2,309 persons lived in Kemps Creek. Compared to Liverpool LGA, Kemps Creek had a higher proportion of older residents aged over 49 years and smaller proportion of children aged under 12 years.

A high proportion of families lived in Kemps Creek (85% compared to 82% in Liverpool LGA). Most families were couples with children (57%), which was consistent with Liverpool LGA). Although lower than the LGA average, lone person households were significant in Kemps Creek (13%).

The community was culturally diverse, with a quarter of residents born in non-English speaking countries (including Italy, China and Malta) and 41% speaking a language other than English at home. The most spoken languages other than English were Italian, Arabic and Chinese languages.

The median weekly household income ($1,148) was lower than Liverpool LGA ($1,299). Labour force participation was consistent with the LGA, while the unemployment rate was lower (3.7% compared to 7% in the LGA). The most common occupations among residents were managers, technicians and trades, and clerical and administrative jobs.

Almost all households owned a motor vehicle, representing a high car dependency among residents.



	Kemps Creek	Liverpool LGA
Median age	**38**	**33**
Born in a Non English speaking country	**25%**	**36%**
Speaks another language other than English at home	**41%**	**50%**
Family households	**85%**	**82%**
Couple family with children	**55%**	**57%**
Average household size	**3.4**	**3.2**
Lone person household	**13%**	**16%**
Median weekly household income	**$1,148**	**$1,299**
Workforce participation	**58%**	**58%**
Unemployed persons	**3.7%**	**7%**
Households without a motor vehicle	**4%**	**10%**

7. Luddenham

The village of Luddenham is located on The Northern Road, a major road which connects South West Sydney with North West Sydney. The town centre features a service station, large IGA supermarket to the south and the Luddenham showground to the north. Luddenham is characterised by traditional suburban housing, with a mix of older and more recent residential development, particularly to the east of the Northern Road and bordering the WSA site.

A small shopping village services the town, along with Luddenham Primary School, Holy Family Catholic Primary with before and after school care, a child care centre, two churches and three parks. The largest of these is Sales Park which features a sports field, cricket pitch and nets and amenities, with a community hall and playground co-located on neighbouring sites. Other parks include Willmington Reserve, located across from the public school with a basketball/netball court and bike track, and Freeburn Park with a playground. The Luddenham Showground at the northern end of town includes associated facilities for the annual show.

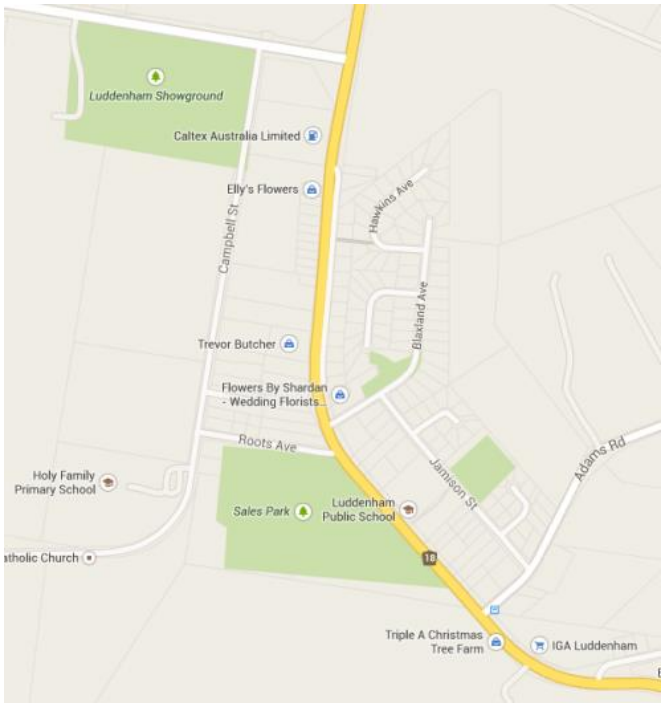




Figure – Freeburn Park



Figure – Luddenham shopping village

Community Infrastructure

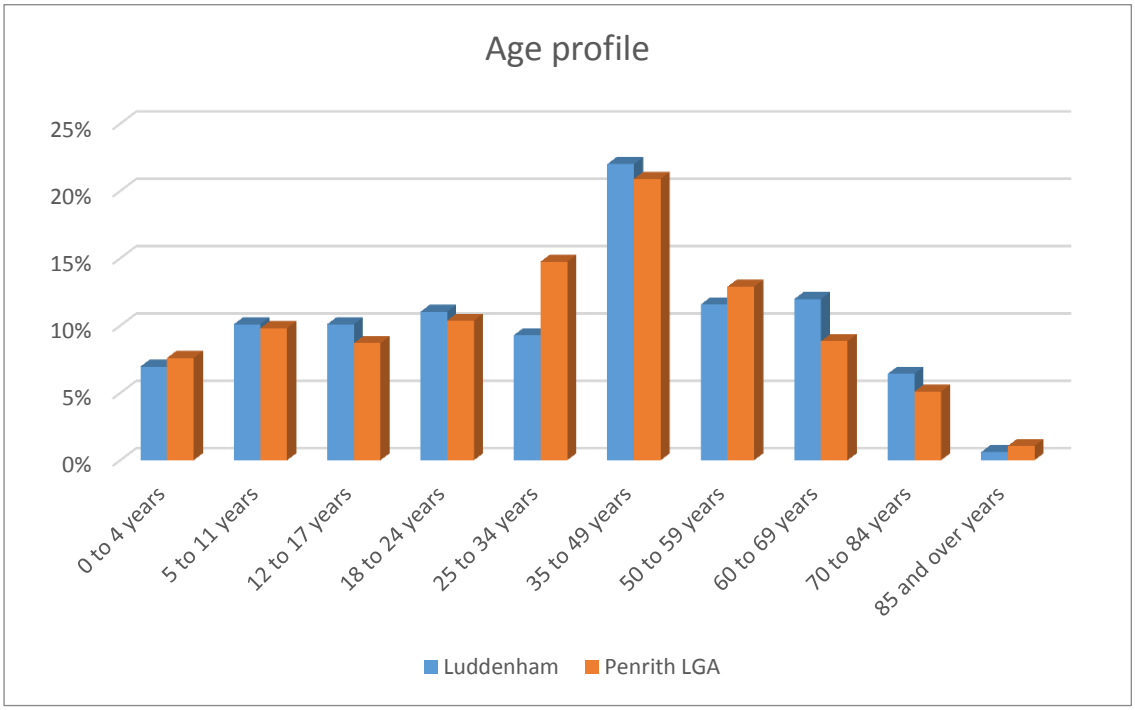
- 1x Recreational oval and amenities
- 1x Before and after school care
- 1x Community hall
- 1x Showground
- 1x Childcare centre
- 2x Churches
- 2x Reserves/parks
- 2x Primary schools

Luddenham population snapshot

In 2011, the population of Luddenham was 1,496 persons. The age profile of Luddenham was fairly consistent with Penrith LGA although there was a smaller proportion of adults aged 25 to 34 years and higher proportion of older adults aged 60 to 69 years. Luddenham had a higher proportion of families, including couples with school aged children (between 5 to 17 years), compared to the LGA. Few residents in Luddenham were from non-English speaking backgrounds.

Households in Luddenham generally earned a higher income ($1,562) than Penrith LGA ($1,398). Participation in the workforce was slightly higher, with a lower unemployment rate (4.3% compared to 5.5% in the LGA). The most common occupations of residents were managers, clerical and administrative, and technicians and trades roles.

Almost all households owned a motor vehicle, reflecting a high dependency on cars among residents.



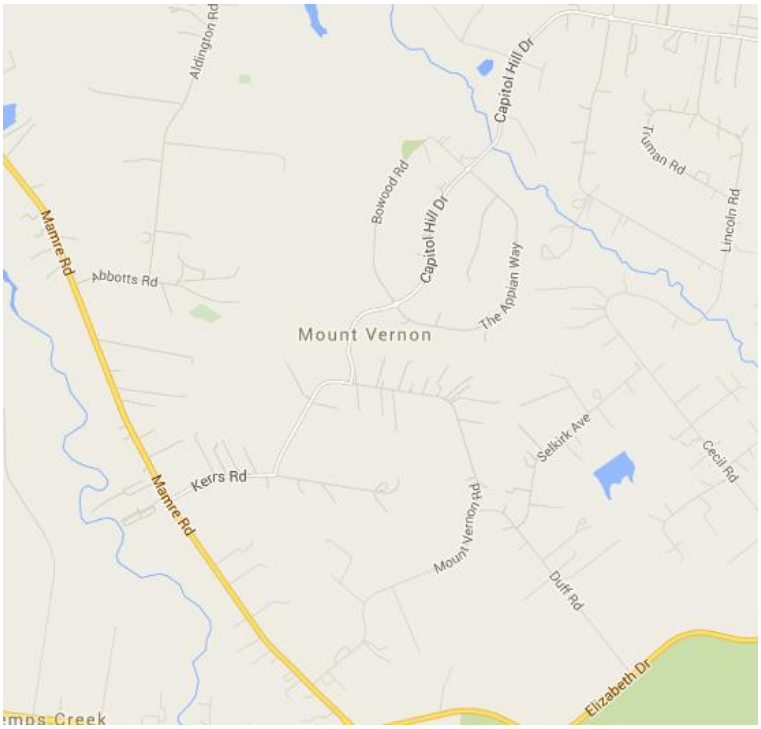
	Luddenham	Penrith LGA
Median age	36	34
Family households	84%	78%
Couple family with children	53%	50%
Average household size	3.2	2.9
Lone person household	14%	19%
Median weekly household income	$1,562	$1,398
Workforce participation	67%	66%
Unemployed persons	4.3%	5.5%
Households without a motor vehicle	2%	8%

8. Mount Vernon

There is no defined centre or shopping village within the suburb of Mount Vernon, with the closest centre being Horsley Park. Mount Vernon is characterised by large lot residential properties. Overall, residential properties appear to be well maintained, featuring large and relatively new houses.

The Do-re-mi Day Care Centre is located in Mount Vernon which is privately run.

Mount Vernon is accessed from the north via Horsley Road, Kerrs Road or Mount Vernon Road from the west and Wallgrove Road from the east, which runs parallel to the M7.



Community Infrastructure

- 1x Long day care centre

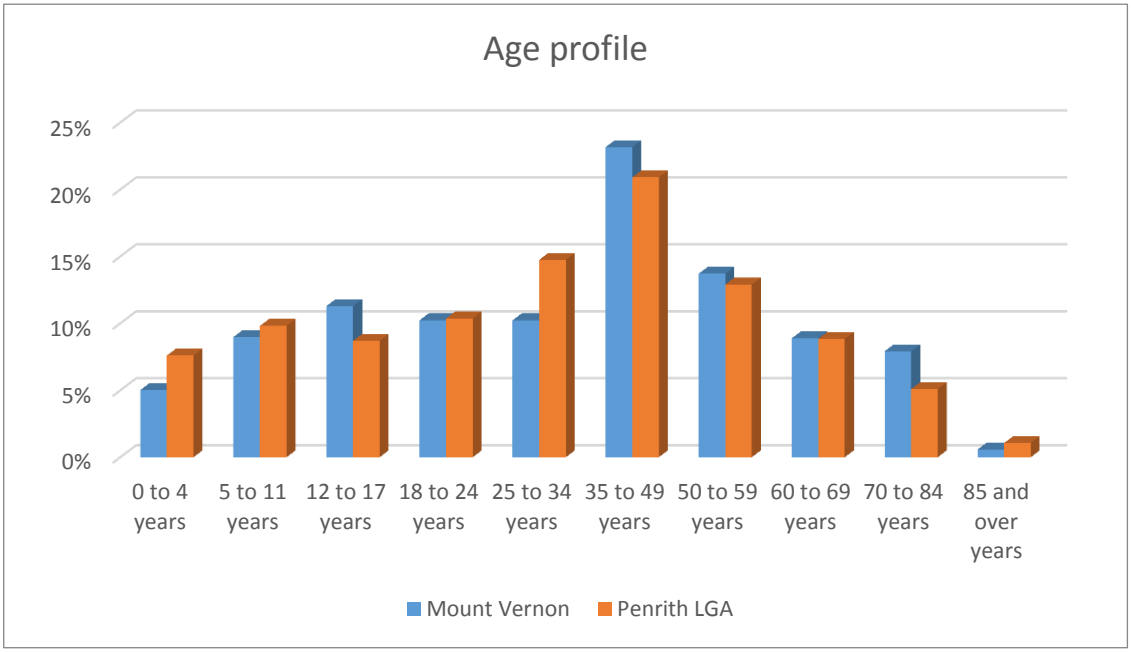
Mount Vernon population snapshot

In 2011, the population of Mount Vernon was 1,036 persons. Mount Vernon had a high proportion of families (92% compared to 78% in Penrith LGA), with most of these being couples with school aged children (between 5 to 17 years). Compared to Penrith LGA, there was a higher proportion of high school aged children (between 12 to 17 years) and older adults aged 70 to 84 years.

The Mount Vernon community is culturally diverse, with almost of quarter of residents born in a non-English speaking country (including Italy, Malta and Croatia) and a third of residents speaking another language other than English at home. The most spoken languages other than English were Italian, Assyrian and Croatian.

Households in Mount Vernon generally earned a higher income ($1,773) than Penrith LGA ($1,398). Participation in the workforce was slightly higher, with a lower unemployment rate (3.2% compared to 5.5% in the LGA). The most common occupations of residents were technicians and trades, clerical and administrative, and managers.

Almost all households owned a motor vehicle, reflecting a high dependency on cars among residents.



	Mount Vernon	Penrith LGA
Median age	39	34
Born in a Non English speaking country	23%	13%
Speaks another language other than English at home	33%	15%
Family households	92%	78%
Couple family with children	68%	50%
Average household size	3.5	2.9
Median weekly household income	$1,773	$1,398
Workforce participation	67%	66%
Unemployed persons	3.2%	5.5%
Households without a motor vehicle	1%	8%

9. Mulgoa

Mulgoa features a small village shopping centre on the corner of Mulgoa Road and Allan Road. It includes a medical practice, chemist, post office and a supermarket.

The centre is surrounded by areas of low density residential properties mainly to the east of Mulgoa Road. The local public school and Mulgoa Park are located to the north within walking distance to the centre and homes. Mulgoa Hall and tennis courts are located within Mulgoa Park and these facilities appear to be well maintained.

Community facilities outside the village centre include the Mulgoa Preschool and Gow Park, which has two sporting fields, cricket pitch and amenities.

Access to the Mulgoa village is via Mulgoa Road from the north and south and via Littlefields Road from the east.





Figure – Mulgoa Community Hall



Figure – Mulgoa shops

Community Infrastructure

- 1x primary school
- 1x child care centre
- 3x parks/reserves
- 3x churches
- 1x community hall
- 1x conference centre

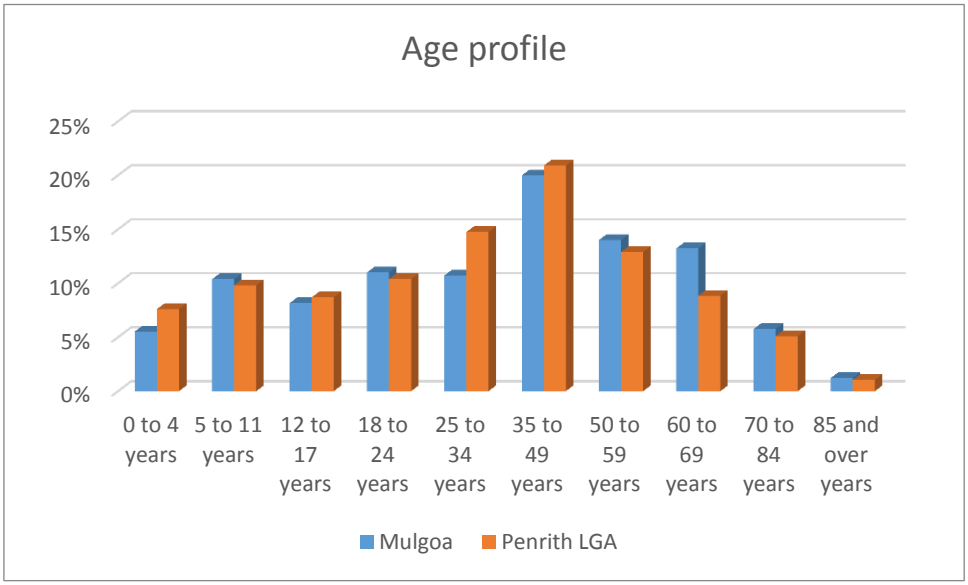
Mulgoa population snapshot

In 2011, 1,792 persons lived in Mulgoa. The age profile of Mulgoa was generally older than Penrith LGA, with a smaller proportion of 25 to 49 year olds and higher proportion of 50 to 84 year olds. Mostly families lived in Mulgoa. Around half of families were couples with children (49%). 15% were lone person households. Few residents were from non-English speaking backgrounds.

The weekly median household income in Mulgoa ($1,783) was higher than Penrith LGA ($1,299). Labour force participation was also higher, while the unemployment rate was lower (4.6% compared to 5.5% in the LGA).

The most common occupations among residents were clerical and administrative, technicians and trades, and professionals.

Almost all households owned a motor vehicle.



	Mulgoa	Penrith LGA
Median age	37	34
Family households	84%	78%
Couple family with children	49%	50%
Couple families without children	38%	30%
Average household size	3.1	2.9
Lone person household	15%	19%
Median weekly household income	$1,783	$1,398
Workforce participation	68%	66%
Unemployed persons	4.6%	5.5%
Households without a motor vehicle	1%	8%

10. Rossmore

Rossmore is a large, rural residential suburb. Bringelly Road is the suburb's main east-west access road and location of the small town centre comprised of a service station and some small shops opposite the public school. Bellfield College, two private childcare centres and two equestrian facilities are located away from the main road. A Buddhist Temple and Cambodian Temple are situated in the northern part of the suburb.

The suburb is next to Bringelly, which has a larger town centre with a small supermarket, post office, pharmacy, Bringelly Public School, Bringelly Recreation Reserve and Bringelly Community Centre. Rossmore residents are likely to access these services and facilities.



Community Infrastructure

- 3x child care centres
- 2x churches
- 2x religious temples
- 2x parks/reserves
- 1x primary school
- 1x combined school



Figure – Rossmore Public School

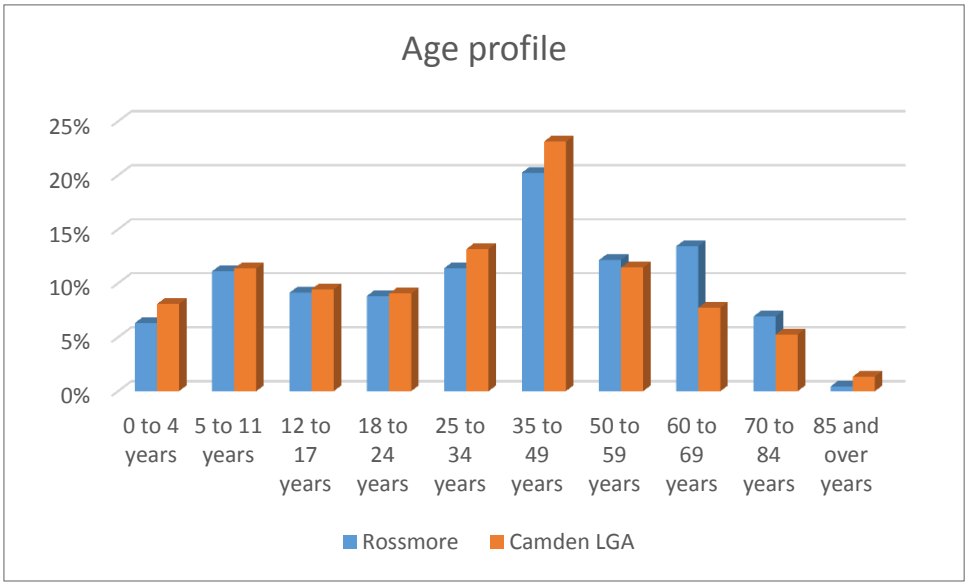
Rossmore population snapshot

In 2011, 2,412 persons lived in Rossmore. The age profile of Rossmore was generally older than Camden LGA, with around a third of residents in the 50 to 84 year age group (compared to around a quarter of residents in Camden LGA). Mostly families lived in Rossmore, with couples with children most prevalent (55% consistent with the LGA). 14% were single parent families, consistent with the LGA average.

Rossmore's community was culturally diverse, with 23% of residents born in a non-English speaking country (including Italy, China and Lebanon) and 35% speaking another language other than English at home. The most common languages spoken other than English were Arabic, Italian and Chinese languages.

The median weekly household income in Rossmore ($1,284) was lower than Camden LGA ($1,727). A smaller percentage of residents participated in the workforce (58% compared to 70% in the LGA). The unemployment rate in Rossmore was higher (5.9%) than Camden LGA (4%). The most common occupations among residents were managers, technicians and trades, and clerical and administrative jobs.

Motor vehicle ownership in Rossmore was consistent to Camden LGA.



	Rossmore	Camden LGA
Median age	37	34
Born in a Non English speaking country	23%	9%
Speaks another language other than English at home	35%	10%
Family households	87%	84%
Couple family with children	55%	55%
Single parent families	14%	14%
Average household size	3.3	3
Median weekly household income	$1,284	$1,727
Workforce participation	58%	70%
Unemployed persons	5.9%	4%
Households without a motor vehicle	3%	3%

11. Silverdale

Silverdale is a low density residential suburb located to the south of Warragamba. While it has no defined town centre, Silverdale residents are close to Warragamba town centre. The Warragamba town centre features a Town Hall, community hall, child care centre and shops.

Silverdale is also close to Warragamba's public swimming pool, sports fields, playgrounds, skate park and tennis/basketball courts. Warragamba Public School is the closest primary school to Silverdale residents.

Silverdale has a child care centre within the main residential area of the suburb, which is a privately run preschool.

The Silverdale Rifle Range is located to the south of the main residential area, near the Bents Basin State Conservation Area.

Silverdale is accessed via Silverdale Road from the north and south and via Warradale Road from Warrangamba to the north.

Community Infrastructure

- 1x park
- 1x church
- 1x child care centre
- 1x sport (rifle) facility





Figure – Silverdale child care



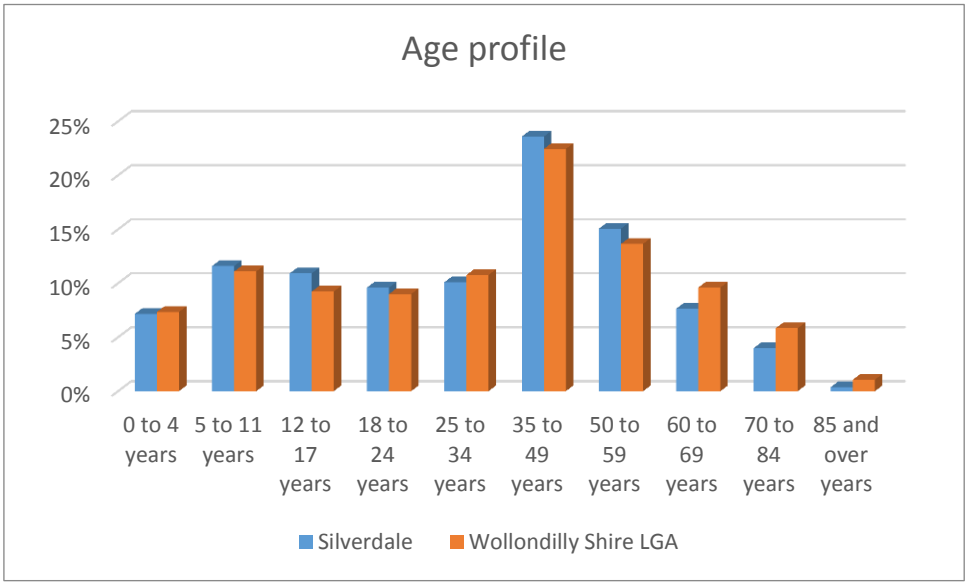
Figure – Silverdale residential area

Silverdale population snapshot

In 2011, 3,439 persons lived in Silverdale. The age distribution in Silverdale was broadly similar to Wollondilly Shire LGA, although there was a smaller proportion of people aged over 59 years. A higher proportion of families lived in Silverdale (91% compared to 82% in the LGA), as well as couples with children (63% compared to 53% in the LGA). Very few residents in Silverdale were from non-English speaking backgrounds.

The median weekly household income in Silverdale ($1,806) was higher than Wollondilly Shire ($1,478). In Silverdale, labour force participation was higher and the unemployment rate was slightly lower 2.8% compared to 4.2% in Wollondilly Shire). The most common occupations among residents were technicians and trades, clerical and administrative and managers.

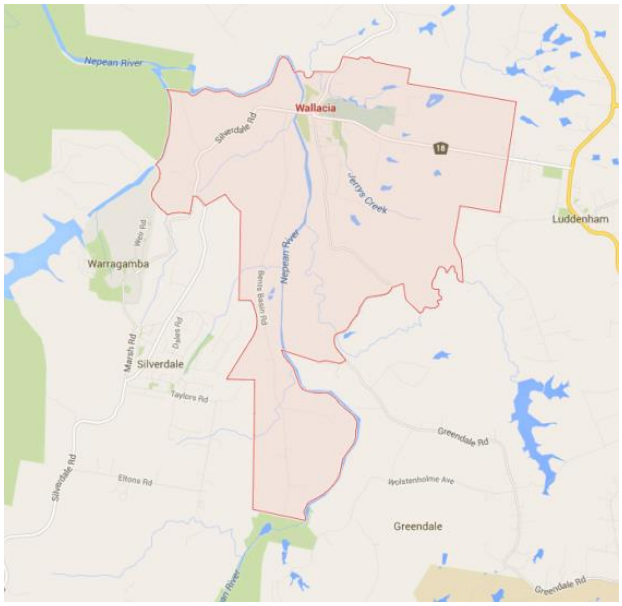
Almost all households in Silverdale owned a motor vehicle.



	Silverdale	Wollondilly Shire LGA
Median age	35	36
Family households	91%	82%
Couple family with children	63%	53%
Average household size	3.3	3
Median weekly household income	$1,806	$1,478
Workforce participation	74%	67%
Unemployed persons	2.8%	4.2%
Households without a motor vehicle	1%	3%

12. Wallacia

The suburb of Wallacia is located beside the Nepean River to the east. It has a large residential precinct with low density residential properties. Access to Wallacia is via Park Road to the east, Greendale Road to the south, Silverdale road to the west and Mulgoa Road to the north.



Wallacia's small village centre is focused around the intersection of Mulgoa Road and Park Road and includes the iconic Wallacia Hotel, small shops and Wallacia Public School. Wallacia Golf Club is adjacent to the centre in the east, while Blaxland Crossing Reserve and Fowler Reserve to the west are the closest open spaces. Wallacia was previously a popular tourist destination for camping and recreation. While campgrounds are still available at these reserves, their facilities appear dated.

Overall, the suburb has limited community facilities with residents likely to travel to the larger town centre of Warragamba, which features a Town Hall, community hall, child care centre and shops. Further, the Wallacia Progress Hall is at risk of closing down due to lack of funding.

Community Infrastructure

- 3x parks/reserves
- 1x sport (golf) facility
- 1x community hall
- 1x bowling green
- 1x primary school
- 1x health retreat



Figure – Wallacia village shops



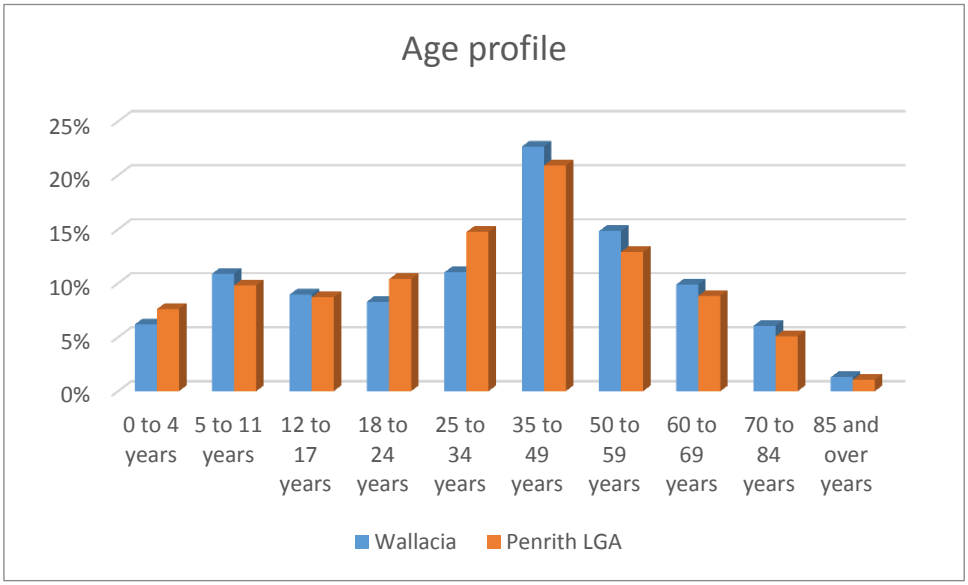
Figure – Wallacia Hotel

Wallacia population snapshot

In 2011, 1,700 persons lived in Wallacia. The age profile of Wallacia was generally older than Penrith LGA, with over half of residents aged over 34 years. Mostly families lived in Wallacia, with couples with children most common (53% compared to 50% in Penrith LGA). Lone person households were also significant (22% compared to 19% in Penrith LGA). Very few residents were from non-English speaking backgrounds.

The median weekly household income in Wallacia ($1,309) was lower than Penrith LGA ($1,398). Labour force participation was slightly higher in Wallacia, while the unemployment rate was lower (3.5% compared to 5.5% in the LGA). The most common occupations among residents were managers, technicians and trades, and clerical and administrative jobs.

A high proportion of households owned a motor vehicle.



	Wallacia	Penrith LGA
Median age	39	34
Family households	76%	78%
Couple family with children	53%	50%
Average household size	2.9	2.9
Lone person household	22%	19%
Median weekly household income	$1,309	$1,398
Workforce participation	68%	66%
Unemployed persons	3.5%	5.5%
Households without a motor vehicle	5%	8%

13. Warragamba

The key feature of Warragamba is the Warragamba Dam, which provides water to metropolitan Sydney. The town centre features a large roundabout, with shops, services and community facilities facing onto this and on the streets which intersect. These include the Town Hall, a community hall, Warragamba Public School and a child care centre.

Warragamba also features a number of sporting and recreational facilities including a public swimming pool, sports fields, playgrounds, skate park and tennis/basketball courts. The Warragamba Dam and Visitor Centre attracts high numbers of visitors who also make use of the recreational areas surrounding the dam.

The main residential area of the town is located to the north of the village centre, characterised by narrow streets and mainly weatherboard and brick houses. A small industrial area is located to the west of the centre with light industrial and rural supply facilities. Warragamba is also the nearest centre for the neighbouring suburb of Silverdale.

Community Infrastructure

- 1x Community hall
- 1x Swimming pool complex
- 1x Neighbourhood centre
- 1x Tennis court complex
- 1x Public school
- 1x Out of hours school service
- 1x Dam visitor centre
- 2x Long day cares
- 3x Churches
- 7x Parks and reserves

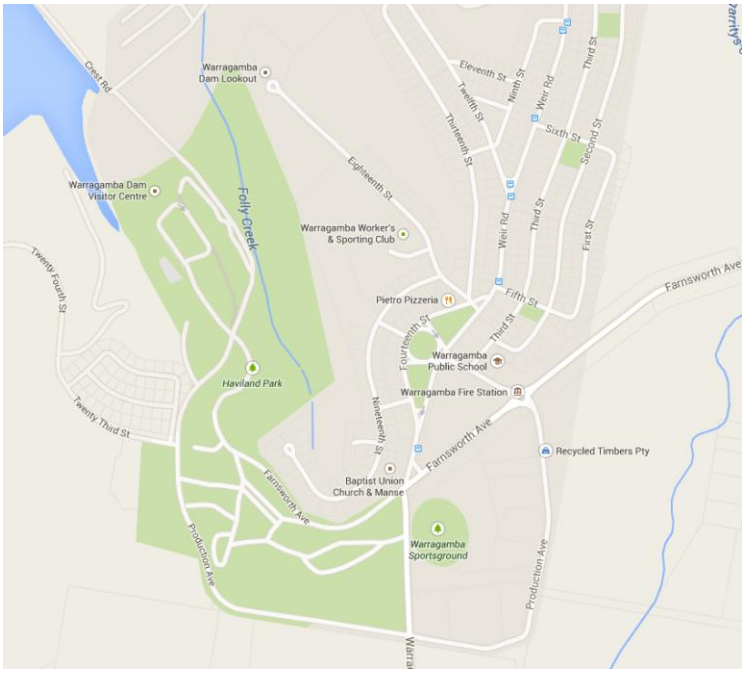




Figure – Warragamba Town Hall



Figure – Warragamba-Silverdale swimming complex

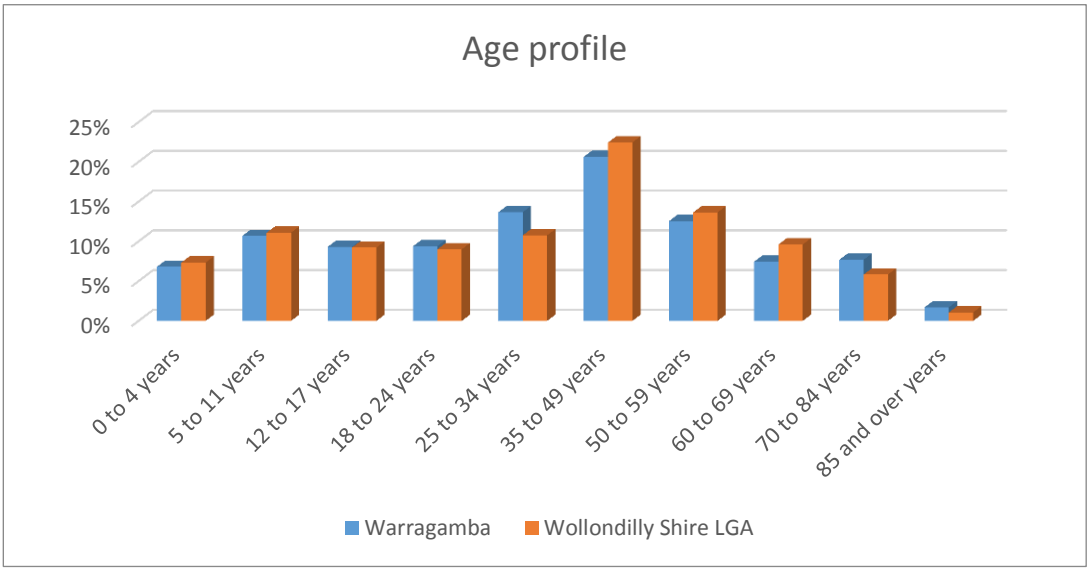
Warragamba population snapshot

In 2011, the population of Warragamba was 1,236 persons. Overall, Warragamba had a slightly younger age profile compared to the average for Wollondilly Shire, with a higher proportion of adults aged 25 to 34 years and smaller proportion of adults aged 35 to 69 years. However there was a higher proportion of residents aged over 69 years. Although the most prevalent household type was families, there was a smaller proportion of couples with children, compared to Wollondilly Shire. The average household size was also smaller, indicating a higher proportion of singles and couples (particularly within the 25 to 34 years and over 69 years age groups) in the area. Very few residents in Warragamba were from non-English speaking backgrounds.

Warragamba showed indications that there may be vulnerable and disadvantaged residents due to a higher proportion of lone person households (many of whom may be older residents), significantly more single parent families, lower income households and higher need for assistance compared to the LGA averages. In terms of SEIFA Index of Disadvantage scores, Warragamba had a lower score (941) indicating a higher proportion of relatively disadvantaged people, compared to other areas within the study area (between 914 to 1,080).

The unemployment rate was also higher (5.1% compared to 4.2% in the LGA). The most common occupations of residents were technicians and trades, clerical and administrative and labourers.

Although there was a lower proportion of households with a motor vehicle compared to Wollondilly Shire, there was still a high dependency on cars among residents.



	Warragamba	Wollondilly Shire LGA
Median age	35	36
Family households	68%	82%
Couple family with children	44%	53%
Single parent families	26%	14%
Average household size	2.6	3
Lone person households	28%	16%
Need for assistance	4.9%	3.8%
Median weekly household income	$1,073	$1,478
Low income households	27%	17%

Appendix H – Social infrastructure impacted by one or more operational noise sources

Social infrastructure impacted by one or more operational noise sources identified in the *Assessment of Ground Based Noise*

Facility type	LGA	Suburb	Name	Services
Childcare	Liverpool	Luddenham	Luddenham Childcare Centre	Preschool, long day care
	Penrith	Mulgoa	Schoolies at Mulgoa	Before and after school hours, vacation care
			Mulgoa Pre School	Preschool, long day care
Education	Liverpool	Luddenham	Holy Family Catholic Primary and Church	K-6 primary school
			Luddenham Public School	K-6 primary school
Places of worship	Liverpool	Luddenham	Holy Family Catholic Primary and Church	Church
			St James Luddenham	Church
			Luddenham Uniting Church	Church
Parks	Liverpool	Luddenham	Freeburn Park	Playground
			Sales Park	Oval with cricket pitch and nets, toilets
			Wilmington Reserve	Open space, basketball court, bicycle track
Recreation	Liverpool	Luddenham	Hubertus Country Club	Club, restaurant, rifle range, carpet bowls
			Luddenham Showground	Showground with associated facilities
			Luddenham Raceway	Go kart centre - paintball and car circuit to be completed august 2015

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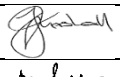
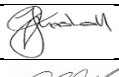
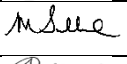
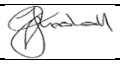
A	Dr P.Mandke L.Harding	G.Marshall		G Marshall		20.08.15
B	DrP.Mandke	M.Sullivan		D Chubb		02.09.15
C	DrP.Mandke	G.Marshall		D Chubb		10.09.15

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VOLUME 4

Appendix P2
Property values

Western Sydney Airport EIS

Potential Impacts on Property Values

Prepared for: Australian Government – Department of Infrastructure and Regional Development

Australian Government
Department of Infrastructure and Regional Development

FINAL

29 September 2015

Table of Contents

Executive Summary **5**

Scope and Objectives 5

Methodology 6

Aircraft Noise Measurement 6

Study Limitations 8

Key Findings 8

Summary of Findings 15

Part A - INTRODUCTION **18**

1 Introduction **19**

1.1 Background to the Proposal 19

1.2 Location Context and Surrounding Land Uses 20

1.3 Growth of Western Sydney 21

2 Potential Impacts on Land Uses **24**

2.1 Impact of a Greenfield Airport on Property Values 24

2.2 Residential vs. Non Residential Land Use Considerations 24

Part B – INVESTIGATION AND ANALYSIS **25**

3 Methodology **26**

3.1 Approach 26

3.2 Aircraft Noise Measurement 27

3.3 Defining the Outputs from the Regression Analysis 28

3.4 Limitations 29

4 Review of Prior Studies **30**

4.1 Academic Literature and Professional Studies 30

4.2 JLW Advisory Technical Paper 4 (1997-1999 EIS) 32

5 Residential Cross Section Analysis **39**

5.1 Objective 39

5.2 Methodology 39

5.3 Melbourne – Melbourne Airport 40

5.4 Brisbane – Brisbane Airport 41

5.5 Sydney Airport 42

5.6 Adelaide – Adelaide Airport 43

5.7 Summary of Key Findings 44

6 Residential Time Series Analysis **45**

6.1 Objective 45

6.2 Methodology 45

6.3 Data Analysis 45

6.4 Summary of Key Findings 45

7 Large Lot Land Holding Cross Section Analysis **48**

7.1 Objective 48

7.2 Methodology 48

7.3 Melbourne – Melbourne Airport 49
7.4 Melbourne – Avalon Airport 50
7.5 Perth – Perth Airport 50
7.6 Summary of Key Findings 51
8 Price Change Related to the Announcement of the Proposed Airport at Badgerys Creek 53
8.1 Objective 53
8.2 Methodology 53
8.3 Data Analysis 53
8.4 Key Findings and Limitations 54
Part C – SUMMARY AND CONCLUSIONS 57
9 Summary and Conclusions 58
9.1 Scope and Objectives 58
9.2 Conclusions and Recommendations 58
10 References 60
Disclaimer 62
Appendix A – Summary of Literature Reviewed 63

List of Tables

Table 1: Housing Price Devaluation Factors Applied to Badgerys Creek (1997-1999 EIS) 10
Table 2: Significance of Noise as a Determinant of House Prices from Regression Analysis 11
Table 3: Impact of Exposure to Different Levels of Noise on House Prices, Brisbane and Adelaide 11
Table 4: Significance of Noise Exposure in Excess of 20 ANEF on Large Lot Land Holdings Pricing 13
Table 5: Long Term Residential Growth around Badgerys Creek before and after 2014 Announcement 14
Table 6: Summary of Assessment of Noise Impact on Property Values by Land Use Type 16
Table 7: Median Price Movements – Sydney Region....33
Table 8: House Price Movements 1994/95....34
Table 9: Suburbs under Northern Flight Path and 'Control Areas' 34
Table 10: Suburbs under Eastern and Western Flight Paths and 'Control Areas'....36
Table 11: Areas Surveyed with Survey of Real Estate Agents....37
Table 12: Assessed Impact of Aircraft Noise on Property Values from Survey of Real Estate Agents....37
Table 13: Housing Price Devaluation Results – (JLW 1997) 38
Table 14: Movements at Melbourne Airport for the 2014 Calendar Year....40
Table 15: Results of Regression Analysis for Melbourne Airport 41
Table 16: Movements at Brisbane Airport for the 2014 Calendar Year....41
Table 17: Results of Regression Analysis for Brisbane Airport....41
Table 18: Movements at Sydney Airport for the 2014 Calendar Year 42
Table 19: Results of Regression Analysis for Sydney Airport....42
Table 20: Movements at Adelaide Airport for the 2014 Calendar Year 43
Table 21: Results of Regression Analysis for Adelaide....43

Table 22: Results of Additional Regression Analysis for Adelaide 44
Table 23: Summary of Cross Section Analysis Results 44
Table 24: Impact of Exposure to Different Levels of Noise on House Prices, Brisbane and Adelaide 44
Table 25: Price Growth of Noise Affected Areas, Unaffected Areas and the Sydney Metropolitan Area 46
Table 26: Movements at Melbourne Airport for the 2014 Calendar Year 49
Table 27: Results of Regression Analysis for Melbourne Airport 49
Table 28: Movements at Avalon Airport for the 2014 Calendar Year 50
Table 29: Results of Regression Analysis for Avalon 50
Table 30: Movements at Perth Airport for the 2014 Calendar Year 51
Table 31: Results of Regression Analysis for Perth 51
Table 32: Significance of Noise Exposure on Large Lot Land Holdings Pricing 51
Table 33: Definition of "Western Sydney" 54
Table 34: Long Term Residential Growth Rates in 5 suburbs Around Badgerys Creek Before and After 2014 Announcement 54
Table 35: Assessment of Noise Impact on Property Values by Land Use Type 58

List of Figures

Figure 1: Price Growth in Noise Affected & Non-Noise Affected Sydney Suburbs (1991-2015, Based to 100) 12
Figure 2: Residential Price Growth around Badgerys Creek (1991-2015, Based to 100) 14
Figure 3: Residential Price Growth around Badgerys Creek (Q2-2014 to Q2-2015, Based to 100) 15
Figure 4: Location of the Proposed Airport in Metropolitan Sydney 20
Figure 5: South West Growth Centre Structure Plan 22
Figure 6: South West Growth Centre Structure Plan 22
Figure 7: Western Sydney Infrastructure Plan 23
Figure 8: Price Growth of Noise Affected, Unaffected and Sydney Metropolitan Area (Base 100) 46
Figure 9: Residential Price Growth around Badgerys Creek (1991-2015, Based to 100) 55
Figure 10: Residential Price Growth around Badgerys Creek (Q2-2014 to Q2-2015, Based to 100) 55

Executive Summary

Scope and Objectives

This technical paper has been prepared as part of the Western Sydney Airport EIS to examine the potential impact the operation of the Western Sydney Airport (proposed airport) may have on land and property values within the area around the airport site. Specifically it seeks to explore from empirical analysis of sales price data, the effect that aircraft and airport operations may have on property prices in the vicinity, particularly property prices for residential and large lot land holdings.

The most readily apparent and assessable effect of an airport on surrounding non-commercial real estate is from aircraft noise, although potential health impacts and odour as a result of aircraft emissions and fuelling operations can also be significant (Yim et al, 2015; Dedoussi, IC and Barrett S, 2014). Whilst numerous studies attest to these effects, there is no evidence to suggest a separately quantifiable direct impact on property prices. Accordingly for the purposes of this study on property price impacts, aircraft noise is considered as the principal factor, whilst acknowledging that this may reflect a combination of other factors. Other studies also consider a number of additional factors resulting from the implementation of new infrastructure may have a co-incident effect on property prices which are hard to disaggregate including: changes to access conditions, visual effects, subdivision, etc.

This paper does not specifically quantify the impacts of the proposed airport on property prices from commercial or employment based land uses due to difficulties in measurement. Whilst the study addresses noise impact on residential property and large lot land holdings, non-residential land uses may also be affected by proximity to the airport and by noise incidence. Commercial (office, hotel, retail etc.), industrial and employment related uses are considered to be less adversely impacted, due to their building characteristics, nature of activities and lower evening/night time use. More importantly these land uses are likely to materially benefit from the increased economic activity that will come from their proximity of the airport site, which will positively impact land values. Community type land uses, such as schools, places of worship, health care and aged care facilities which are affected by noise are less contestable in the market and likely to be restricted by land use zoning and planning controls, hence the impact of noise is not generally price related. Accordingly, the study does not seek to quantify price effects on such non-residential property.

Using multiple regression techniques to analyse property sales data from areas around Sydney (Kingsford Smith) Airport (Sydney Airport) and a number of other Australian airports, the study seeks to explore the effect of airport operations on the sale prices of residential property and whether such effects are sustained over time. Recognising that the effects may differ depending on the nature of residential development in terms of density and housing type, the study considers property pricing within two separate categories:

1. urban housing within established urban areas, where land parcels are typically less than 2000 square metres, referred to herein as ‘residential’ or ‘residential land’; and
2. dwellings on land zoned for residential, rural or rural/residential use, lying outside the main urban area, with land parcels typically greater than 1 hectare and referred to in this study as ‘large lot land holdings’.

It is noted that much of the land in the vicinity of the airport site falls within this second category, differing markedly from higher density, more land intensive uses surrounding the existing Sydney Airport.

It is noted that there are few, if any, units and apartments in the vicinity of the airport site. Pricing of units has thus been excluded from the analysis because of this and also because units’ characteristics such as; a lack private open space, units are shielded from noise by adjacent units and have varying orientation which may make pricing less influenced by noise than houses with similar exposure. Additionally, new unit developments have a tendency to skew the results because they typically sell for higher prices than the existing stock.

The empirical findings from this quantitative analysis have also been considered in the context of previous Australian and International studies which have sought to gauge the impact of noise and other factors on housing prices in the vicinity of major airports.

Methodology

The methodology in this study builds on the previous studies, particularly those prepared by JLW Advisory (1997) in relation to the Second Sydney Airport Proposal Envirnmental Impact Statement (1997-1999) and JLW Research and Consultancy (1993) in relation to Sydney Airport's third runway. It is informed by a review of these and other published studies seeking to address the impact of noise in property prices in Australia and internationally.

Following an inspection of the area around the airport site, residential and large lot land holdings sales data for areas in the vicinity of the airport site, together with those around Sydney, Adelaide, Brisbane, Melbourne and Perth airports were sourced from data provider, CoreLogic. CoreLogic maintains a comprehensive data series of property sales pricing and transaction information collected from public sources and real estate market participants for all Australian states and territories and is considered to be the most extensive and reliable source of such data.

The sale price data series for analysis were selected at state suburb level, based on inspection of noise data relating to each of the main airports. These data series were 'cleansed' to remove outliers and obvious anomalies and analysed using multiple regression techniques to assess the effect and significance of aircraft noise and other factors on the property sales price.

Unlike previous studies which have largely focused on a single airport, the analysis sought to examine the relationship at a range of Australian airports and to separately explore the impact on residential and large lot land holdings. In addition, by analysing time series sale price data, the study sought to examine the extent to which any impact endured over time, as residential purchasers adjusted to prevailing noise levels and other conditions.

The findings from the analyses were considered in terms of their robustness and significance with reference to standard statistical measures.

The analysis and approach can be considered under the following headings:

Review of Prior Studies:

- literature review of academic and consultant studies from Australia and overseas; and
- review of the JLW Advisory Technical Paper 4 (1997 EIS)

Current Study:

- cross sectional analysis of sales data, being between 2011 and 2014 for residential and between 2000 and 2014 for large lot land holdings. Using multiple regression analysis of these sales with noise exposure included as one of a number of independent variables explaining the dependant variable (sale price);
- longitudinal analysis of sales price data within Sydney over time to compare price trends of noise affected and non-noise affected areas; and
- longitudinal analysis of sales data from suburbs in the vicinity of the proposed airport to examine the impact before and after the 1997 and 2014 announcements of the related to the proposed airport at Badgerys Creek.

Notwithstanding the literature and academic review had reference to some international examples, this report has had primary reference to greenfield and brownfield airports in Australia.

Aircraft Noise Measurement

Aircraft noise is generally regarded as the most apparent and discernible impact on residential property in the vicinity of an airport and under the aircraft flight paths. As noted previously, air pollution may be considered to exhibit co-linearity with noise in terms of possible price effect.

The degree of perceived disturbance is related to factors such as:

- the intensity, pitch and duration of the noise events; and

- the frequency of noise events and their incidence, particularly at different times of the day

These in turn are related to:

- aircraft types and payload;
- aircraft operating characteristics in flight;
- Height and angle of climb/descent;
- Aircraft ground operating modes, taxiing, engine testing and holding;
- Prevailing wind and temperature;
- Ambient noise levels;
- Dwelling construction and orientation;
- Nature and utility of private outdoor areas associated with dwellings; and
- Characteristics of the affected household.

To take account of these various characteristics and perceptions, aircraft noise is commonly measured in terms of Noise Exposure Forecast (NEF), a technique developed in the 1960s in the US to gauge the impact on affected communities. In 1979, the Australian Government commissioned a major survey into community reactions to aircraft noise by the National Acoustic Laboratories (Hede and Bullen, 1982) which led to a refined system named the Australian Noise Exposure Forecast (ANEF).

The ANEF system is primarily a land use planning tool which takes account of the:

- intensity, frequency and duration of aircraft noise events; and
- distribution of take offs and landing movements throughout the day and night, with greater weighting given to noise events between 7pm and 7am.

The information is presented in the form of maps showing sets of contours of equal noise exposure, which may represent:

- actual or historic exposure, termed Australian Noise Exposure Index (ANEI), based on noise measurement of flight data for a previous period, typically for a calendar year
- predicted exposure, termed ANEF which describes potential impacts of aircraft noise based on assumptions of airport and aircraft operations, traffic mix and flight paths.

Under the Airports Act, the Airport Lessee Companies of federally leased airports are required to prepare ANEF maps every five years using Australian Standard AS2021 methodology. These then need to be endorsed by Airservices Australia. They typically have a 20 year time horizon based on forecast traffic mix, and show noise forecasts between 20 and 45 ANEF at 5 step intervals (i.e. 20, 25, 30, 35, 40, 45).

The critical contour is the 20 ANEF which corresponds to the minimum level for acceptability for residential buildings (McLeod I and Latimore M. 2014), Australian Standards AS2021. It corresponds to 10 per cent of the population being seriously affected by noise, according to the 1980 NAL study. The region within the range of 20-25 ANEF is classed as conditionally acceptable for residential buildings, requiring noise attenuation to meet the target levels of AS2021. (McLeod and Latimore, Airservices Australia, 2014).

In addition to ANEF/ANEI measures, aircraft noise is also measured with regard to the number of instances in a given period of noise events above a certain volume. Most Australian airport master plans now include contour maps showing measures such as N70 (N noise events of 70 decibels). Typically the areas affected by 70 decibel events extend well beyond the 20 ANEF area (McLeod and Latimore, op cit). However, these plans are not subject to Airservices Australia endorsement. Because of the dynamic nature of these measures, they are less susceptible to relating to property sales price data and hence have not been used as a primary noise measure in this study.

This study has had regard to ANEI and ANEF contour maps prepared by the airport operating companies for Brisbane, Melbourne, Adelaide and Perth airports and Airservices Australia for

Sydney Airport. In the absence of ANEF plans for Melbourne's Avalon airport, this study has had regard to an estimated impact area, being at the northern point of the runway, 2 kilometres across and 10 kilometres north. These parameters were selected from analysing the ANEF contours of the other selected airports.

Areas falling within ANEI or ANEF contour bands 20 to 35 have been the focus of this study. Areas subject to ANEI or ANEF above 35 are not considered suitable for residential use under Australian Standards and any residences falling within this noise exposure level at other Australian airports have either been subject to Government acquisition or extensively insulated and are not considered a part of the residential market.

Study Limitations

Undertaking analysis to determine the impact on property prices of a new airport is challenging. No single study or method provides definitive results that have perfect comparability for the proposed airport, especially with the context of the current land uses around the airport site at Badgerys Creek which comprises rural, rural-residential and a small amount of traditional residential. Key limitations identified in this report relate to:

- real estate based limitation, relating to the lack of homogeneity in the evidence. Notwithstanding, this, the report has analysed large real estate transactional datasets to derive statistically significant results;
- aircraft noise data limitations; and
- method specific limitations.

Key Findings

Review of Prior Studies

Academic Literature and Professional Studies

A review of a number of Australian and international studies found there is support for the hypothesis that aircraft noise (among other factors) adversely impacts residential property values. Importantly, however, it is noted that these studies have mostly analysed sales of 'traditional' residential property and do not explicitly consider lower density, large lot land holdings similar to those found in and around Badgerys Creek. For these large lot properties, a dwelling potentially represents a smaller proportion of the total asset; as such the noise impact on pricing may be different. This hypothesis has been explored within the current study.

The quantitative studies generally adopt hedonic price modelling techniques (e.g. Kholodilink, 2014, BIS Shrapnel, 1990, Burns & Associates, 1990) which seek to relate the sale price of dwellings to a range of independent variables, including aircraft noise, to enable the impact of noise exposure to be assessed. Others have used matched pair techniques (Nelson, 2004; Bell, 2001) to compare the sale prices for similar properties subject to different noise levels.

These quantitative studies indicate changes in house values range from a low of 0.3 per cent per unit of ANEF to a maximum of 2.6 per cent. They highlight the wide range of factors which influence house prices and also the wider variance in overseas studies compared with those of Australian prices. The results from studies of Sydney Airport for example are more consistent, ranging from a minimum of 0.4 per cent to a maximum of 1.1 per cent per ANEF for a specific flight path, with the greater impact in areas subject to greater noise exposure, suggesting that the relationship between noise and price impact is not linear and increases with ANEF level.

Other consistent findings in the literature suggest that:

- higher priced dwellings are more affected by noise exposure (JLW Research and Consultancy, 1993);
- properties located in areas of higher noise levels suffer disproportionately higher rates of deprecation in comparison to areas with lower noise levels (JLW Research and Consultancy 1993; Levesque, 1994);
- the statistical significance of a relationship between price impact and noise levels below 20 ANEF was consistently found to be low (BIS Shrapnel, 1990; Paulsen, 1990); and

- the impact on property values varies according to the type of property, with some studies showing differences between detached dwellings, units and townhouses, possibly for some of the reasons mentioned above (JLW Advisory, 1997).

Time series analysis indicates that properties affected by noise pollution were reduced in value at a rate of 0.5 to 0.6 per cent per decibel (above standard levels in urban areas). Properties affected by flight path noise experienced average noise levels of 65 to 80 decibels while urban areas outside the flightpath are subject to typical background noise levels in the 50-60 decibel range (Nelson, 2004) Alternative studies indicative higher level affectation of between -15.7 per cent to -19 per cent (Bell, 2001).

A study (JLW, 1997) on the effect of noise on house prices undertaken as part of the previous 1997 EIS for an airport at Badgerys Creek may be of particular relevance. This study included both quantitative and qualitative assessment of the noise impacts relating to Sydney Airport flight paths to the north of the airport following the opening of the third runway in November 1994 and the temporary (and subsequently reversed) closure of the east–west runway in late 1994.

It thus covered areas of both long term exposure to aircraft noise and areas which had experienced recent change in noise levels as a result of the new runway and the closure of the east-west runway. It examined price movements in selected post code areas under existing Sydney airport flight paths, before and after the opening of the third runway and qualitative analysis of perceived impacts on prices in areas where ANEI levels were below 20, based on interviews with real estate agents and valuers.

Using postcode level price data from the NSW Valuer-General, the study compared differences in aggregate house price movements between areas under flight paths and areas not under flight paths in 1994-95. This study also compared house price movements in various ANEI contour zones under the flight paths and in similar control areas away from the flight paths, over the period 1992 to 1996.

Based on a comparison of house price sales from 24 postcodes under the northern flight path, which experienced an average increase in ANEI of 4 units following the opening of the third runway in November 1997, compared with that from 172 post codes not under the flight path, there was a 2.9 per cent divergence in the median sale price in the period leading up to and after the opening of the third runway (i.e. median prices in the affected areas declined by an average of -1.16 per cent whilst those in comparable non affected areas increased by 1.74 per cent).

Conversely, the results under the east-west runway approaches were counter-intuitive. If the reduction in noise levels has been priced into housing, a greater increase in price should have been expected. The study identified two potential reasons. Firstly, buyers believing that the closure was not permanent. Secondly, the postcode data did not precisely match the flight paths.

The study also compared the change in median house price by quartile in a range of areas under the northern flight path subject to changes in ANEI compared to control areas outside the flight path. Although the results from this analysis were inconclusive, it was found that the impact of noise was greatest in higher priced suburbs where it was apparent at levels below 20 ANEI.

In addition to a quantitative analysis of house prices, the study also contained a qualitative survey of real estate agents and valuers. This component of the analysis found:

- a view that aircraft noise was perceived as ‘a big problem’ or ‘of some concern’ in areas within the flight path compared to an issue deemed ‘of little concern’ or ‘satisfactory’ in comparable areas outside the flight path;
- respondents estimated the impact on house prices of between 1.7 and 3.3 per cent in areas within the flight path compared to similar areas and dwellings outside the flightpath;
- the impact of aircraft noise differed depending on buyer type. Young couples with no children were less concerned by aircraft noise when purchasing a property, while conversely elderly and couples with children were more influenced by aircraft noise in their purchase;

- houses were perceived to be generally affected consistently in each area, although higher priced housing in each area appeared to be more sensitive to aircraft noise; and
- apartments or townhouses were perceived to be less affected than houses.

The study had consideration to both the quantitative and qualitative results, as well as the review of literature to determine assumed devaluation factors which it applied to its assessment of the aggregate impact of aircraft noise considered in the EIS. This can be seen in Table 1 below.

Table 1: Housing Price Devaluation Factors Applied to Badgerys Creek (1997-1999 EIS)

ANEC Band[1]	Devaluation Range	Assumed Devaluation[2]
Under 15	Nil	Nil
15 to 20	0 to 6%	3%
20 to 25	5.9% to 13.6%	8%
25 to 30	8.6% to 19.6%	15%
30 to 35	10.9% to 24.3%	20%

Source: JLW Advisory 1997

Note 1: No devaluation estimates for ANEC > 35 because dwellings located in this noise level at other Australian airports have been either acquired or extensively insulted.
Note 2: Compared to under 15 ANEC.

Current Study

Residential – Cross Section Analysis

To further explore and quantify the impact of noise exposure on residential house prices, sales data from suburbs in the vicinity of Sydney (SYD), Brisbane (BNE), Adelaide (ADL) and Melbourne (MEL) airports were examined using multiple regression analysis.

For each airport, a data set of recent house sales from a range of noise affected and non-noise affected areas was analysed using a number of variables relating to each sale to assess the impact of each on the determination of the sale price. The factors considered were:

- Sale price (the independent variable);
- Sales date (quarter and year);
- Suburb;
- Area of lot;
- Number of bedrooms;
- Number of bathrooms; and
- Noise exposure, in terms of location of dwelling within ANEF/ANEI[1] bands:
    - Less than 20 ANEF/ANEI (considered to be unaffected);
    - 20-25 ANEF/ANEI;
    - 25-30 ANEF/ANEI; and
    - 30-35 ANEF/ANEI.

Sales with in excess of 35 ANEF were not included in the analysis as above this level, property is considered to be unsuitable for habitation.

The time period over which sales data was included varied from 2 years (2013 and 2014) in Sydney and Brisbane and 4 years (2011 to 2014) in Melbourne and Adelaide, resulting in

[1] The following sources were used:
Sydney ANEI, AirServices Australia, 2014
Adelaide ANEI, Adelaide Airport, 2013
Brisbane ANEF, Brisbane Airport Australia, 2014
Melbourne ANEF, Melbourne Airport, 2014 (additionally for large lot land holding analysis)
Perth ANEF, Perth Airport, 2014 (used for large lot land holding analysis)

sample sizes, after removal of outliers of between 290 and 682 observations. The time periods were selected based on the availability of satisfactory sample sizes.

Table 2 on the below summarises the results of the analysis of house prices around four Australian international airports.

Table 2: Significance of Noise as a Determinant of House Prices from Regression Analysis

Airport	N (sample size)	r^2	Noise impact on price	Noise factor significance		Comment
				t -stat	P-value	
SYD	682	64.2%	1.4%	1.55	12.11%	Noise is less likely to be significant
MEL	525	66.9%	-1.9%	-1.37	17.25%	Noise is less likely to be significant
BNE	379	45.2%	-10.7%	-5.54	0.00%	Noise is very likely to be significant
ADL	290	83.3%	-6.6%	-3.31	0.10%	Noise is very likely to be significant

Source: CoreLogic, Airservices Australia, JLL

The analysis suggests that there is a strong and robust relationship between house prices and noise exposure in the house sale price data for Adelaide and Brisbane with a high probability that noise is a significant factor. A P-value of less than 5 per cent suggests that there is a more than 95 per cent probability that the factor is significant, similarly a t-stat of 2 or more generally indicates a statistically significant relationship. Exposure to noise of greater than 20 ANEF was found to have an average negative effect on price of around 7 per cent in Adelaide and 11 per cent in Brisbane compared with housing in areas lying outside the 20 ANEF noise contour.

For Sydney and Melbourne, the data is far less strongly correlated, with a level of probability of greater than 10% that the pricing is not related to or significantly influenced by noise. It is noted that the housing in districts around Sydney Airport may be less homogeneous than Adelaide and Brisbane, suggesting other factors such as proximity to the city, housing pressures restricting location choice or the attractions of inner city locations may outweigh noise concerns. It is also considered that dwelling noise attenuation measures in noise affected suburbs may have partly reduced the noise exposure, although this would require further examination (Burgess 1997).

As the noise to price relationship was considered significant in both Adelaide and Brisbane, the data sets were further analysed to examine the relationship between the level of noise exposure in excess of 20 ANEF on house sale prices.

Table 3: Impact of Exposure to Different Levels of Noise on House Prices, Brisbane and Adelaide

Airport		Noise impact on price (compared to noise levels < 20ANEI/ANEF)		
		ANEI/ANEF 20-25	ANEI/ANEF 25-30	ANEI/ANEF 30-35
BNE	Price impact	-10.7%	N/A	N/A
	Sample size	183	No relevant sales	No relevant sales
ADL	Price impact	-8.3%	-14.7%	-19.8%
	Sample size	132	29	14

Source: CoreLogic, Airservices Australia, JLL

In Adelaide, there were sufficient sales of houses within the 20-25, 25-30 and 30-35 ANEI contours to observe a statistically significant relationship between house price and different noise exposure levels. This indicated that a house within the 30-35 ANEI contour would sell for an average of approximately 20 per cent less than the equivalent dwelling outside the 20 ANEI contour.

For Brisbane, whilst the sale price effect for dwellings within the 20-25 ANEF contour was significant, with prices for the 183 house sales showing an average discount of 10.7 per cent compared with those outside the noise affected area, there were very few sales in higher contour bands within the areas analysed. Hence it was not possible to determine a noise impact on prices at the 25-30 or 30-35 ANEF level.

It is noted that the price impacts observed in Brisbane, Adelaide and in Melbourne were all negative, as might be expected, indicating that house sale prices were lower in noise affected areas. However, although not statistically significant, the impact in Sydney was slightly positive, which could arise if other factors positively affecting price (such as accessibility, proximity to rail station or better quality stock) happened to occur in noise affected areas.

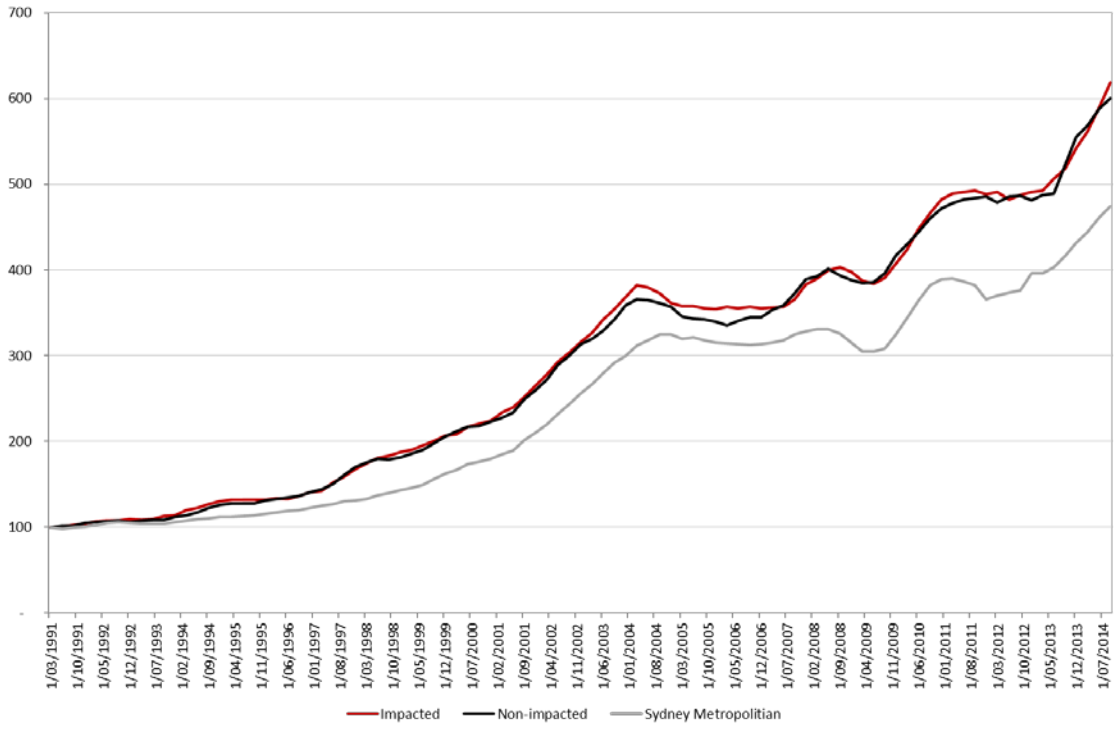
Residential Time Series Analysis (Sydney Airport)

Using the house price sales data for suburbs around Sydney Airport, the impact of noise exposure on long term price growth was explored. In this analysis, the moving annual median house price for 8 affected suburbs and 11 non-affected suburbs listed below were compared, together with that for the Sydney metropolitan area. These suburbs are:

Noise affected:	Kyeemagh, Petersham, Mascot, Stanmore, Tempe, Sydenham, Marrickville and Botany
Non noise affected:	Brighton-Le-Sands, Bexley, Arncliffe, Earlwood, Lewisham, Haberfield, Pagewood, Erskineville, Dulwich Hill, Summer Hill and Alexandria

The annual average median house prices in the two groups compared with that for the Sydney Metropolitan area as a whole are illustrated in Figure 1.

Figure 1: Price Growth in Noise Affected & Non-Noise Affected Sydney Suburbs (1991-2015, Based to 100)



Source: CoreLogic, Airservices Australia, JLL

It is apparent that there is no significant difference in price movements and long term price growth between the affected and non-affected suburbs, with both groups showing house price growth at a rate greater than the metropolitan average. This suggests that, in the suburbs analysed, exposure to aircraft noise does not materially impact the long run house price growth rate.

Large Lot Land Holding – Cross Section Analysis

As noted, much of the land surrounding the airport site is zoned for rural use and used for various agricultural and residential purposes, with large land holdings with lots sizes in excess of 2 hectares. It is considered that there may be a difference in the pricing impact of aircraft noise exposure to such holdings compared to higher density residential dwellings in established urban areas.

Although there are few, if any, comparable large lot land holdings in the vicinity of Sydney Airport, areas to the west of Melbourne Airport (MEL) and north of Perth Airport (PER), as well as land around Avalon Airport (AVV) near Geelong have similar characteristics, some of which are subject to aircraft noise exposure. Accordingly, regression analysis of land and dwelling sales in the vicinity of these airports was analysed to determine if there is evidence of any statistically significant relationship between price and noise exposure. The results are summarised in Table 4 on the next page.

Table 4: Significance of Noise Exposure in Excess of 20 ANEF on Large Lot Land Holdings Pricing

Airport	N (sample size)	r^2	Noise impact on price	Noise factor significance		Comment
				t-stat	P-value	
AVV	330	38.0%	-7.8%	-0.71	47.79%	Not considered significant
MEL	193	54.8%	15.3%	1.88	6.13%	Not considered significant
PER	178	28.9%	0.2%	0.01	98.95%	Not considered significant

Source: CoreLogic, Airservices Australia, JLL

These results suggest that there is no discernible or statistically significant relationship between large lot land holdings exposed to aircraft noise in excess of 20 ANEF and the sale price. It is hypothesized that there are significant factors other than noise which would have a greater impact on price, including the nature and style of the dwelling on the land, the type of activity carried on, the nature and productivity of the land and its physical and biological characteristics.

Structured interviews with real estate agents interstate (Melbourne, Avalon and Perth) could provide a better understanding of the impact on proximity to an operational airport on large lot land holding property values.

Price Change Related to Announcement of Badgerys Creek as a Site of the Proposed Airport

The announcement in April 2014 that the Australian Government is proposing to develop Western Sydney Airport at Badgerys Creek could be expected to have an impact on property values in the vicinity, both from perceptions of possible adverse impacts, such as noise and air pollution, and positive anticipatory and positive effects in terms of improved infrastructure, employment opportunities and potential for higher density and intensity of land use.

This study undertook an analysis on sales in the vicinity of the airport site. The analysis compared the long-term median price growth of suburbs around the airport site with the growth over the same period for Western Sydney and the Sydney metropolitan region. The analysis made primary reference to growth rates both before and after the announcement in April 2014 that Badgerys Creek will be the site for a new airport.

This study has had reference to sales price data series over a 24 year period (1991 to Q1,2015). The study analysed the change in property sales values over the period prior to and the 12 months that followed the April 2014 announcement on land within a 5 kilometre radius of the centre of Badgerys Creek, utilising quarterly moving median prices from the CoreLogic database.

The growth in residential prices in the suburbs lying within 5 kilometres of Badgerys Creek was compared with the Western Sydney and Sydney Metropolitan areas. Overall, this includes some 1,500 residential sales since Q2/1991 in the suburbs of Bringelly, Kemps Creek, Luddenham, Mount Vernon and Rossmore. (Note data series for residential sales in the suburb of Austral and Greendale, which are within 5 kilometres or in Badgerys Creek, were not included due to insufficient sales transactions).

The data represent the average of the four quarterly moving median sale prices for each of the five suburbs around Badgerys Creek (i.e. each quarterly figure is the average of the four preceding quarterly median sale prices for that suburb, and then averaged across the 5 suburbs) index to a base of 100 at Q2 1991.

The findings and growth rates prior to and since the April 2014 announcement are summarised in the table and illustrated in the charts overleaf.

Table 5: Long Term Residential Growth around Badgerys Creek before and after 2014 Announcement

Location	Average Compound Growth Rate 1991 - 2015	
	Pre Announcement	Post Announcement
5 km around Badgerys Creek	6.42%	23.72%
Western Sydney[2]	6.34%	16.65%
Sydney Metropolitan	6.70%	14.04%

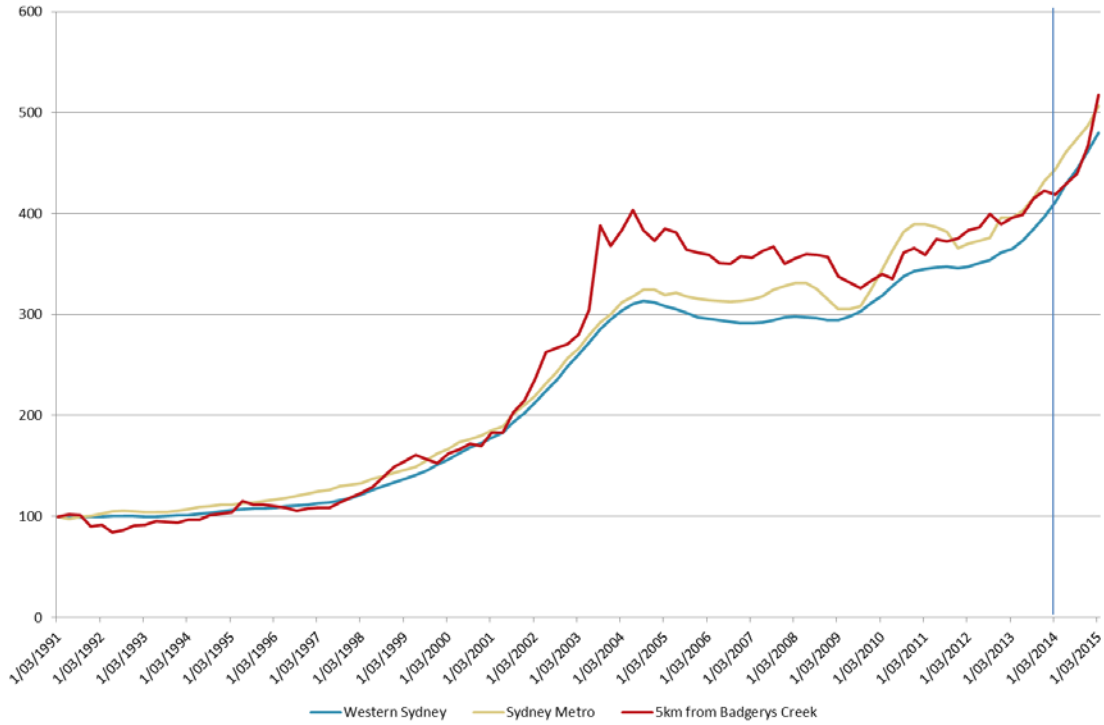
Source: CoreLogic, Airservices Australia, JLL

Whilst average residential prices in the suburbs around Badgerys Creek experienced a growth rate broadly in line with the Western Sydney region and the metropolitan area as a whole, there was a marked acceleration in growth in the 12 months following the 2014 announcement of the proposal to locate the Airport at Badgerys Creek.

Whilst this is not evidence of causality, it is noteworthy that median house prices in the Badgerys Creek area increased at a rate significantly greater than that of the surrounding Western Sydney and the Metropolitan regions. The volume of transactions since the announcement is broadly in line with the long term average of between 15 and 20 sales per quarter.

Although it is not possible to attribute the increased growth to the 2014 announcement, which may be related to a range of external factors including the growing pressures within the Sydney housing market, falling interest rates and the growing commitment to the development of Western Sydney, it suggests that the announcement did not appear to create any diminution in residential values in the broad vicinity of the Airport, which might have been expected if there had been widespread concern about noise or other pollution.

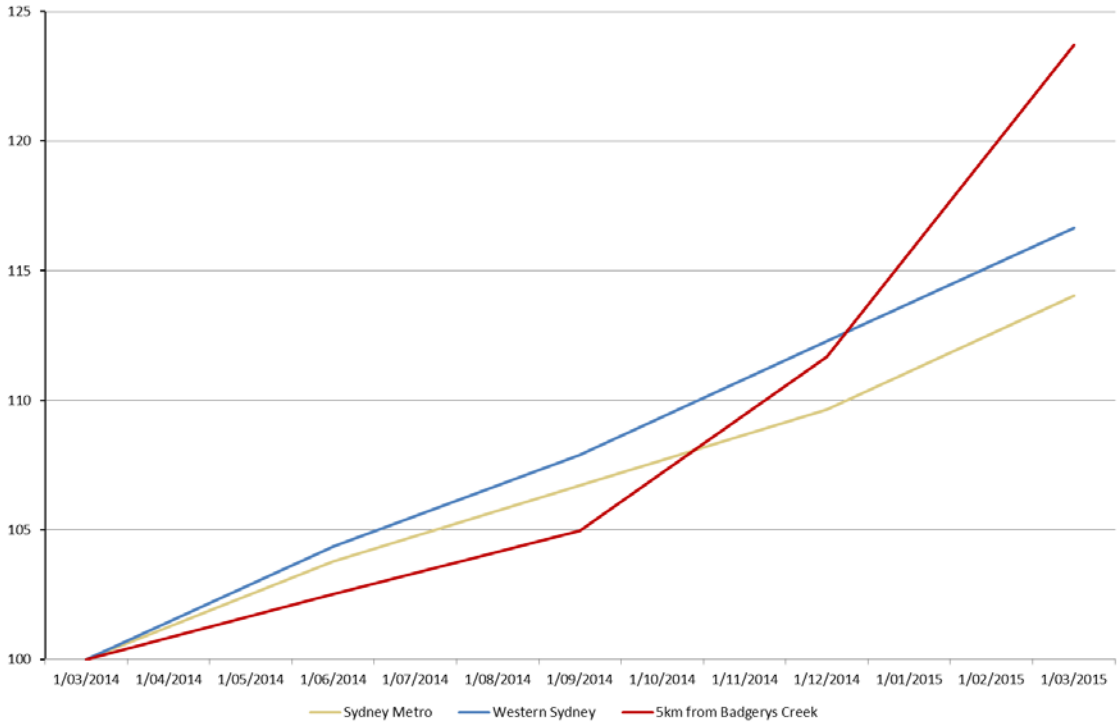
Figure 2: Residential Price Growth around Badgerys Creek (1991-2015, Based to 100)



Source: CoreLogic, Airservices Australia, JLL

[2] Western Sydney is defined as the sum of the following Planning Regions
Sydney South West: Liverpool, Fairfield, Camden, Campbelltown and Wollondilly
Sydney West: Penrith, Hawkesbury and Blue Mountains
Sydney West Central: Auburn, Bankstown, Blacktown, Holroyd, Parramatta and The Hills

Figure 3: Residential Price Growth around Badgerys Creek (Q2-2014 to Q2-2015, Based to 100)



Source: CoreLogic, Airservices Australia, JLL

Summary of Findings

The key findings from this study are summarised below.

- Previous studies have found a relatively consistent adverse effect of aircraft noise on residential prices, of between 0.4 per cent and 1.1 per cent per unit of ANEF, with a greater impact at higher ANEF levels and for higher priced properties.
- None of the previous studies have sought to explore the impact on large lot land holdings comparable to those around Badgerys Creek, where few existing dwellings fall within areas expected to be exposed to noise levels in excess of 20 ANEF.
- The analysis undertaken in this study encompassed over 1,800 residential sales transactions for suburbs in the vicinity of four main Australian international airports found:
    - no statistically significant relationship between noise exposure and housing prices in Melbourne or Sydney;
    - in Adelaide and Brisbane, noise exposure was a more significant factor influencing residential prices;
    - in the case of Brisbane, prices for houses exposed to aircraft noise between 20 and 25 ANEI/ANEF, experienced a -10.7 per cent reduction compared with dwellings outside the noise affected area; and
    - in Adelaide, a statistically significant impact was found ranging from -8.3 per cent (20-25 ANEI/ANEF); -14.7 per cent (25-30 ANEI/ANEF); and -19.8 per cent (30-35 ANEI/ANEF) compared with prices in areas less than 20 ANEI/ANEF.
- At Sydney Airport, analysis of long run house prices since 1991 found no appreciable difference in growth rate between median prices in suburbs subject to in excess of 20 ANEI and those in similar areas not exposed to aircraft noise. Possible reasons may be:
    - housing pressures restrict housing choices;
    - the benefits of living close to the city outweigh possible noise effects in the minds of potential purchasers;

- noise attenuation measures to dwellings with above 20 ANEI may have reduced the impact of noise on residents; and
- aircraft noise sharing protocols and rising ambient noise levels in many suburbs may reduce the perceived impact of noise.

- Examination of sales of large lot land holdings in the vicinity of Melbourne, Perth and Avalon airports failed to establish a statistically significant relationship between noise exposure and property prices. Possible reasons for the lack of clear effect may include:
  - the lesser significance of the dwelling in the context of large land areas, compared with established urban areas;
  - land used primarily for primary production may be less affected by noise; and
  - the wider range of factors influencing price that cannot be analysed from the available sales data, e.g. aspect, topography, soil and micro-climate.
- Analysis of long run growth rates of residential sales in the suburbs around Badgerys Creek indicates that despite short term fluctuations, property prices have grown at a similar rate to the wider Western Sydney and metropolitan regions.
- Rather than suffering a slowing of growth as a result of possible fears of noise or other impact, residential prices in the suburbs around Badgerys Creek grew strongly in the period following the announcement in April 2014 that Badgerys Creek would be the site of the proposed airport, increasing by almost 24 per cent and substantially faster than both Western Sydney and the Sydney metropolitan regions, although it is not possible to attribute this growth to the announcement.
- Overall, the analysis failed to establish conclusive evidence of an adverse impact on large lot land property prices as a result of aircraft noise at levels of 20-25 ANEF that would suggest the development of the proposed airport at Badgerys Creek may have a major adverse impact on property prices in the vicinity.
- Further analysis may be required to provide context to purchasers' preferences that ultimately drives property values around Badgerys Creek. This will be best achieved with structured interviews with real estate agents. Similarly, interviews with real estate agents interstate (Melbourne, Avalon and Perth) will provide a better understanding of the impact on proximity to an operational airport on large lot landholding property values.

After considering the analysis undertaken above the table below summarises the impact of noise on property values by land use type. Broadly, the residential assessment has had primary consideration to the statistically significant results from the Brisbane and Adelaide airports, with support for assessed impact coming from the academic literature and professional studies. The analysis on the large lot land holdings had reference to both the interstate analysis on Avalon, Perth and Melbourne Airports as well as analysis of price changes related to the announcements at Badgerys Creek.

Table 6: Summary of Assessment of Noise Impact on Property Values by Land Use Type

	Noise impact on price (compared to noise levels < 20ANEI/ANEF)		
Land Use	ANEI/ANEF 20-25	ANEI/ANEF 25-30	ANEI/ANEF 30-35
Residential	-9.5%	-14.7%	-19.8%
Large Lot Land Holdings	No discernible impact	No discernible impact	No discernible impact

Finally, consideration was given to the potential impact of property prices that may occur from a second runway opening at the proposed airport. The long term time series analysis on Sydney Airport (see Section 6) suggest no material difference in property pricing of noise versus non-noise affected areas. This outcome is in line with our expectations. That is, that factors of much greater significance will influence property values than any incremental increase in noise. More specifically, it is considered that the positive influences of in-area employment as well as improved amenity and services will more than likely make up for any additional noise from the second runway.

Further, this report makes the observation that there have been significant advancements in aircraft technology over the last 20 years that have meant a material reduction in noise footprints across all major Australian airports, despite increasing aircraft movements. It is considered to be a reasonable assumption that advancements will be made in the future, further reducing aircraft noise. For the above reasons the report has not assessed a negative impact to property prices due to the opening of a second runway at the proposed airport.

Part A – Part A INTRODUCTION

1 Introduction

1.1 Background to the Proposal

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the *Joint Study on Aviation Capacity in the Sydney Region* (Department of Infrastructure and Transport, 2012) and *A Study of Wilton and RAAF Base Richmond for civil aviation operations* (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the *Airports Act 1996* (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Location Context and Surrounding Land Uses

The preferred site for the proposed airport covers an area of approximately 1,700 hectares located at Badgerys Creek in Western Sydney. The airport site is located within the Liverpool local government area, around 50 kilometres west of Sydney's Central Business District and 15 to 20 kilometres from major population centres such as Liverpool, Fairfield, Campbelltown and Penrith.

Figure 4: Location of the Proposed Airport in Metropolitan Sydney



Source: GHD

Within these areas, most of the potentially affected land is zoned for rural use, although it may incorporate some village areas such as Warragamba, Silverdale and Luddenham.

With much of the land in the vicinity of the airport site zoned for rural purposes, the area has predominantly relatively large lot sizes. To the north east, within Penrith Local Government Area (LGA), under the Penrith Local Environmental Plan 2010 the minimum lot size under the AB3 lot size control is 40 hectares, whilst to the south west, in the Liverpool LGA under the Liverpool Local Environmental Plan 2008 AB lot size control the permitted lots sizes are 10-50 hectares, with some small 'Z' areas with minimum sizes of 2 hectares.

For additional locational context, this report makes reference to the comparative impact on noise at the Badgerys Creek location. Cox (2013) identified that as at the 2011 Census, "at Badgerys Creek Airport, there were 2,913 dwellings within the 20 ANEF contour and 328 dwellings within the 25 ANEF contour. At the 2011 census, at Sydney Airport, there were 86,017 dwellings within the 25 ANEF contour." JLL was unable to verify the ANEF contours referred to within this presentation, as such have assumed these to refer to the ANEF contours established by the previous 1997-1999 EIS.

1.3 Growth of Western Sydney

In terms of a regional context, we have provided below high level observations relating to the South West Growth Centre, Broader Western Sydney Employment Area and Western Sydney Infrastructure Plan due to their interrelationship with the proposed airport.

The NSW Government established the North West and South West Growth Centres in 2005. The objective of the Growth Centres is to ensure the creation of attractive, sustainable new communities by supplying land linked to key infrastructure, employment areas, parks, health and education facilities, shops, services and public transport. The recently released metropolitan plan, A Plan for Growing Sydney (NSW Government, 2014), forecasts that Sydney's population will grow by an estimated 1.6 million people in the twenty years to 2031. Of this growth, more than half will occur in Western Sydney with the North West and South West Growth Centres playing a significant role.

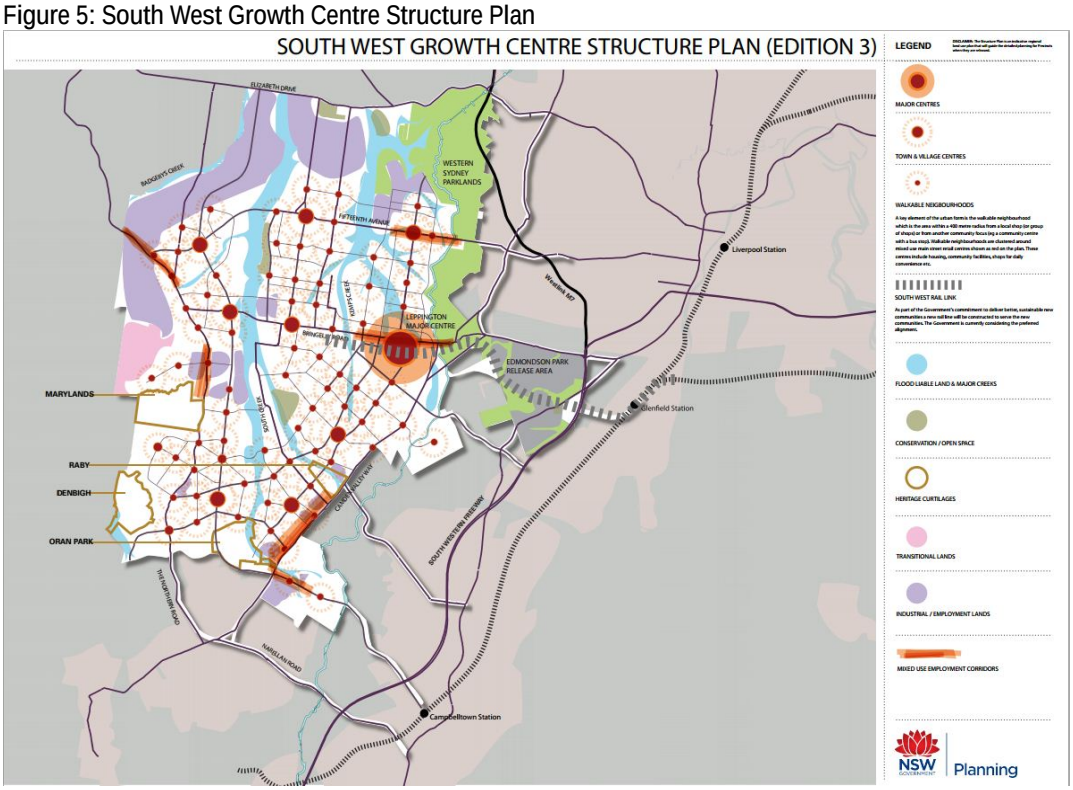
The South West Growth Centre will likely have a particular significance to the immediate area of Badgerys Creek as it is located immediately south of the airport site. Figure 5 shows the structure plan for the South West Growth Centre. The area is made up of approximately 17,000 hectares and falls within the Local Government Areas (LGAs) of Liverpool, Camden and Campbelltown. The Growth Centre has the potential for over 42,000 homes to accommodate 130,000 residents and will be supported by a major centre at Leppington.

The South West Growth Centre is divided into 18 precincts which are progressively being released for rezoning to enable sustainable long-term development. The status of the precincts, as at August 2014, is shown below in Figure 6. As can be seen in the map, seven of the precincts have been rezoned to allow urban development, the Leppington precinct has been released and is undergoing precinct planning, while the remainder are yet to be released or rezoned.

As a means of accommodating the significant growth within Western Sydney, the Australian and NSW Governments are funding a 10 year, $3.6 billion road investment program for western Sydney. The Western Sydney Infrastructure Plan will deliver major road infrastructure upgrades to support an integrated transport solution for the region and capitalise on the economic benefits from developing the proposed airport at Badgerys Creek.

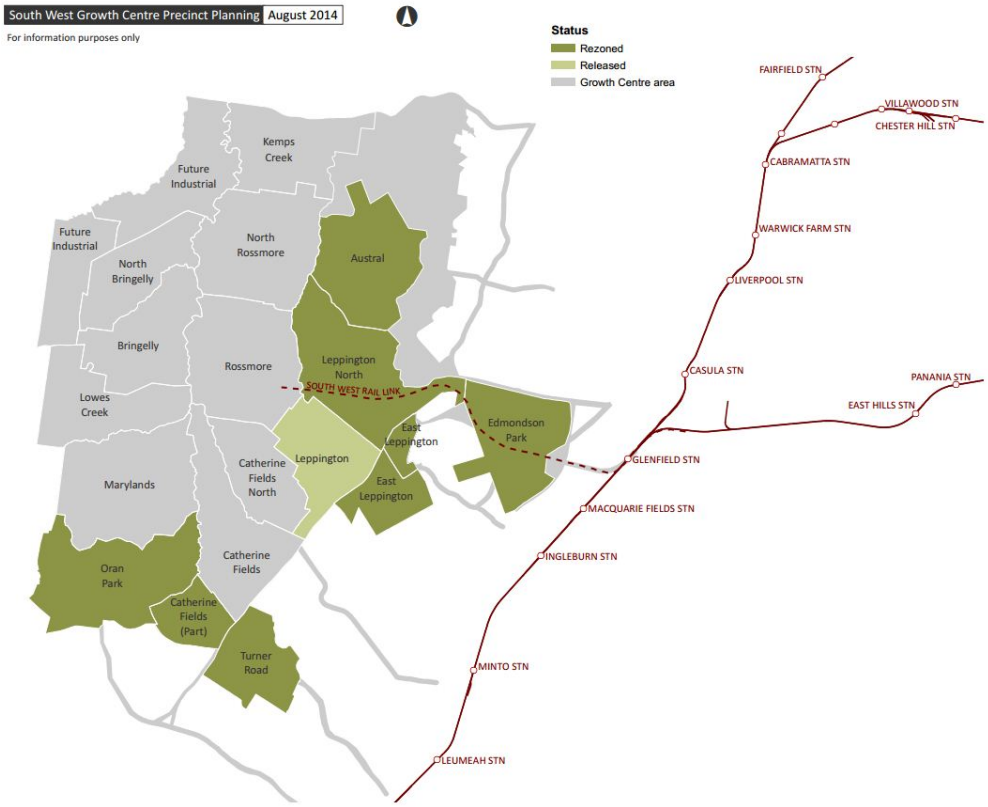
The Plan provides improved road transport capacity ahead of future traffic demand, as planned residential and employment development comes online in western and south western Sydney growth centre precincts and the Broader Western Sydney Employment Area. Figure 7 identifies some of the key infrastructure to be provided surrounding the airport site.

Figure 5: South West Growth Centre Structure Plan



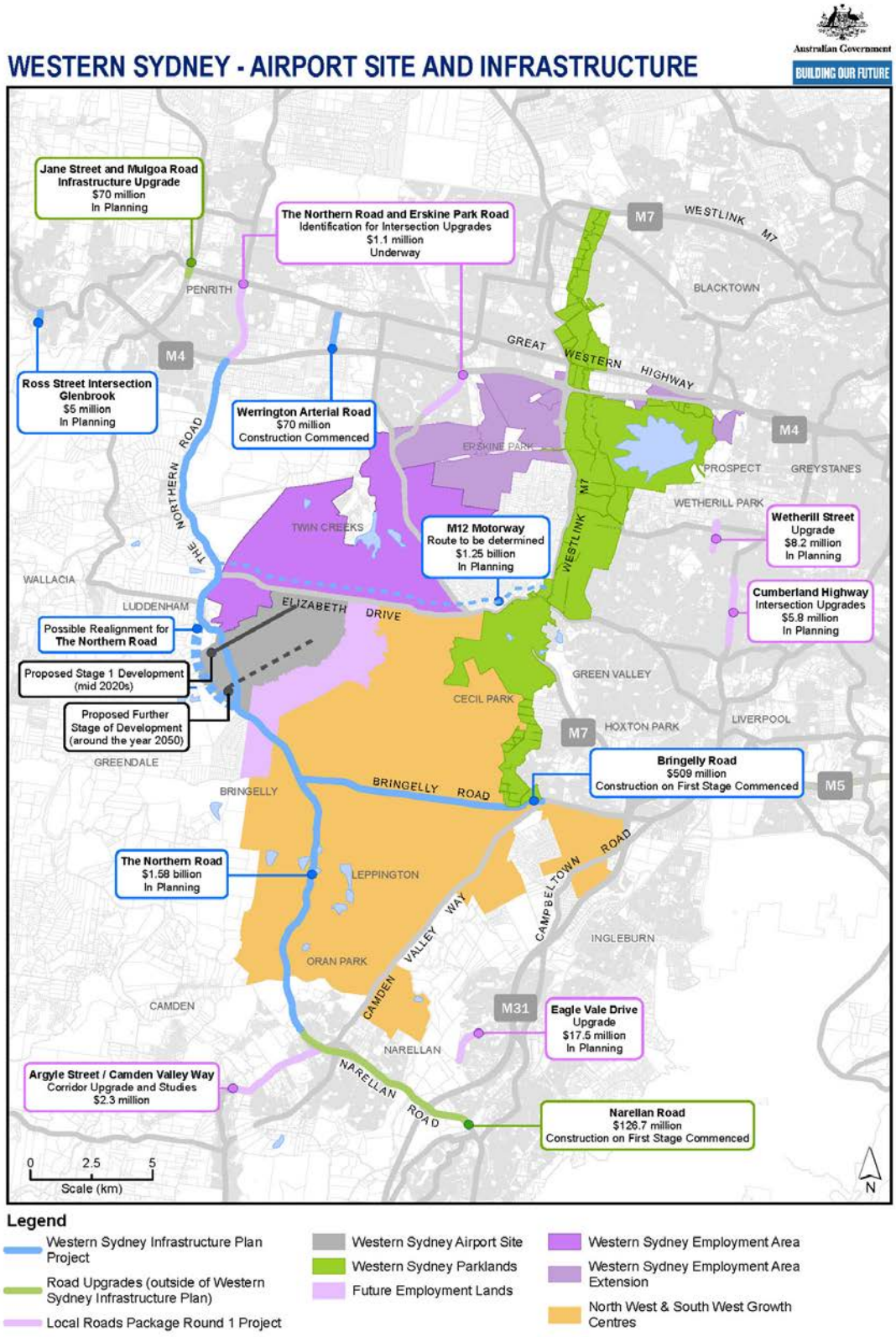
Source: NSW Department of Planning & Environment

Figure 6: South West Growth Centre Structure Plan



Source: NSW Department of Planning & Environment

Figure 7: Western Sydney Infrastructure Plan



Source: Australian Government Department of Infrastructure and Regional Development

2 Potential Impacts on Land Uses

2.1 Impact of a Greenfield Airport on Property Values

The most readily apparent and assessable effect of an airport in terms of surrounding non-commercial real estate is from aircraft noise. Health impacts and odour as a result of aircraft emissions and fuelling operations can also be significant (Yim et al, 2015; Dedoussi, IC and Barrett S, 2014). Whilst numerous studies attest to health effects, there is no evidence to suggest a separately quantifiable direct impact on property prices. Accordingly, for the purposes of this study on property price impacts, aircraft noise is considered as the principal factor, whilst acknowledging that this may reflect a combination of other factors such as air quality emissions and odour as well as noise.

2.2 Residential vs. Non Residential Land Use Considerations

This paper does not specifically quantify the impacts of the proposed airport on property prices from commercial or employment based land uses due to difficulties in measurement. Whilst the study addresses noise impact on residential property and large lot land holdings, non-residential land uses may also be affected by proximity to the airport site and by noise incidence. Commercial (office, hotel, retail etc.), industrial and employment related uses are considered to be less adversely impacted, due to their building characteristics, nature of activities and lower evening/night time use. More importantly these land uses are likely to materially benefit from the increased economic activity that will come from their proximity of the proposed airport, which will positively impact land values. Community type land uses, such as schools, places of worship, health care and aged care facilities which are affected by noise are less contestable in the market and likely to be restricted by land use zoning and planning controls, hence the impact of noise is not generally price related. Accordingly, the study does not seek to quantify price effects on such non-residential property.

Part B – INVESTIGATION AND ANALYSIS

3 Methodology

This section provides a description of the approaches and methodology used in this assessment.

This report has been prepared in accordance with the EIS guidelines for the proposed airport development issued by the Australian Government Department of the Environment on 22 January 2015.

3.1 Approach

Assessing the impact of noise to property values is challenging. This report had initially intended to assess the impact of noise on property values surrounding the airport site through reference to 'greenfield airport' development sites. However, due to the lack of availability of these sites and the lack of location comparability with overseas sites, this report has instead had primary reference to a number of airports throughout Australia. These have been selected based on their comparability of scale and/or proximity to state capital cities.

This assessment adopted a robust multi-tiered methodology that ensures multiple factors are considered.

Review of Prior Studies

To inform the study, an extensive review of prior studies was undertaken. This included a mix of academic studies, both quantitative and qualitative. Approximately 10 studies were reviewed from local and international sources in order to provide context and to determine how other professionals' (academic and industry) research compares with the analysis undertaken within this report. This section makes specific reference to the property value analysis undertaken as part of the 1997-1999 Second Sydney Airport EIS. While the analysis is now dated, it does still provide a robust and valid assessment of the changes in house prices due to aircraft exposure from the establishment of a third runway at Sydney Airport.

Residential – Cross Section Analysis

This report performed a cross section analysis of areas surrounding a number of Australian airports. This analysis was performed on airports where a significant composition of the surrounding land is considered residential land. The cross section analysis utilised multiple regression techniques to identify noise as a variable and determine the impact, if any, it has on sale price.

Residential Time Series Analysis for Sydney Airport

This report performed an analysis of the price change over time which may, in part, be attributable to noise. Utilising Sydney Airport as a case study, we identified suburbs deemed to be affected by aircraft noise and compared their long term historic growth rates with suburbs deemed unaffected by aircraft noise.

Large Lot Land Holding – Cross Section Analysis

This report performed a cross section analysis of areas surrounding a number of Australian airports. This analysis was performed on airports where a significant composition of the surrounding land is large lot land holdings. The cross section analysis utilised multiple regression techniques to identify noise as a variable and determine the impact, if any, it has on sale price.

Price Change Related to Announcement of Airport Development at Badgerys Creek

This report performed analysis on sales within a 5 kilometre radius of the airport site. The analysis compared the long-term median price growth of suburbs around the airport site with the growth over the same period for Western Sydney and the Sydney metropolitan region. The analysis made primary reference to growth rates both pre and post the most recent announcement of 14 April 2014 that Badgerys Creek will be the site for the proposed airport.

3.2 Aircraft Noise Measurement

Aircraft noise is generally regarded as the most apparent and discernible impact on residential property in the vicinity of an airport and under the aircraft flight paths. However, there is no evidence to suggest that air pollution may be considered to exhibit co-linearity with noise in terms of possible price effect.

The degree of perceived disturbance is related to factors such as:

- the intensity, pitch and duration of the noise events; and
- the frequency of noise events and their incidence, particularly at different times of the day.

These in turn are related to:

- aircraft types and payload;
- aircraft operating characteristics in flight;
- height and angle of climb/descent;
- aircraft ground operating modes, taxiing, engine testing, and holding;
- prevailing wind and temperature;
- ambient noise levels;
- dwelling construction and orientation;
- nature and utility of private outdoor areas associated with dwellings; and
- Characteristics of the affected household.

To take account of these various characteristics and perceptions, aircraft noise is commonly measured in terms of Noise Exposure Forecast (NEF), a technique developed in the 1960s in the US to gauge the impact on affected communities. In 1979, the Australian Government commissioned a major survey into community reactions to aircraft noise by the National Acoustic Laboratories (Hede and Bullen, 1982) which led to a refined system named the Australian Noise Exposure Forecast (ANEF).

The ANEF system is primarily a land use planning tool which takes account of the:

- Intensity, frequency and duration of aircraft noise events; and
- Distribution of take offs and landing movements throughout the day and night, with greater weighting given to noise events between 7pm and 7am.

The information is presented in the form of maps showing sets of contours of equal noise exposure, which may represent:

- Actual or historic exposure, termed Australian Noise Exposure Index (ANEI), based on noise measurement of flight data for a previous period, typically for a calendar year; and
- Predicted exposure, termed ANEF which describes potential impacts of aircraft noise based on assumptions of airport and aircraft operations, traffic mix and flight paths.

ANEF maps are prepared for major airports using Australian Standard AS2021 methodology as part of their masterplanning requirements every five years, and are required to be endorsed by Airservices Australia. They typically have a 20 year time horizon based on forecast traffic mix, and show noise forecasts between 20 and 45 ANEF at 5 step intervals.

The critical contour is the 20 ANEF which corresponds to the minimum level for acceptability for residential buildings. It corresponds to 10 per cent of the population being seriously affected by noise, according to the 1980 NAL study. The region within the range of 20-25 ANEF is classed as conditionally acceptable for residential buildings, requiring noise attenuation to meet the target levels of AS2021. (McLeod and Latimore, Airservices Australia, 2014).

In addition to ANEF/ANEI measures, aircraft noise is also measured with regard to the number of instances in a given period of noise events above a certain volume. Most Australian airport master plans now include contour maps showing measures such as N70 (N noise events of 70 decibels). Typically, the areas affected by 70 decibel events extend well beyond the 20 ANEF area (McLeod and Latimore, op cit). However, these plans are not subject to Airservices Australia endorsement and hence, have not been used as a primary noise measure in this study.

This study has had regard to ANEI and ANEF contour maps prepared by Brisbane, Melbourne, Adelaide and Perth airports and Airservices Australia for Sydney Airport. In the absence of ANEF plans for Melbourne's Avalon airport this study has had regard to an estimated impact area, being at the northern point of the runway, 2 kilometres across and 10 kilometres north. These parameters were selected from analysing the ANEF contours of the other selected airports.

Areas falling within ANEI or ANEF contour bands 20 to 35 have been the focus of this study. Areas subject to ANEI or ANEF above 35 are not considered suitable for residential use under Australian Standards and any residences falling within this noise exposure level at other Australian airports have either been subject to Government acquisition or extensively insulated and are not considered a part of the residential market.

3.3 Defining the Outputs from the Regression Analysis

As identified above, for a number of the approaches undertaken, we have utilised regression analysis as a tool to understand the statistical relationship between aircraft noise and property prices.

What is regression analysis?
Linear regression analysis measures the strength in the relationship between two variables. Multi-variable regression analysis measures the strength in the relationship between multiple variables and the dependent variable. For these analyses, a multi-variable analysis using Sale Price as the dependent variable was run. The strength of regression was measured against the independent variables (see **Sections 5.2** and **7.2** for the list of independent variables utilised).

Key Outputs
The regression analyses provide a number of outputs; the key ones utilised for this study are as follows:

- **R-Squared** – This number explains how much of the variation in the dependant variable (sale price) is explained by the independent variables (number of bedrooms, land size etc.). The closer to 1.0, the better the regression line fits the inputted data. For example; the R-Squared of the Adelaide analysis, 0.83, means that 83 per cent of variation in Sale Price is explained by changes in the independent variables selected.
- Any R-Squared value above 0.7 is considered to be a strong and statistically significant relationship. A value between 0.5 and 0.7 is considered a moderate relationship. A value below 0.5 indicates weak-to-no relationship with minimal statistical significance.

- **T-Stat –** This allows determination of the strength in statistical significance of each of the independent variables examined. The t-stat is the coefficient estimate divided by the standard error. If your regression is based on what statisticians call a "large" sample (30 or more observations), a t-statistic greater than 2 (or less than -2) indicates the coefficient is significant with >95 per cent confidence (University of Delaware, 2008).

- **P-Value –** This also allows determination of the statistical significance of each of the independent variables examined. The P-Value is a percentage value of the statistical probability that the hypothesis of the variable being an influential factor upon the dependant variable is not true. A P-Value of less than 5 per cent (5 per cent uncertainty) is considered to be statistically significant for this study. This figure is a benchmark figure from cited literature (Princeton University, 2007).

3.4 Limitations

Introduction

As supported by the report's review of relevant literature, undertaking analysis to determine the impact on property prices of aircraft noise in particular is challenging. No single study or method provides definitive results that have perfect comparability for the proposed airport. Further, consideration must be given to the mix of current land uses around Badgerys Creek which comprises rural, rural-residential and a small amount of traditional residential.

As a result of the above, this report has relied upon a number of methodologies to produce a series of results which when analysed together, can show a general trend. This trend can then be used to draw more clear conclusions on the affectation on property values.

Real Estate Data Limitations

Real-estate, by definition, lacks homogeneity as every landholding and transaction is different. Notwithstanding this, this report has analysed large real estate transactional datasets to derive statistically significant results for this study and our observation is that many of the variables that explain price are not within these data sets. A number of variables that have not been accounted for include, but is not limited to:

- Property views
- Natural light
- Soil type
- Proximity to services
- Accessibility to public transport

This observation holds true, especially on the large lot land holdings, as there can be a larger number of variables that potential buyers may consider including the nature and style of the dwelling on the land, the type of activity carried on, the nature and productivity of the land and its physical and biological characteristics.

Aircraft Noise Data Limitations

In order to determine which properties lie within each contour band, the properties were geographically mapped and then overlayed with ANEI/ANEF mapping. This enabled each property to be individually identified within each ANEI/ANEF range. There may be limitations to the identification of properties in each ANEI/ANEF range due to:

- mapping irregularities
- human error
- properties partially within 2 ranges

The property sales information gathered was supplied by CoreLogic and thus we are unable to ensure its quality and reliability. Notwithstanding this, various initiatives have been implemented to improve the quality and reliability of this data to the extent possible.

Method Specific Limitations

The methodologies used within the report pose some limitations. The limitations are method-specific and will be discussed within each section below.

4 Review of Prior Studies

4.1 Academic Literature and Professional Studies

This review of literature aims to isolate the effect that airports has upon property values. This can be a difficult condition to isolate due to the negatives and positives of the locality (i.e. noise pollution, traffic conditions, ease of public transportation) with a focus on the main influential factor being noise pollution. In order to determine the effects upon property prices that airports have on the local property market, academic articles and industry reports have been reviewed. These documents use differing methodologies and techniques such as exploiting models and equations, measuring noise levels and measuring distances in order to estimate a discount upon property prices within the affected area.

4.1.1 Approaches

1. Hedonic Price Models

Hedonic price models, in the form of multiple regression models, are commonly adopted (e.g. Abelson 1980 & Kholodilin and Mense 2014). The value of a dwelling is assumed to be determined by a range of dwelling-specific and locality-related characteristics, such as: the type of property, the number of bedrooms and rooms, the property's age, the distance to transport, socio-economic characteristics of the neighbourhood and environmental factors. Following this logic, a multiple regression equation can be set up with the property's value as the dependant variable and the various characteristics as independent, explanatory variables. A varying number of models have been designed to determine the value of dwellings, with the primary method altering values dependant on the dwellings noise exposure forecast (NEF).

The strength of the hedonic price model method is that it enables the specific contribution to values (positive and negative) of each housing characteristic to be isolated. Provided that enough of the correct explanatory variables are included in the regression analysis, and that they are accurately measured, the technique should be robust.

Limitations

- It may be difficult to obtain accurate and consistent information for all the explanatory variables that are, and have to be, included in the regression model. In some cases these variables need to be approximated. There may also be a degree of subjectivity in the process of estimation, such as the “quality of a view”;
- If significant explanatory variables are not included in the regression analysis, for example because of a lack of information, then specification errors may arise where significant explanatory power is incorrectly attributed to other variables;
- The explanatory variables have to be truly independent. For example, neighbourhood characteristics can lead to problems of multi-collinearity. This may influence the quantity of variables that should be assessed, with increased quantities of variables increasing chances of overlap. Multi-collinearity may also have a significant bearing on other descriptors such as the size and quality of housing; and
- It may be difficult to achieve a statistically significant result of the impact of aircraft noise on property values. To obtain a statistically significant number is increasingly difficult as the level of noise affectation decreases to levels where there is no consensus on whether the noise affectation noticeably affects people’s lives. The level where it generally becomes subjective to the population is under the 20 ANEF noise contour.

Findings of Hedonic Price Models

This report has selected a number of studies, including those reviewed for the previous EIS (JLW, 1997), that utilise the measurement of noise affectation of ANEF or equivalent. These studies are listed in Appendix A and summarised below.

The studies that determined a quantitative analysis of the affected areas have been made comparable through the associated depreciative property value as a percentage per ANEF

value. The overall assessment of these studies is that there is a correlation within a range of 0.3 per cent to 2.25 per cent discount of property value per unit of ANEF.

The studies illustrate a large range in which property prices can be influenced. However, when looking specifically at the studies directly comparable to Sydney, the rates are more consistent ranging from a discount of 0.4 – 1.1 per cent per unit of ANEF.

While this broad price depreciation range from noise affectation appears to be relevant, there is a number of limitations of applying the results to a broader area. It became apparent from this data that:

- higher priced dwellings are more affected by noise exposure (JLW Research and Consultancy, 1993)
- property located in areas of higher noise levels suffer disproportionately higher rates of deprecation in comparison to areas with lower noise levels (JLW Research and Consultancy 1993; Levesque, 1994)
- the statistical significance of a relationship between price impact and noise levels below 20 ANEF was consistently found to be low (BIS Shrapnel, 1990; Poulsen, 1990)
- the impact on property values varies according to the type of property, with some studies showing differences between detached dwellings, units and townhouses, possibly for some of the reasons mentioned above (JLW, 1997).

2. Match Pair Analysis

Some literature identifies an alternative approach to assess the impact on property values:, a match pair analysis (Nelson, 2004; Bell, 2001; JLW Research & Consultancy, 1993). This method is similar to Hedonic Price Models as noise is still utilised as a variable to explain price. Within this method, properties are selected that are similar in nature (i.e. dwelling and land size, number of bedrooms, aspect, etc.) where one is impacted by noise and the other is considered un-impacted. By comparing the transacted price of two properties with the same characteristics, differentiated primarily by noise, the analysis effectively accounts for all other variables. As such, the theory suggests that the price differential represents the impact associated with noise.

Limitations

The method described above is conceptually similar to the Hedonic Pricing approach, however, the key limitation identified relates to the lack of sample size typically utilised. Further, the potential for human error is introduced in this method with the requirement of selecting similar properties, especially with the lack of homogeneity in Australian housing stock.

3. Time Series Analysis

As an alternative to the above two approaches, some literature discusses the longer term impact of having a property affected by noise. The approach used to assess this impact is a time series analysis (e.g. Bell, 2001 and Nelson, 2004). This is where movements in prices in the affected area are benchmarked against other unaffected areas which have similar housing characteristics. Other factors which may affect the change in median or average prices in an area such as new dwelling construction, alterations and additions activity or the opening of new roads may need to be accounted for. Also, differential growth rates may occur depending upon distance to the city centre and strength of housing sub markets.

Determining price movements in the market around an airport before and after its construction can be further analysed by comparing this to other influential variables such as distance from flight paths, distance from the airport, turnover rates and increase of noise above thresholds.

Nelson (2004) performed a study of 23 airports, both international and Australian, and their impact on the market over a set period of time. The results concluded that properties affected by noise were reduced in value at a rate of 0.5 to 0.6 per cent per decibel (above standard levels in urban areas). Properties affected by flight path noise experience average noise levels of 65-80 decibels while regular urban areas are 50-60 decibels. This finding is consistent with other studies of a property value reduction of 10 per cent.

Furthermore, Bell (2001) also determined how property values are impacted by noise within the United States and came to similar conclusions. It was determined that properties incurred a 1.12

per cent loss of value per decibel above the 'quiet' threshold. This quiet threshold is not directly stated as it can change depending on local conditions. The adverse impact of noise on the residential property market ranges from -15.7 per cent to -19 per cent for moderately priced dwellings which is a higher range than other findings such as Nelson (2004).

Limitations

Housing prices may move in anticipation of an impending change in aircraft noise (or other influence). Following a change in noise levels, the market may 'over-correct' as existing owners sensitive to noise try to sell, leading to a relative oversupply of stock. Hence, time series analysis may be more appropriately undertaken for a period before and after the change in noise levels. It does not account for other factors that could impact upon the median house price such as new dwelling construction, alterations, urbanisation/urban renewal and additions activity or the opening of new roads.

4.1.2 Conclusions and Implications for this Study

While it is noted that there is a large range of influences that could be affecting the variation of property values in noise affected areas, case studies within Australia and internationally support the hypothesis that aircraft noise adversely impacts property values.

The quantitative studies indicate there is a large range in which property prices can be influenced by noise. While this study of reviewed papers cannot directly isolate the price influence of noise, the studies directly associated with Australia and specifically Sydney conclude a more consistent value ranging from 0.4 per cent – 1.1 per cent of depreciation per unit of ANEF. It is also apparent through this data that the values of higher-priced houses are impacted more dramatically than lower-priced houses.

Time series analysis indicates that properties affected by noise were reduced in value at a rate of 0.5 to 0.6 per cent per decibel (above standard levels in urban areas). Properties affected by aircraft flight path noise experience average noise levels of 65-80 decibels while regular urban areas are 50-60 decibels. This finding is consistent with other studies of a property value reduction of 10 per cent. Alternative studies indicative higher level affectation of between -15.7 per cent to -19 per cent.

In summary, the literature review found that predominantly, three methods of analysis have historically been used in assessments of the impact of noise to pricing. These methods assess two different impacts, they are:

- The Hedonic Price Model (also referred to as Regression Analysis) and Match Pair Analysis – these quantify the impact of noise as a variable in determining price.
- Time Series Analysis – this determines any longer-term impact of growth in pricing of a noise affected location compared to a non-noise affected location.

Considering the above, we have determined to utilise a method that assesses each of the above impacts. Based on the ability to draw upon significant data sets, we have elected to utilise the hedonic price model. We have also determined to perform a time series analysis for the study.

Unlike previous studies, we have conducted both approaches on 'traditional' residential uses, as well as on large lot land holdings, which are more comparable with that found at Badgerys Creek and surrounding suburbs.

4.2 JLW Advisory Technical Paper 4 (1997-1999 EIS)

JLW Advisory authored the Technical Paper 4: Property Values that formed part of the 1997-1999 Second Sydney Airport EIS (JLW Advisory, 1997). This report focussed on extrapolating the changes experienced in property values following the opening of the Sydney Airport's third runway in November 1994 which represented the first major change in aircraft operations in Sydney for several decades. Noise levels changed as a result of increased north-south operations on the existing runway and the new runway, and the closure of the east-west runway.

The prior study performed two separate methods of analysis: quantitative and qualitative. These are summarised below.

4.2.1 Quantitative Analysis

The quantitative analysis undertaken involved an examination of housing price changes under the flight paths of Sydney Airport as a result of changed aircraft operations in 1994/1995. The approach used is as follows:

- Establish general housing price trends in the Sydney region;
- Test for differences in aggregate price movements between areas under flight paths and not under flight paths; and
- Examine house price movements in noise zones under flight paths, and in similar 'control areas' away from flight paths.

Sydney Metropolitan and Regional Price Trends

Changes to median house and strata titled dwelling values are provided below in Table 7.

Table 7: Median Price Movements – Sydney Region

	Annual Change 1992-96	Total Change 1992 - 1996	Change 1994-1995	Local Government Areas
Houses				
Sydney Region	3.1%	11.9%	0.5%	Excludes Gosford, Wyong, Blue Mountains, and Wollondilly
Northern	3.9%	15.4%	-2.8%	Ku-ring-gai, Ryde, Hornsby, Hunters Hill, Lane Cove, Willoughby
Inner West	5.3%	21.2%	-3.3%	Leichhardt, Marrickville, Drummoyne, Concord, Burwood, Ashfield
Eastern	7.4%	30.8%	-6.8%	Botany, Randwick, Woollahra, Waverley
Southern	3.8%	14.9%	0.4%	Hurstville, Rockdale, Kogarah, Sutherland
Multi-Unit Dwellings				
Sydney Region	3.4%	13.3%	1.8%	Excludes Gosford, Wyong, Blue Mountains, and Wollondilly
Northern	3.7%	14.7%	0.0%	Ku-ring-gai, Ryde, Hornsby, Hunters Hill, Lane Cove, Willoughby
Inner West	4.0%	15.7%	3.2%	Leichhardt, Marrickville, Drummoyne, Concord, Burwood, Ashfield
Eastern	8.0%	33.5%	0.0%	Botany, Randwick, Woollahra, Waverley
Southern	2.0%	7.6%	0.0%	Hurstville, Rockdale, Kogarah, Sutherland

Source: NSW Valuer General
Note: The annual change is the average change between December 1992 and September 1996.

Between December 1992 and September 1996, median annual growth rates for houses and units were in the 3-3.5 per cent range for the Sydney region as a whole.

There are however clear regional differences in growth rates. The following patterns are evident:

- Prices increased most in the eastern region which covers the eastern suburbs excluding the City of Sydney. Median prices for houses and units increased by 7.4 percent and 8 percent per annum respectively;
- The inner west region also grew strongly, by 5.3 per cent per annum for houses and 4 percent for units (strata titled dwellings); and
- Much lower growth was experienced in 1995 in all regions, reflecting the slowdown in the housing market as a whole in that year. The largest fall was in the eastern region, where house prices fell by 6.8 per cent in 1995.

Aggregate Price Impacts of the Opening of the Third Runway

To assess the price impact of the changes in flight operations, the study reviewed house price movements at the postcode level between 1994 and 1995 comparing prices between areas

under the approaches from the north, approaches from the east and west, and all other postcodes in the Sydney region. These results are summarised in Table 8 below.

Table 8: House Price Movements 1994/95

	Average Change in Price	Change in Prices (Standard Deviation)	T Statistic @ 95% Against Not Under Approaches	Number of Postcodes
Under Northern Approaches	-1.16%	5.33%	1.75	24
Not under Approaches	1.74%	7.85%	-	172
Under East/West Runway	1.55%	4.10%	0.11	20

Based on the above, there appeared to be a statistically significant adverse impact on house prices under the northern approaches compared to not under the approach. Such a finding is consistent with previous airport noise impact research for Sydney Airport (BIS Shrapnel, 1990). However, the results under the east-west runway approaches were counter-intuitive. If the reduction in noise levels has been priced into housing, a greater increase in price should have been expected. The study identified two potential reasons. Firstly, buyers believing that the closure was not permanent. Secondly, the postcode data did not precisely match the flight paths.

Median Price Trends under the Flight Path Compared to 'Control Areas'

To further explore the effects of the changed aircraft noise levels at Sydney Airport, the study identified areas directly impacted by noise, both along the north-south and east-west flight paths. The median price of these areas was then compared to a number of 'control areas' to derive any pattern associated with noise.

The table below identifies the suburbs selected along the north-south flight path as well as the 'control areas'. For the suburbs under the northern flight path, the study provided the 1995 ANEI levels and the approximate change in ANEI between 1992/1993 and 1995.

Table 9: Suburbs under Northern Flight Path and 'Control Areas'

Suburb/Locality	ANEI Band 1995	ANEI Change 1992/3 to 1995 (Increase)
Marrickville	30+	2-3.5
Marrickville/Stanmore	25-30	2.4-4.3
Enmore/Stanmore/ Leichhardt	25-30	2.4-4.2
Leichhardt	25-30	2.4-4.3
Petersham, Enmore, Lilyfield, Leichhardt	20-25	2.8-7.1
Enmore, Lilyfield	20-25	3.6-7.1
Petersham, Leichhardt	20-25	2.8-5.4
Newtown/Annandale/Lilyfield	15-20	3.8-7.1
Drummoyne	20-25	3.1-4.6
Glebe/Balmain (Control)	Under 10	-
Croydon/Ashfield (Control)	Under 10	-
Hunters Hill	20-25	3.2-5.2
Hunters Hill/Boronia Park	15-20	4.3-5.9
Gladesville	10-15	3.3-6.5
Hunters Hill	10-15	3.2-4.3
West Lane Cove	15-20	4.0-5 .3

East Ryde	15-20	4.0-6.5
West lane Cove/ Riverview	10-15	2.9-4.3
East Ryde	10-15	4.6-5.5
West Lindfield /West Pymble	10-15	2.4-3.4
St Ives /East Lindfield (Control)	Under 10	-
Putney/Ryde (Control)	Under 10	-

The key observations from the study of house price movements to the north of Sydney Airport between 1992 and 1996 are summarised below:

- Marrickville, containing houses at ANEI levels above 30 in 1995, experienced a significant reduction in median and mean prices in 1995, compared to 1994, though the volume of sales was relatively low. However, for the whole 1992 to 1996 period, median and mean price growth was not significantly different to that of the inner west as a whole. The ANEI change from 1992/3 to 1995 was between 2 and 3.5;
- Marrickville/Stanmore and the Petersham, Enmore, Lilyfield and Leichhardt areas (being in the 25-30 and 20-25 ANEI in 1995) showed price movements very similar to the control areas (inner west, Glebe/ Balmain and Croydon/Ashfield). There was a reasonably consistent pattern of price growth between 1992 and 1996. Growth rates fell with distance from the city centre. While Marrickville/Stanmore did experience lower overall price growth between 1992 and 1996 than other areas in the inner west, there was no reduction in prices in 1995.
- It was possible that the eastern parts of Marrickville/Stanmore and the Petersham, Enmore, Lilyfield and Leichhardt areas, being between the existing northern flight path and that of the new third runway, would have experienced a more significant price change compared to western parts of these areas. To test this, these areas were split into western and eastern components. The results did not confirm the hypothesis. In fact, properties on the eastern shoulder of the main north-south runway appreciated at least as much or more than those on the western shoulder. Stronger price growth closer to the city centre may have contributed to this;
- Newtown/Annandale/Lilyfield is under the flight path of the third runway and experienced a relatively large rise in ANEI in 1995 (between 3.8 and 7.1). The area was in the 15-20 ANEI band in 1995. Median price growth between 1992 and 1996 and in 1994/95 was very similar to the Glebe/Balmain control area to the east;
- Boronia Park and Hunters Hill experienced a significant drop in sales activity in 1995. Median and mean price growth was well under growth for the northern Sydney region. Middle and upper quartiles grew very little. Sales price movements on the Hunters Hill peninsula are volatile and heavily influenced by waterfront sales;
- A clearer pattern emerged when areas to the north of the Parramatta River were grouped according to the 1995 ANEI level. In the 15-20 ANEI band (Hunters Hill/Boronia Park; West Lane Cove and East Ryde), median and mean price movements were well below the northern Sydney region control area. Sales volumes were also down 24 percent compared to -10 percent in the northern control area;
- Once areas in ANEI 10-15 were aggregated, any third runway price effect possibly evident in some suburbs disappeared. Median and mean price growth was at least equal to the northern Sydney region and no fall in medians or means were evident in 1995, even though the northern Sydney region as a whole fell three percent on both measures; and
- Even though Lane Cove West/Riverview appeared to experience a significant fall in median and average values in 1995, median and mean price growth was around 30 percent for the 1992 to 1996 period, well in excess of the northern Sydney region growth rates.

The table below identifies the suburbs selected along the east-west flight path as well as the 'control areas'. For the suburbs under the eastern and western flight path, the study provided the 1995 ANEI levels and the approximate change in ANEI between 1992/1993 and 1995.

Table 10: Suburbs under Eastern and Western Flight Paths and 'Control Areas'

Suburb/Locality	ANEI Band 1992/3	ANEI Change 1992/3 to 1995 Decrease
Kingsford/South Coogee	20-25	-10 to -15
Matraville/Maroubra (Control)	Under 10	-
Randwick/Bronte (Control)	Under 10	-
Rockdale	25-30	-10 to -15
Penshurst	20-25	-10 to -15
Peakhurst/Mortdale	15-20	Over -10
Kingsgrove (Control)	Under 10	-

Houses in areas west of Sydney Airport, which had previously been under the flight path (Rockdale; Penshurst; and Peakhurst/Mortdale), experienced median price increases of between 25 percent and 33 percent for the 1992 to 1996 period. However, only Rockdale which was in the 25-30 ANEI in 1992/3, experienced a rise in prices in the year following the closure of the east-west runway. Control areas to the north (Kingsgrove) and south (Blakehurst) experienced lower overall growth rates.

Median house prices in Kingsford/South Coogee increased by 26 percent between 1992 and 1996 and six percent in 1995. However there were substantial differences between the control areas to the north and south. To the north, median house price growth in Randwick/Bronte was very high, up 63 percent over the same period. Price growth to the south was much lower at 16 percent.

It could not be concluded that median price growth in Kingsford/South Coogee was a direct result of the reduction in aircraft noise. Rather, growth is consistent with wider house price trends in the area over the period being examined.

Other Influences on Housing Values Under Flight Paths

Apart from general influences on housing markets such as interest rates, other factors identified within the study that may have changed housing values in those areas affected by variations in aircraft noise are discussed below.

- Housing Supply and Improvements – The supply and alterations of housing can cause shifts in housing value. The study identified that aside from typical housing supply and alteration numbers during the period assessed, a significant change related to dual occupancy housing within this period may have had an influence toward house prices. In 1991, State Environmental Planning Policy No. 25 was amended to permit Torrens title subdivision across Sydney down to 230 square metres. In May 1995, the subdivision clause was removed and meant that dual occupancy developments could then only offer separate title in areas permitting strata titled dwellings to be constructed.
- Infrastructure – Three major road infrastructure changes in the Sydney region occurred within the study period. This included; the opening of the Gore Hill Freeway and Harbour Tunnel in August 1992, the opening of the Glebe Island Bridge and Arterial in December 1995 and the opening of the M2 Motorway linking Ryde to Baulkham Hills in 1997.
- Sydney Olympics – The awarding of the 2000 Olympic Games in October 1993 was identified as a potential influence on the housing market in the inner west regions.

4.2.2 Qualitative Analysis (Survey of Real Estate Agents)

The qualitative analysis undertaken involved a survey of 28 real estate agents, covering six areas under the northern flight path of Sydney Airport from West Pymble to Hunters Hill. The study performed this analysis as a way of assessing impacts associated with lower levels of noise as well as a means of verifying the results of the quantitative analysis.

The real estate agents were asked to compare identical dwellings in two nearby areas. One of the properties was under the flight path within 10-15 or 15-20 ANEI (1995) and the other property was in an area under 10 ANEI which was used as a control. The subject and control areas are shown in Table 11 below.

Table 11: Areas Surveyed with Survey of Real Estate Agents

Interview Area	Comparison Areas		Number of Real Estate Agents Surveyed
	Subject Area (A)	Control Area (B)	
1	Hunters Hill	Woolwich	4
2	Boronia Park	Gladesville	4
3	East Ryde	Ryde	4
4	West Lane Cove	Lane Cove	6
5	West Lindfield, Killara	East Lindfield	6
6	West Pymble	Pymble, St Ives	4

Utilising the conclusions derived from the survey, the study made an assessment of impact related to aircraft noise on property values. This has been summarised in Table 12 below. Study areas 2 and 3 were excluded from this component of the analysis as the survey identified the subject area property values were higher than the 'control areas' and the housing stock was not homogenous enough to provide confidence in the real estate agents belief of noise affectation correlation to value.

Table 12: Assessed Impact of Aircraft Noise on Property Values from Survey of Real Estate Agents

Interview Area	Average Assessed House Value		Assessed Impact of Aircraft Noise ($) on Subject Area House		Assessed Impact of Aircraft Noise (%) on Subject Area House	
	Subject Area	Control Area	Minimum	Maximum	Minimum	Maximum
1	$656,250	$847,500	$0	$24,400	0	3.1
4	$350,000	$395,000	$0	$9,000	0	2.8
5	$368,333	$407,500	$2,000	$6,000	0.5	1.7
6	$408,000	$463,000	$0	$15,000	0	3.3

There was considerable variation in the estimated impact of aircraft noise in each interview area. Maximum impacts were generally below three percent. In many areas, at least one agent believed noise had no effect on relative values. If selected at all, aircraft noise and over-flying was never the most important contributor to house price differences.

Results for Interview Area 1 (Hunters Hill) and Interview Area 4 (Lane Cove West) were surprising given that the previous median price analysis showed a much more significant price effect in 1994/95. The small impact found in the survey may be because the respective control areas were quite close to the flight path of the third runway and therefore not totally noise free.

These results suggest that there may be a price discount for houses in the 10-15 and 15-20 ANEI ranges, but it is quite small.

Other key observations from the survey included:

- The impact of aircraft noise differed depending on buyer type. Young couples with no children were less concerned by aircraft noise when purchasing a property, while conversely the elderly and couples with children were more influenced by aircraft noise in their purchase;
- Houses were perceived to be generally affected consistently in each geographic area, although higher priced housing in each area appeared to be more sensitive to aircraft noise; and
- Apartments or townhouses were perceived to be less affected than houses with units not positioned on the top floor seen to benefit from a degree of noise insulation both from above and adjacent.

4.2.3 Conclusions and Implications for the Study

Although not directly derived from the quantitative analysis, the study had consideration to the results of the quantitative and qualitative assessments and the literature review to determine devaluation factors applied to the assessment of the aggregate impact of aircraft noise. This can be seen in Table 13 overleaf.

Table 13: Housing Price Devaluation Results – (JLW 1997)

ANEC Band[1]	Devaluation Range	Assumed Devaluation[2]
Under 15	Nil	Nil
15 to 20	0 to 6%	3%
20 to 25	5.9% to 13.6%	8%
25 to 30	8.6% to 19.6%	15%
30 to 35	10.9% to 24.3%	20%

Note: 1. No devaluation estimates were made for ANEC > 35 in the 1997 study because dwellings located in this noise band at the other Australian airports have been either acquired or extensively insulted.
2. Compared to under 15 ANEC.

The assessment of the possible impacts on residential property values due to perceived noise affectation shows a direct correlation to purchaser's confidence and property value. Within the analysis, there was a clearer relationship between noise affectations to urbanised housing stock in comparison to apartments.

The study did not consider rural land lots which are more highly dominant in areas such as Badgerys Creek. The study then put forward that, with this limitation in mind, it could be assumed that there will be some level of consistency in results.

We believe that the large lot land holdings, comparable with those found in proximity to the airport site, fundamentally differs from traditional urbanised residential property and as such, the impact of noise to its pricing would also differ. Therefore, as previously mentioned, in undertaking this current study separate analysis was performed for traditional residential property as well as large lot land holdings.

5 Residential Cross Section Analysis

5.1 Objective

The objective of this analysis is to gain an understanding of the discount, if any, of aircraft noise to residential property values.

5.2 Methodology

In seeking to derive the potential discount of noise to property values, we have utilised multiple variable regression analysis. This report has performed a cross section analysis of areas surrounding a number of Australian airports. This analysis was performed on airports where a significant composition of the surrounding land comprises residential land in order to achieve a significant sample size. The cross section analysis utilised regression to identify noise as a variable and determine the impact, if any, it has on sale price.

The airports selected for the analysis consisted of Melbourne Airport (Melbourne), Brisbane Airport (Brisbane), Sydney (Sydney) and Adelaide Airport (Adelaide). These airports have been selected based on their comparability of scale and/or proximity to state capital cities.

In order to create a dataset for analysis, recent sales evidence were sourced from the CoreLogic database. In order to ensure a significant sized data set, the period of time was adjusted depending on location. This timeframe was either set at 2011 to 2014 (Adelaide and Melbourne) or 2013 to 2014 (Sydney and Brisbane).

These sales were plotted on a mapping system and overlayed with ANEI/ANEF contour bands of each airport to determine the level of affectation of each property. These ANEI/ANEF contour bands were sourced from airport master plan documents (Adelaide Airport, 2013; Brisbane Airport Australia, 2014; Melbourne Airport, 2014; Perth Airport, 2014) or from Air Services Australia (2014).

Sales of both affected and unaffected residential properties in different ANEI/ANEF contour bands were collated. Four contour bands were used[3]:

- Less than 20 ANEI/ANEF;
- 20 to 25 ANEI/ANEF;
- 25 to 30 ANEI/ANEF; and
- 30 to 35 ANEI/ANEF.

The sales data was then refined in order to determine a more homogeneous property sample as well as to improve the integrity of the data and remove some outliers to the data set. In order to do this, the following were removed:

- Non-residential properties;
- Unit and apartment sales;
- Sales where no bedrooms were noted;
- Land areas of less than 100 square metres;
- Sales exchanged for less than $100,000[4];
- Sales greater than $2,000,000; and
- Any additional outliers we were able to identify (i.e. potential development site sales).

[3] For the purpose of our analysis, we considered "Less than 20 ANEI" as unaffected. We did not source sales within areas greater than 35 ANEI as evidence was too limited to perform the analysis. It is also our understanding that this level is generally accepted as too high for residential occupation.
[4] $500,000 for Sydney

Once the data set was finalised, the regression analysis was performed. The first step in performing this analysis was the identification of various independent variables, which in part explain the dependant variable (sale price). The variables that were analysed, where possible, included:

- Suburb;
- Number of bedrooms[5];
- Number of bathrooms[6];
- Land size;
- Building area;
- Time factor (i.e. when the sale occurred); and
- Noise affectation.

5.3 Melbourne – Melbourne Airport

5.3.1 Locational Context

Melbourne Airport is Victoria's primary passenger airport and is located approximately 23 kilometres north west of the Melbourne central business district (CBD). The table below provides a summary of the aircraft movements for Melbourne airport.

Table 14: Movements at Melbourne Airport for the 2014 Calendar Year

Airport	Over 136 tonnes	Between 7 and 136 tonnes	Under 7 tonnes	Helicopter	Military	Total
MEL	46,664	180,554	806	-	310	228,334

Source: Airservices Australia[7]

The airport is surrounded by a variety of land uses, including low density residential, parklands, rural-residential, rural and industrial facilities. The majority of low density residential is clustered towards the east of the airport.

5.3.2 Melbourne Specific Considerations

In performing this analysis specifically for Melbourne Airport, we had reference to the following:

Suburbs analysed: Attwood, Coolaroo and Dallas (All east of airport).

Variables: Suburb, Number of beds, Land size, Time factor and Noise affectation.

Sales period: 2011 to 2014 (inclusive).

The analysis was performed on sales that fell in the following ANEF contour bands: Less than 20, 20 to 25 and 25 to 30.

5.3.3 Findings and Limitations

The table below summarises the results of the regression analysis performed for residential sales surrounding Melbourne Airport.

[5] All sales with a number of bedrooms greater than 5 were noted as 5. This was a small portion of sales (Sydney 10, Melbourne 2, Brisbane 4 and Adelaide 3).
[6] All sales with a number of bathrooms greater than 3 were noted as 3. This was a small portion of sales (Sydney 10 & Adelaide 1). Due to quality of data, we were unable to utilise this variable for Brisbane & Melbourne.
[7] http://www.airservicesaustralia.com/wp-content/uploads/Airport-Movement-Calendar-YTD-November-2014_ORS1.pdf

Table 15: Results of Regression Analysis for Melbourne Airport

	Result	Implication
R Squared	0.67	Moderate relationship
t-Stat (Noise)	-1.37	Not significant
P-Value	0.17	Not Significant
Impact (Noise)	-1.93%	Not considered

Source: CoreLogic, JLL Strategic Consulting.

The R-Squared reveals a moderate relationship between the independent variables and the dependent variable (sale price). However, the t-Stat and P-Value for the noise variable identifies that, although a relationship between the variables does exist, the relationship between noise and price is not significant. The impact assessed for noise is a devaluation of 1.93 per cent, however it is not considered relevant as neither the t-Stat nor P-Value is significant.

5.4 Brisbane – Brisbane Airport

5.4.1 Locational Context

Brisbane Airport is Queensland's primary passenger airport and is located approximately 18 kilometres south west of the Brisbane CBD. The table below provides a summary of the aircraft movements for Brisbane airport.

Table 16: Movements at Brisbane Airport for the 2014 Calendar Year

Airport	Over 136 tonnes	Between 7 and 136 tonnes	Under 7 tonnes	Helicopter	Military	Total
BNE	22,394	186,498	16,640	210	836	226,578

Source: Airservices Australia[8]

The airport is surrounded by a variety of land uses with significant industrial holdings to the south. The majority of low density residential is clustered towards the west, south and south west of the airport.

5.4.2 Brisbane Specific Considerations

In performing this analysis specifically for Brisbane, we had reference to the following:

Suburbs analysed: Cannon Hill, Hawthorne and Morningside (South and south west of airport).

Variables: Suburb, Number of beds, Land size, Time factor and Noise affectation.

Sales period: 2013 to 2014 (inclusive).

The analysis was performed on sales that fell in the following ANEF contour bands: Less than 20 and 20 to 25.

5.4.3 Findings and Limitations

The table below summarises the results of the regression analysis performed for residential sales surrounding Brisbane Airport.

Table 17: Results of Regression Analysis for Brisbane Airport

	Result	Implication
R Squared	0.45	Weak relationship
t-Stat (Noise)	-5.54	Significant
P-Value	0.00	Significant
Impact (Noise)	-10.67%	Considered

Source: CoreLogic, JLL Strategic Consulting

[8] http://www.airservicesaustralia.com/wp-content/uploads/Airport-Movement-Calendar-YTD-November-2014_ORS1.pdf

The R-Squared reveals a weak relationship between the independent variables and the dependent variable (sale price). However, the P-Value and t-Stat for the noise variable identifies that, although the overall relationship between the variables is weak, the relationship between noise and price is significant. The impact assessed for noise is a devaluation of 10.67 per cent.

A limitation to the analysis performed in Brisbane is the impact to pricing associated with proximity to, as well as views of, water. While the suburb variable will partially account for this factor, it cannot completely asses its impact. The exclusion of this as a variable has likely impacted the R-Squared result for the Brisbane analysis.

5.5 Sydney Airport

5.5.1 Locational Context

Sydney Airport is Australia's primary passenger airport and is located approximately 12 kilometres south of the Sydney CBD. The table below provides a summary of the aircraft movements for Sydney Airport.

Table 18: Movements at Sydney Airport for the 2014 Calendar Year

Airport	Over 136 tonnes	Between 7 and 136 tonnes	Under 7 tonnes	Helicopter	Military	Total
SYD	70,302	239,478	7,362	11,726	720	329,588

Source: Airservices Australia[9]

The airport is surrounded by a variety of land uses with significant industrial holdings to the north and north east. The majority of residential properties are towards the west, north and east of the airport.

5.5.2 Sydney Specific Considerations

In performing the analysis specifically for Sydney, we had reference to the following:

Suburbs analysed: Marrickville, Stanmore, Sydenham and Tempe (North and north west of airport).

Variables: Suburb, Number of beds, Number of baths, Land size, Time factor and Noise affectation.

Sales period: 2013 to 2014 (inclusive).

The analysis was performed on sales that fell in the following ANEI contour bands: Less than 20, 20 to 25, 25 to 30 and 30 to 35.

5.5.3 Findings and Limitations

The table below summarises the results of the regression analysis performed for residential sales surrounding Sydney Airport.

Table 19: Results of Regression Analysis for Sydney Airport

	Result	Implication
R Squared	0.64	Moderate relationship
t-Stat (Noise)	1.55	Not significant
P-Value	0.12	Not Significant
Impact (Noise)	1.40%	Not considered

Source: CoreLogic, JLL Strategic Consulting

The R-Squared reveals a moderate relationship between the independent variables and the dependent variable (sale price). However, the t-Stat and P-Value for the noise variable identifies that, although a relationship between the variables probably exists, the relationship between

[9] http://www.airservicesaustralia.com/wp-content/uploads/Airport-Movement-Calendar-YTD-November-2014_ORS1.pdf

noise and price is not significant. The impact assessed for noise is an appreciation of 1.40 per cent, however, is not considered relevant as the t-Stat and P-Value is not significant.

5.6 Adelaide – Adelaide Airport

5.6.1 Locational Context

Adelaide Airport is South Australia's primary passenger airport and is located approximately 8 kilometres west of the Adelaide CBD. The table below provides a summary of the aircraft movements for Adelaide Airport.

Table 20: Movements at Adelaide Airport for the 2014 Calendar Year

Airport	Over 136 tonnes	Between 7 and 136 tonnes	Under 7 tonnes	Helicopter	Military	Total
ADL	3,574	80,708	18,164	4,912	240	107,598

Source: Airservices Australia[10]

The airport is primarily surrounded by low density residential uses, with some industrial facilities immediately adjacent.

5.6.2 Adelaide Specific Considerations

In performing this analysis specifically for Adelaide, we had reference to the following:

Suburbs analysed: Cowandilla, Hilton and North Adelaide (North west of airport).

Variables: Suburb, Number of beds, Number of baths, Land size, Building area, Time factor and Noise affectation.

Sales period: 2011 to 2014 (inclusive).

The analysis was performed on sales that fell in the following ANEI contour bands: Less than 20, 20 to 25, 25 to 30 and 30 to 35.

5.6.3 Findings and Limitations

The table below summarises the results of the regression analysis performed for residential sales surrounding Adelaide Airport.

Table 21: Results of Regression Analysis for Adelaide

	Result	Implication
R Squared	0.83	Strong relationship
t-Stat (Noise)	-3.31	Significant
P-Value	0.00	Significant
Impact (Noise)	-6.59%	Considered

Source: CoreLogic, JLL Strategic Consulting

The R-Squared reveals a strong relationship between the independent variables and the dependent variable (sale price). The t-Stat and P-Value additionally highlights that this relationship also exists for the noise variable as the relationship between noise and price is significant. The impact assessed for noise is a devaluation of 6.59 per cent.

In terms of the Adelaide analysis, it is likely that due to the availability of more reliable data on the building area/size, the R-Squared showed a strong relationship as the relationship between building area and sale price was significant (t-Stat of 14.76).

As Adelaide showed a significant relationship between noise and sale price, further analysis was performed. This analysis separated the different levels of ANEI as separate variables[11]. The results of this additional analysis can be seen below.

[10] http://www.airservicesaustralia.com/wp-content/uploads/Airport-Movement-Calendar-YTD-November-2014_ORS1.pdf

Table 22: Results of Additional Regression Analysis for Adelaide

Adelaide – Noise impact on price (compared to noise levels < 20 ANEI)			
Correlation			
R Squared			0.83
Noise Specific Outputs			
Noise Range (ANEI)	t-Stat (Noise)	P-Value (Noise)	Impact (Noise)
20 to 25	-2.96	0.00	-8.27%
25 to 30	-2.17	0.03	-14.74%
30 to 35	-2.30	0.02	-19.75%

Source: CoreLogic, JLL Strategic Consulting

The R-Squared remained at a similar level (i.e. maintained an overall strong relationship). While the t-Stat did decrease, it remained significant. The above table shows that according to the regression analysis, the devaluation increases as the noise band increases, although at a lesser rate than the initial devaluation.

5.7 Summary of Key Findings

The table below summarises the key results of the cross section analysis performed for the four case studies.

Table 23: Summary of Cross Section Analysis Results

Airport	N (sample size)	r^2	Noise impact on price	Noise factor significance		Comment
				t -stat	P-value	
SYD	682	64.2%	1.4%	1.55	12.11%	Noise is less likely to be significant
MEL	525	66.9%	-1.9%	-1.37	17.25%	Noise is less likely to be significant
BNE	379	45.2%	-10.7%	-5.54	0.00%	Noise is very likely to be significant
ADL	290	83.3%	-6.6%	-3.31	0.10%	Noise is very likely to be significant

Source: CoreLogic, JLL Strategic Consulting

As identified above and discussed previously, the results of the analysis differed greatly by location. We had primary reference to the relationship between noise and price (represented by the t-Stat and P-Value) as opposed to the R-Squared. This is because we are assessing the impact associated with noise and not the ability of all the variables selected to explain price.

The low percentage of the P-Value of both Adelaide and Brisbane shows the impact of noise affectation on property prices is directly related with a low level of uncertainty. This certainty of the correlation between factors enables the study to focus more clearly on both Adelaide and Brisbane in order to determine definitive results. In contrast, the Sydney and Melbourne analysis provided high uncertainty, and therefore has not been analysed further.

The impact for Adelaide and Brisbane is summarised in the table overleaf. As previously identified, this impact has been split by ANEI noise area.

Table 24: Impact of Exposure to Different Levels of Noise on House Prices, Brisbane and Adelaide

Airport		Noise impact on price (compared to noise levels < 20ANEI/ANEF)		
		ANEI/ANEF 20-25	ANEI/ANEF 25-30	ANEI/ANEF 30-35
BNE	Price impact	-10.7%	N/A	N/A
	Sample size	183	No relevant sales	No relevant sales
ADL	Price impact	-8.3%	-14.7%	-19.8%
	Sample size	132	29	14

Source: CoreLogic, Airservices Australia, JLL

[11] We were unable to perform this additional analysis on the other case study with significant relationship, Brisbane, as the sales for that case study were all either Less than 20 or 20 to 25 ANEF.

6 Residential Time Series Analysis

6.1 Objective

The objective of this analysis is to test if areas impacted by aircraft noise from Sydney Airport have a price growth differential compared with non-impacted suburbs.

6.2 Methodology

In deriving the growth differentials, we have compared growth rates from the following long term data series:

- Average house prices from noise impacted suburbs in Sydney (defined as suburbs with more than 50 per cent of their area within an ANEI of 20 or greater).
- Average house prices from non-noise impacted suburbs in Sydney (defined as suburbs with less than 50 per cent of their area within a ANEI of 20 or greater) but located close to the noise impacted areas
- Average house prices from the Sydney metropolitan area

6.3 Data Analysis

In performing this analysis, research was based on the period commencing 31 March 1991 to period ending 30 September 2014. This report has equally weighted all suburbs by basing all data series to 100.

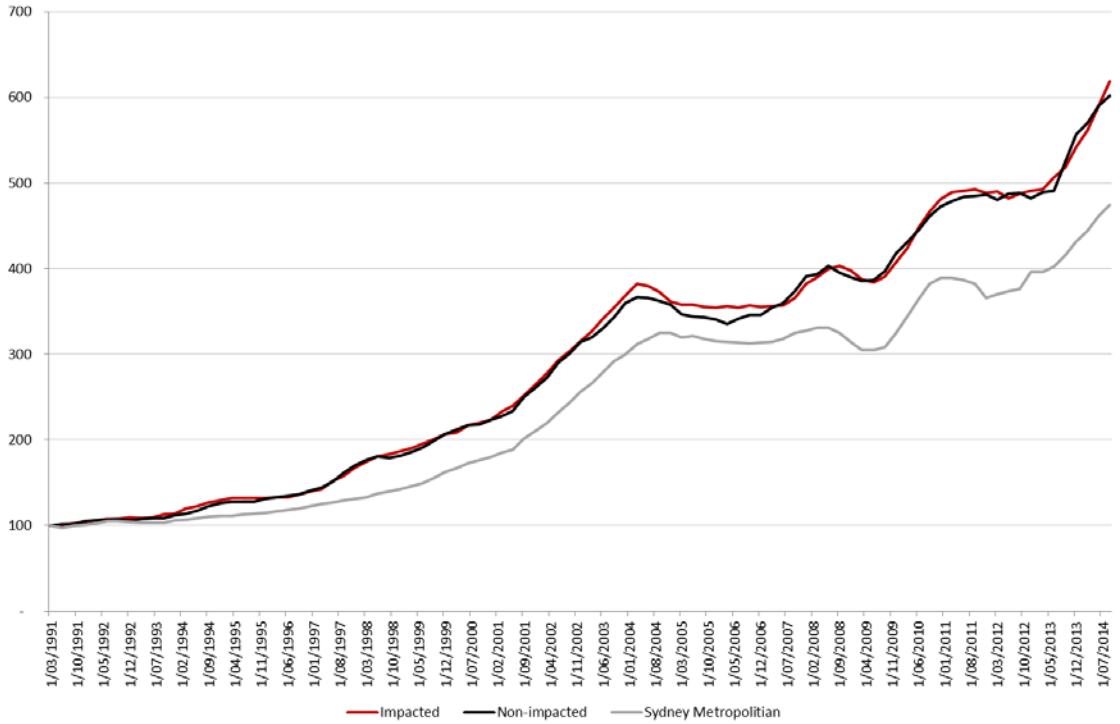
Specific suburbs selected in this analysis are provided below:

Noise Affected:	Kyeemagh, Petersham, Mascot, Stanmore, Tempe, Sydenham, Marrickville and Botany
Noise Unaffected:	Dulwich Hill, Summer Hill Brighton-Le-Sands, Bexley, Arncliffe, Earlwood, Lewisham, Haberfield, Pagewood, Erskineville and Alexandria
Sydney metropolitan:	All Sydney

6.4 Summary of Key Findings

The chart overleaf identifies the relative price growth of all data series. The data series of both affected and unaffected respond to growth similarly due to their proximity to one another. Their growth rate is higher than the Sydney metropolitan area data series due to their proximity to the city and location within high demand areas. The Sydney metropolitan area data set is influenced by all suburbs throughout Sydney and has a lower growth rate due to the incorporation of the suburbs with sub-par growth rates.

Figure 8: Price Growth of Noise Affected, Unaffected and Sydney Metropolitan Area (Base 100)



Source: CoreLogic, JLL

The table below compares the annualised growth outputs of noise affected, noise unaffected and Sydney Metropolitan areas.

Table 25: Price Growth of Noise Affected Areas, Unaffected Areas and the Sydney Metropolitan Area

	Annual Price Growth 1991-2014
Affected	7.98%
Unaffected	7.84%
Sydney Metropolitan	6.77%

Source: CoreLogic, JLL

The results suggest that there is no material difference in property pricing between areas that are defined as noise affected versus those that are nearby but considered not noise affected. This is further supported by the comparison to the Sydney metropolitan area data which comprises an average of all suburbs (but mostly those not affected), and which has shown significant underperformance compared with the two other data series.

This reports observation on the above is that factors of greater significance than noise also affect their long term growth profile, with gentrification being the key factor relevant to the Inner Sydney data series over this timeframe. Another key factor is the level of desirability or demand for housing in inner Sydney areas with proximal localities to amenities and the city.

While this analysis does provide an indication of noise affectation on property values, it cannot draw any definitive findings. Other methods such as cross sectional analysis of large lot land holdings should be able to draw more comparable results to the proposed airport development through the similarity of large lot land sizes.

Leveraging off this analysis, this report has also had consideration to the potential impact of property prices that may occur from a second runway opening at the proposed airport. The long term time series analysis on Sydney Airport (see Section 6) suggest no material difference in property pricing of noise versus non-noise affected areas. This outcome is in line with our expectations – that is, that factors of much greater significance will influence property values than any incremental increase in noise. More specifically, it is considered that the positive influences of in-area employment as well as improved amenity and services will more than likely make up for any additional noise from the second runway.

Further, this report makes the observation that there have been significant advancements in aircraft technology over the last 20 years that have meant a material reduction in noise footprints across all major Australian airports, despite increasing aircraft movements. It is considered to be a reasonable assumption that advancements will be made in the future, further reducing aircraft noise. For the above reasons this report has not assessed a negative impact to property prices due to the opening of a second runway at the proposed airport.

7 Large Lot Land Holding Cross Section Analysis

7.1 Objective

The objective of this analysis is to gain a greater understanding of the discount, if any, of aircraft noise to large lot land property values as distinct from the previous analysis which is primarily related to other types of residential areas which are dissimilar to the context of the proposed airport. It is noted that the combination of the two key factors (new greenfield airport and large lot land holdings) is intrinsically linked and this report has found a scarcity of specific relevant literature which applies to these circumstances.

7.2 Methodology

Similar to the method used to derive the discount for residential property values, this section performed a cross section analysis of areas surrounding a number of Australian airports. This analysis was performed on airports where a significant composition of the land surrounding is considered large lot land holdings, and where the airports are comparable in scale and/or proximity to state capital cities. The cross section analysis utilised regression to identify noise as a variable and determine the impact, if any, it has on sale price.

The airports selected for the analysis consisted of: Melbourne Airport, Perth Airport and Avalon Airport.

Sales evidence was sourced from the CoreLogic database. Unlike the residential analysis, in order to create a significantly sized dataset to analyse, sales evidence over an extended period was required. This timeframe was either set at 2000 to 2014 (Perth and Avalon) or 2004 to 2014 (Melbourne).

Sales of both affected and unaffected large lot land holdings were gathered. Due to the scale and size of the properties and in instances the limited information related to ANEF contours, these sales were assessed based on an affected versus unaffected[12] variable rather than by ANEF contour bands.

The ANEF contours were sourced through the airport master plans for Melbourne and Perth, however the ANEI contours were unavailable for Avalon Airport. Due to this, this report adopted a 2 kilometre wide and 10 kilometre long area from the end of the runway, as an estimated ANEF contour. These parameters were selected from analysing the ANEF contours of the other selected airports.

The sales data was then refined in order to determine a more homogeneous property sample as well as to improve the integrity of the data and remove some outliers to the data set. In order to do this, the following were removed:

- Non-rural or residential properties (i.e. commercial premises);
- Land areas of less than 1,500 square metres[13];
- Sales exchanged for less than $100,000[14]; and
- Any additional outliers we were able to identify (i.e. development site sales).

Once the data set was finalised, the regression analysis was performed. The first step in performing this analysis was the identification of various independent variables, which in part explain the dependant variable (sale price). The variables that were analysed, where possible, included:

- Suburb;

[12] For the purpose of our analysis, we considered “Less than 20 ANEI” as unaffected.
[13] 1,500 sqm was selected as eliminated all ‘traditional’ residential uses from the analysis
[14] $150,000 for Melbourne Airport

- Land size;
- Time factor (i.e. when the sale occurred); and
- Noise affectation.

7.3 Melbourne – Melbourne Airport

7.3.1 Locational Context

Melbourne Airport is Victoria's primary passenger airport and is located approximately 23 kilometres north west of the Melbourne CBD. The table below provides a summary of the aircraft movements for Melbourne Airport.

Table 26: Movements at Melbourne Airport for the 2014 Calendar Year

Airport	Over 136 tonnes	Between 7 and 136 tonnes	Under 7 tonnes	Helicopter	Military	Total
MEL	46,664	180,554	806	-	310	228,334

Source: Airservices Australia[15]

The airport is surrounded by a variety of uses, including low density residential, parklands, rural-residential, rural and industrial facilities. The majority of large lot land holdings are clustered towards the north, north-west and west of the airport.

7.3.2 Melbourne Airport Specific Considerations

In performing this analysis specifically for Melbourne Airport, we had reference to the following:

Suburbs analysed: Bulla, Diggers Rest, Oaklands Junction and Wildwood (North, north-west and west of airport).

Variables: Suburb, Land size, Time factor and Noise affectation.

Sales period: 2004 to 2014 (inclusive).

The analysis was performed on sales that were either affected or unaffected by aircraft noise.

7.3.3 Findings and Limitations

The table below summarises the results of the regression analysis performed for rural and rural-residential sales surrounding Melbourne Airport.

Table 27: Results of Regression Analysis for Melbourne Airport

	Result	Implication
R Squared	0.55	Moderate relationship
t-Stat (Noise)	1.88	Not significant
P-Value (noise)	0.06	Not Significant
Impact (Noise)	15.35%	Not considered

Source: CoreLogic, JLL Strategic Consulting

The R-Squared reveals a moderate relationship between the independent variables and the dependent variable (sale price). However, the t-Stat and P-Value for the noise variable identifies that, although a relationship between variables does exist, the relationship between noise and price is not significant. The impact assessed for noise is an appreciation of 15.35 per cent, however this is not considered relevant as the t-Stat and P-Value is not significant.

[15] http://www.airservicesaustralia.com/wp-content/uploads/Airport-Movement-Calendar-YTD-November-2014_ORS1.pdf

7.4 Melbourne – Avalon Airport

7.4.1 Locational Context

Avalon Airport is located approximately 55 kilometres south west of the Melbourne CBD. The table below provides a summary of the aircraft movements for Avalon Airport.

Table 28: Movements at Avalon Airport for the 2014 Calendar Year

Airport	Over 136 tonnes	Between 7 and 136 tonnes	Under 7 tonnes	Helicopter	Military	Total
AVV	108	3,618	1,038	560	128	5,452

Source: Airservices Australia[16]

The airport is surrounded primarily by rural, rural-residential and low density residential land. The majority of large lot land holdings are clustered towards the north and west of the airport.

7.4.2 Avalon Specific Considerations

In performing this analysis specifically for Avalon, we had reference to the following:

Suburbs analysed: Avalon, Lara, Littler River (North and west of airport).

Variables: Suburb, Land size, Time factor and Noise affectation.

Sales period: 2000 to 2014 (inclusive).

The analysis was performed on sales that were either affected or unaffected by aircraft noise.

7.4.3 Findings and Limitations

The table below summarises the results of the regression analysis performed for large lot land holdings sales surrounding Avalon Airport.

Table 29: Results of Regression Analysis for Avalon

	Result	Implication
R Squared	0.38	Weak relationship
t-Stat (Noise)	-0.71	Not significant
P-Value (noise)	0.48	Not Significant
Impact (Noise)	-7.84%	Not considered

Source: CoreLogic, JLL Strategic Consulting

The R-Squared reveals a weak relationship between the independent variables and the dependent variable (sale price). In addition, the t-Stat and P-Value for the noise variable identifies that the relationship between noise and price is not significant. The impact assessed for noise is a devaluation of 7.84 per cent, however, is not considered relevant as the t-Stat and P-Value is not significant.

7.5 Perth – Perth Airport

7.5.1 Locational Context

Perth Airport is located approximately 12 kilometres east of the Perth CBD. The table below provides a summary of the aircraft movements for Perth Airport.

[16] http://www.airservicesaustralia.com/wp-content/uploads/Airport-Movement-Calendar-YTD-November-2014_ORS1.pdf

Table 30: Movements at Perth Airport for the 2014 Calendar Year

Airport	Over 136 tonnes	Between 7 and 136 tonnes	Under 7 tonnes	Helicopter	Military	Total
PER	30,632	111,774	6,412	678	414	149,910

Source: Airservices Australia[17]

The airport is surrounded by a variety of uses, including low density residential, parklands, rural-residential, rural and industrial facilities. The majority of large lot land holdings are clustered towards the north of the airport.

7.5.2 Perth Specific Considerations

In performing this analysis specifically for Perth, we had reference to the following:

Suburbs analysed: Caversham and West Swan (both north of airport).

Variables: Suburb, Land size, Time factor and Noise affectation.

Sales period: 2000 to 2014 (inclusive).

The analysis was performed on sales that were either affected or unaffected by aircraft noise.

7.5.3 Findings and Limitations

The table below summarises the results of the regression analysis performed for large lot land holdings sales surrounding Perth airport.

Table 31: Results of Regression Analysis for Perth

	Result	Implication
R Squared	0.29	Weak relationship
t-Stat (Noise)	0.01	Not significant
P-Value (noise)	0.99	Not Significant
Impact (Noise)	0.20%	Not considered

Source: CoreLogic, JLL Strategic Consulting

The R-Squared reveals a weak relationship between the independent variables and the dependent variable (sale price). In addition, the t-Stat and P-Value for the noise variable identifies that the relationship between noise and price is not significant. The impact assessed for noise is an appreciation of 0.20 per cent, however, is not considered relevant as the t-Stat and P-Value is not significant.

7.6 Summary of Key Findings

The table below summarises the key results of the cross section analysis performed for large lot land holdings sales for the selected three case studies.

Table 32: Significance of Noise Exposure on Large Lot Land Holdings Pricing

Airport	N (sample size)	r^2	Noise impact on price	Noise factor significance		Comment
				t-stat	P-value	
MEL	193	54.8%	15.3%	1.88	6.13%	Not considered significant
AVV	330	38.0%	-7.8%	-0.71	47.79%	Not considered significant
PER	178	28.9%	0.2%	0.01	98.95%	Not considered significant

Source: CoreLogic, Airservices Australia, JLL

These results suggest that there is no discernible or statistically significant relationship between large lot land holdings exposed to aircraft noise in excess of 20 ANEF and the sale price. It is hypothesised that there are significant factors other than noise which have a greater impact on price, including the nature and style of the dwelling on the land, the type of activity carried on, the nature and productivity of the land and its physical and biological characteristics.

[17] http://www.airservicesaustralia.com/wp-content/uploads/Airport-Movement-Calendar-YTD-November-2014_ORS1.pdf

Structured interviews with real estate agents interstate (Melbourne, Avalon and Perth) would likely provide a better understanding of the impact on proximity to an operational airport on large lot land holding property values.

8 Price Change Related to the Announcement of the Proposed Airport at Badgerys Creek

8.1 Objective

The objective of this analysis is to gain an understanding of the impact to pricing, if any, of the announcements of the commencement of the EIS for Badgerys Creek airport in 1996 and the in April 2014 announcement that Badgerys Creek would be site of a new airport to large lot land holdings in the vicinity of the airport site.

8.2 Methodology

In 1996 the then Australian Government announced the commencement of the Second Sydney Airport Proposal EIS (1997-1999 EIS), which was focussed on Badgerys Creek as the site for an airport. Similarily on April 2014 the Australian Government confirmed that the site for Western Sydney's new airport would be Badgerys Creek. These announcements could be expected to have had an impact on property values in the vicinity, both from perceptions of possible adverse impacts, such as noise and air pollution, and positive anticipatory and positive effects in terms of improved infrastructure, employment opportunities and potential for higher density and intensity of land use.

This study undertook an analysis on sales in the vicinity of the airport site. The analysis compared the long-term median price growth of suburbs around the airport site with the growth over the same period for Western Sydney and the Sydney metropolitan region. The analysis made primary reference to growth rates both before and after the announcement in April 2014 that Badgerys Creek will be the site for a new airport.

This study has had reference to sales price data series over a 24 year period (1991 to 2015). The study analysed the change in property sales values over the period prior to and the 12 months that followed the April 2014 announcement on land within a 5 kilometre radius of the centre of Badgerys Creek, utilising quarterly moving median prices from the CoreLogic database.

The growth in residential prices in the suburbs lying within 5 kilometres of Badgerys Creek was compared with the Western Sydney and Sydney Metropolitan areas. Overall, this includes some 1,500 residential sales since Q2/1991 in the suburbs of Bringelly, Kemps Creek, Luddenham, Mount Vernon and Rossmore. (Note data series for residential sales in the suburb of Austral and Greendale, which are within 5 kilometres or in Badgerys Creek, were not included due to insufficient sales transactions).

The data represent the average of the four quarterly moving median sale prices for each of the five suburbs around Badgerys Creek (i.e. each quarterly figure is the average of the four preceding quarterly median sale prices for that suburb, and then averaged across the 5 suburbs) index to a base of 100 at Q2 1991.

8.3 Data Analysis

In order to perform this analysis, we utilised the long-term CoreLogic median house price data series at a suburb level. Included within the CoreLogic data series is their definition of house, being "generally, a house is defined as any dwelling situated on a single title".

Within this analysis we have utilised the definition of 'Western Sydney' as provided by GHD. The table below identifies both the planning regions and Local Government Areas included within this definition.

Table 33: Definition of "Western Sydney"

Planning Region (from A Plan for Growing Sydney)	Local Government Areas
Sydney South West	Liverpool
	Fairfield
	Camden
	Campbelltown
	Wollondilly
Sydney West	Penrith
	Hawkesbury
	Blue Mountains
Sydney West Central	Auburn
	Bankstown
	Blacktown
	Holroyd
	Parramatta
	The Hills

Source: GHD

8.4 Key Findings and Limitations

The analysis indicated a slight diminution of value in the 12 months following the previous announcement of the Airport in 1996 of 2.28 per cent compared with a growth of 3.55 per cent in Western Sydney and 6.50 per cent in the Sydney Metropolitan areas. We consider the findings from the 1996 announcement must be discounted as it relates to the context of that period. Factors that influenced the then announcement include: the lack of site specific certainty, with other locations still considered; noise sensitivity in the community, in part influenced by the opening of the third runway at Sydney Airport; and, the strong local opposition from a number of groups, as well as a statement by Qantas citing its preference of increased capacity at Sydney Airport.

The findings and growth rates for the April 2014 announcement are summarised in the table below and illustrated in the charts overleaf.

After considering the analysis undertaken above the table below summarises the impact of noise on property values by land use type. Broadly, the residential assessment has had primary consideration to the statistically significant results from the Brisbane and Adelaide Airports, with support for assessed impact coming from the academic literature and professional studies. The analysis on the large lot land holdings had reference to both the interstate analysis on Avalon, Perth and Melbourne Airports as well as analysis of price changes related to the announcements at Badgerys Creek.

Table 34: Long Term Residential Growth Rates in 5 suburbs Around Badgerys Creek Before and After 2014 Announcement

Location	Average Compound Growth Rate 1991 - 2015	
	Pre Announcement	Post Announcement
5km around Badgerys Creek	6.42%	23.72%
Western Sydney	6.34%	16.65%
Sydney Metropolitan	6.70%	14.04%

Source: CoreLogic, Airservices Australia, JLL

Whilst average residential prices in the suburbs around Badgerys Creek experienced a growth rate broadly in line with the broader Western Sydney region and the metropolitan area as a whole, there was a marked acceleration in growth in the 12 months following the announcement to locate the proposed airport at Badgerys Creek.

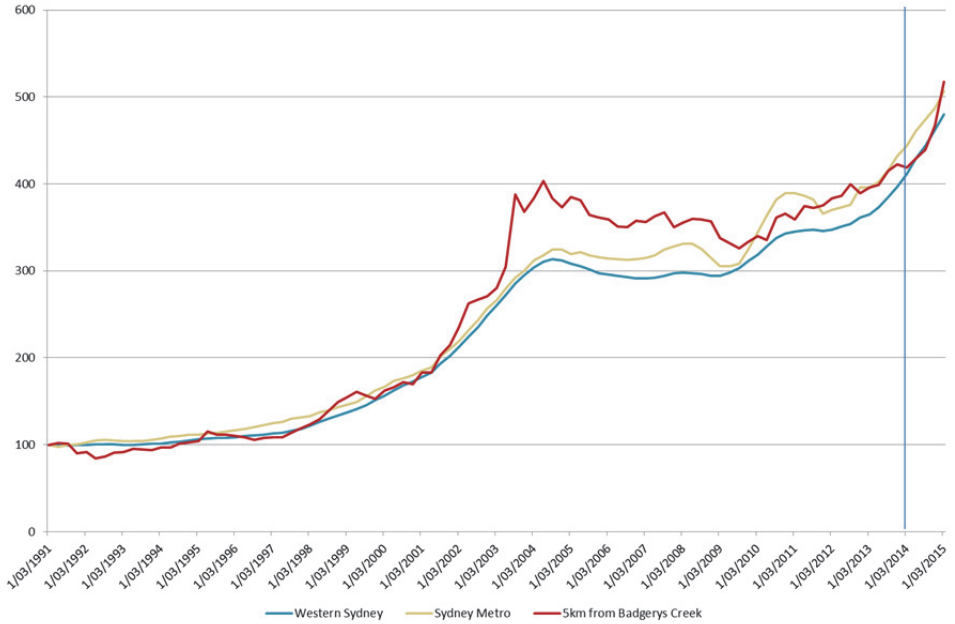
Whilst this is not evidence of causality, it is noteworthy that median house prices in the Badgerys Creek area increased at a rate significantly greater than that of the surrounding Western Sydney

region and the Metropolitan region. The volume of transactions since the 2014 announcement is broadly in line with the long term average of between 15 and 20 sales per quarter.

Although it is not possible to singly attribute the increased price growth to the 2014 announcement, which may be related to a range of external factors including the growing pressures within the Sydney housing market, falling interest rates and the growing commitment to the development of Western Sydney, it suggests that the announcement did not appear to create any diminution in residential values in the broad vicinity of the airport site, which might have been expected if there had been widespread concern about noise or impacts of the airport development.

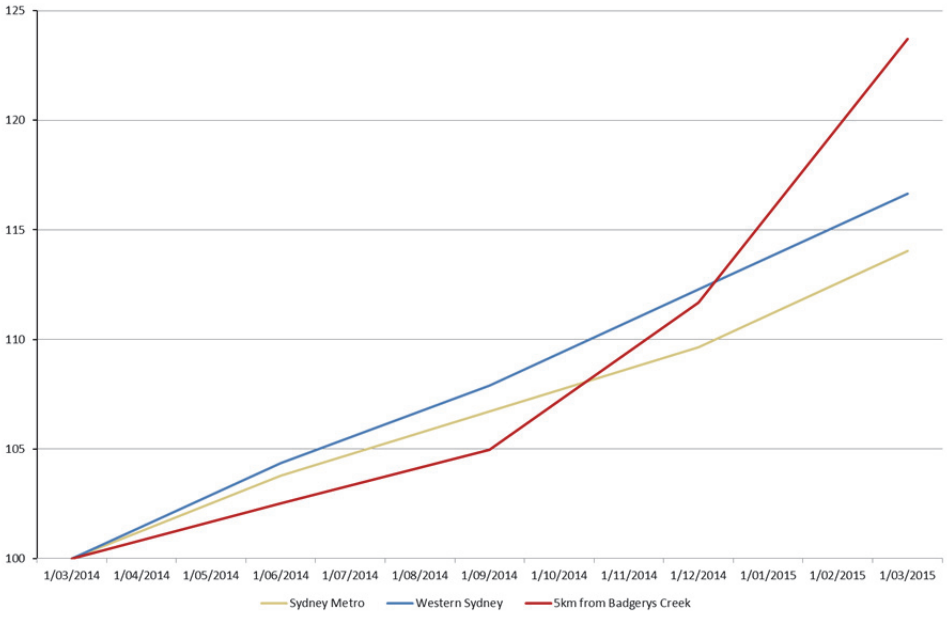
Further analysis may be required to provide context to purchaser preferences that ultimately drives property values around Badgerys Creek. This will be best achieved with structured interviews with real estate agents.

Figure 9: Residential Price Growth around Badgerys Creek (1991-2015, Based to 100)



Source: CoreLogic, JLL

Figure 10: Residential Price Growth around Badgerys Creek (Q2-2014 to Q2-2015, Based to 100)



Source: CoreLogic, JLL

Part C – SUMMARY AND CONCLUSIONS

9 Summary and Conclusions

9.1 Scope and Objectives

This technical paper has been prepared as part of the Western Sydney Airport EIS process to examine the potential impact the operation of the proposed airport may have on land and property values within the area around the airport site. Specifically, it seeks to explore, from empirical analysis of sales price data, the effect that aircraft and airport operations may have on property prices in the vicinity of the airport site, particularly those for residential and large lot land holdings.

9.2 Conclusions and Recommendations

Conclusions

The key findings from this study are summarised below.

- This paper does not specifically quantify the impacts of the proposed airport on property prices from commercial or employment based land uses due to difficulties in measurement however these land uses are likely to materially benefit from the increased economic activity that will come from their proximity of the airport site, which will positively impact land values.
- Previous studies have a found a relatively consistent adverse effect of aircraft noise on residential prices, of between 0.4 per cent and 1.1 per cent per unit of ANEF, with a greater impact at higher ANEF levels and for higher priced properties.
- None of the previous studies have sought to explore the impact on large lot landholdings comparable to those around Badgerys Creek, where few existing dwellings fall within areas expected to be exposed to noise levels in excess of 20 ANEF.
- The analysis encompassing over 1,800 residential sales transactions for suburbs in the vicinity of four main Australian international airports found:
    - No statistically significant relationship was found between noise exposure and housing prices in Melbourne or Sydney.
    - In Adelaide and Brisbane, noise exposure was found to be a more significant factor influencing residential prices.
    - In the case of Brisbane, prices for houses exposed to aircraft noise in between 20-25 ANEF experienced a -10.7 per cent reduction compared with dwellings outside the noise affected area.
    - In Adelaide, a statistically significant impact was found ranging from -8.3 per cent (20-25 ANEF); -14.7 per cent (25-30 ANEF); and -19.8 per cent (30-35 ANEF) compared with prices in areas with less than 20 ANEF.
- In Sydney, analysis of long run house prices since 1991 found no appreciable difference in growth rate between median prices in suburbs subject to in excess of 20 ANEF and those in similar areas not exposed to aircraft noise. Possible reasons may be:
    - Housing pressures restrict housing choices
    - The benefits of living close to the city outweigh possible noise effects in the minds of potential purchasers
    - Noise attenuation measures to dwellings in above 20 ANEF noise contours may have reduced the impact of noise on residents
    - Aircraft noise sharing protocols and rising ambient noise levels in many suburbs may reduce the perceived impact of noise
- Examination of sales of large lot landholdings in the vicinity of Melbourne, Perth and Avalon airports failed to establish a statistically significant relationship between noise exposure and property prices. Possible reasons for the lack of clear effect may include:

- The lesser significance of the dwelling in the context of large land areas, compared with established urban areas
- Land used for primary production may be less affected by noise
- The wider range of factors influencing price that cannot be analysed from the available sales data, e.g. aspect, topography, soil and micro-climate

- Analysis of long run growth rates of residential sales in the suburbs around Badgerys Creek indicates that despite short term fluctuations, property prices have grown at a similar rate to the wider Western Sydney and Sydney metropolitan regions.
- Rather than suffering a slowing of growth as a result of possible fears of noise or other impacts of an airport, residential prices in the suburbs around Badgerys Creek grew strongly in the period following the April 2014 announcement that Badgerys Creek would be the site of the proposed airport, increasing by almost 24 per cent and substantially faster than both Western Sydney and the Sydney metropolitan regions.
- Overall, the analysis failed to establish conclusive evidence of a negative impact on large lot land property prices as a result of aircraft noise at levels of 20-25 ANEF. Suggesting that the development of the proposed airport at Badgerys Creek may not have a major adverse impact on property prices in the vicinity.

The table below summarises the impact of noise on property values by land use type. In deriving the residential component below, this report had primary reference to the analyses which showed a statistically significant result (i.e. Adelaide and Brisbane).

Table 35: Assessment of Noise Impact on Property Values by Land Use Type

	Noise impact on price (compared to noise levels < 20ANEI/ANEF)		
Land Use	ANEI/ANEF 20-25	ANEI/ANEF 25-30	ANEI/ANEF 30-35
Residential	-9.5%	-14.7%	-19.8%
Large Lot Land Holdings	No discernible impact	No discernible impact	No discernible impact

Finally, this report has also had consideration to the potential impact of property prices that may occur from a second runway opening at the proposed airport. The long term time series analysis on Sydney Airport (see Section 6) suggest no material difference in property pricing of noise versus non-noise affected areas. This outcome is in line with our expectations – that is, that factors of much greater significance will influence property values than any incremental increase in noise. More specifically, it is considered that the positive influences of in-area employment as well as improved amenity and services will more than likely make up for any additional noise from the second runway.

Further, this report makes the observation that there have been significant advancements in aircraft technology over the last 20 years that have meant a material reduction in noise footprints across all major Australian airports, despite increasing aircraft movements. It is considered to be a reasonable assumption that advancements will be made in the future, further reducing aircraft noise. For the above reasons this report has not assessed a negative impact to property prices due to the opening of a second runway at the proposed airport.

10 References

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Appendix A – Summary of Literature Reviewed

Author	Year of Study	Location	Depreciation in Housing Values per unit ANEF/NEF (%)	Comments
Australian Studies				
Abelson	1977	Sydney Airport	0.4	Non-linear model. Limited to houses. Significantly greater than 25 ANEF in Marrickville
BIS Shrapnel	1990	Sydney Airport	0.4 – 0.6	Limited to houses. Minimum found for 20-25 ANEF range, maximum for 30-35 ANEF range- both in Marrickville
Poulsen	1990	Sydney Airport	0.86 – 1.1	Range for linear and non-linear models, northern flight path, applies greater than 30 ANEF
JLW Research and Consultancy	1993	Sydney Airport	0.5 – 1.0	Minimum found for less than 30 ANEF in Drummoyne, maximum found for greater than 35 ANEF in Sydenham
Burns and Associates	1990	Adelaide Airport	0.36 – 0.39	Range only applies to houses in the 27.5 – 30 ANEF zone
Overseas Studies				
Emerson	1969	Minneapolis	0.4	
Mclure	1969	Los Angeles	1.62	
Paik	1972	New York (Kennedy)	2.0	
Roskill	1971	London (Gatwick) Medium-priced houses High-priced houses	1.6 2.6	Limited to houses 2 price ranges
Roskill	1971	London (Heathrow) Medium-priced houses High-priced houses	0.9 2.25	Limited to houses 2 price ranges
Colman	1972	Los Angeles	1.6	
Price	1974	Boston (Logan)	0.8	
Dygert	1973	San Francisco (Sam Mateo Country)	0.5	
Dygert	1973	San Jose (Santa Clara Country)	0.68	
Gautrin	1975	London (Heathrow)	0.5 – 0.68	
Nelson	1975-78	Washington	1.0	
DeVany	1976	Dallas	0.58	Within two to three miles of the airport
Maser	1977	Rochester	1.1	
McMillan et al	1978	Edmonton	0.5	

Mieszkowski and Saper	1978	Toronto (Etobicoke, Missisauga)	0.3 – 1.3	Linear models used Limited to Houses
Uyeno et al	1993	Vancouver	0.65 – 0.9	Non-linear model. Minimum detached houses, Richmond, greater than 25 ANEF, maximum units, Richmond, greater than 25 ANEF

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VOLUME 4

Appendix P3
Economic analysis



Western Sydney Airport

Draft Technical Report to the draft EIS

Draft Economic Analysis

September 2015



Building a better working world

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Glossary of terms

Airport	The airport located at the Airport Site. Note: the airport is referred to in the Airports Act as Sydney West Airport and is also commonly known as Western Sydney Airport
Airport Site	The airport site for Sydney West Airport as defined in the Airports Act
Airport-lessee company	The company that is granted an airport lease over the airport site
ATMs	Annual Traffic Movements – a landing or departure constitutes one ATM
Aviation activity	Any activity for the arrival, departure, movement or operation of aircraft and includes aircraft aprons, helipads, heliports, runways, taxiways, navigational aids and the like
Base Case:	Scenario where the Western Sydney Airport is not developed – i.e. this represents the status quo
BTS	NSW Bureau of Transport Statistics
CGE	Computable general equilibrium (CGE) models are a class of economic models that use existing data to estimate how an economy might respond to changes in external factors
DPE	NSW Department of Planning and Environment
Earthworks	Means excavation or filling
Economic footprint	The total or gross contribution of an investment / expenditure / operations to employment or expenditure in the community (i.e. this does not account for substitution impacts)
Environmental Impact Statement	Means the environmental impact statement prepared in relation to the airport under the *Environment Protection and Biodiversity Conservation Act 1999* following a referral dated 4 December 2014.
FTE	Full time equivalent (FTE) is a standard unit of measurement of employee time
Greater Metropolitan Area (GMA) of Sydney	A wide classification of Sydney, stretching from Newcastle in the north to Kiama in the south and Blue Mountains in the west. Sydney GMA is broken into four catchments: the WSA catchment, KSA catchment, Marginal catchment and Other
Joint Study	*Joint study into aviation capacity in the Sydney region*, Report to the Australia and NSW Governments, 2012
KSA	Sydney (Kingsford-Smith) Airport or Sydney Airport
Land Side	That area of an airport and buildings to which the public normally has access, consistent with Section 9 of the *Aviation Transport Security Act 2004*.
MAP	Million annual passengers

Person years	A unit of measurement which accounts for the employment of one person in a full-time capacity for one year. It provides a consistent basis for accounting for employment where, for example, one person might be employed full time for five years or five different people working in different roles of one year each (both of which would be 5 person years).
Project Case:	Scenario where the Western Sydney Airport is developed and operating by 2025
SA3	Statistical Area Level 3. Statistical Areas Level 3 (SA3s) are built from aggregations of whole Statistical Area Level 2 (SA2) boundaries to represent regions of between approximately 30,000 people and 130,000 people to cover the whole of Australia. These boundaries reflect a combination of widely recognised informal regions as well as existing administrative regions such as State Government Regions in rural areas and local Government Areas in urban areas.
Sydney basin area	The Sydney basin is identified as the Sydney Greater Capital City Statistical Area, as defined by the ABS. It is bordered by Sutherland and Bargo in the south, Lake Macquarie and the Hawkesbury River in the north and Mt Victoria in the west.
Sydney West Airport	The Airport. Note: this is the name used in the Act. The airport is also commonly known as Western Sydney Airport
Terminal	Means services and facilities for passengers and freight of a kind usually provided within an airport terminal building including food and drink premises, kiosks, shops, airline lounges, medical centers, transfer corridors, business, premises, office premises, retail premises, passenger transport facility, public administration facility, vehicle hire premises and facilities for the conduct of events, functions, conferences and the like.
Transfer corridor	Means the provision of an area for the facilitation of inter- or intra terminal transfers of passengers or baggage
Up-gauging	An increase in the aircraft size (B737 to A340) by an airline to increase the number of available seats for a flight destination in lieu of adding an additional flight segment during the day. This will result in an increase in passengers per ATM.
Wilton-Richmond Study	The technical study commissioned by the Government in 2012 and completed in 2013 which considered Wilton's suitability as a second airport and explored the use of RAAF Base Richmond for limited civil operations.
Western Sydney Airport (WSA)	The Airport. Under the Act the airport is referred to as Sydney West Airport

Table of contents

1. Introduction 7
   1.1 Background 7
   1.2 Scope of works 8
   1.3 Approach 8
   1.4 Sources of data 8
   1.5 Assumptions 9
   1.6 Limitations of the analysis 9
   1.7 Structure of the report 10
2. Construction footprint 12
   2.1 Introduction 12
   2.2 Economic footprint of construction 13
3. Employment at WSA 20
   3.1 Introduction 20
   3.2 Direct employment 20
   3.3 On-site business park employment 22
   3.4 Conclusions 25
   3.5 Limitations of this section 26
4. Land use econometric model 27
   4.1 Land use econometric model 27
   4.2 Land use model methodology 28
   4.3 Population model results 32
   4.4 Population Impacts 32
   4.5 Employment model results 34
   4.6 Employment impacts 34
   4.7 Conclusions 36
   4.8 Limitations 38
5. CGE analysis 40
   5.1 Data Sources 40
   5.2 CGE Models 40
   5.3 WSA CGE methodology 43
   5.4 Consumption 45
   5.5 Production 46
   5.6 Labour 46
   5.7 The Australian economy 47
   5.8 The Implementation of Western Sydney Airport 48
   5.9 Results 48
   5.10 Conclusion 50
   5.11 Limitations of the analysis 50

Section A
Introduction



1. Introduction

1.1 Background

Planning investigations to identify a site for a second Sydney airport first commenced in 1946 with a number of comprehensive studies—including two previous environmental impact statements for a site at Badgerys Creek—having been completed over the last 30 years.

More recently, the Joint Study on Aviation Capacity in the Sydney Region (Department of Infrastructure and Transport, 2012) and A Study of Wilton and RAAF Base Richmond for civil aviation operations (Department of Infrastructure and Transport, 2013) led to the Australian Government announcement on 15 April 2014 that Badgerys Creek will be the site of a new airport for Western Sydney. The airport is proposed to be developed on approximately 1,700 hectares of land acquired by the Commonwealth in the 1980s and 1990s. Construction could commence as early as 2016, with airport operations commencing in the mid-2020s.

The proposed airport would provide both domestic and international services, with development staged in response to demand. The initial development of the proposed airport would include a single, 3,700 metre runway coupled with landside and airside facilities such as passenger terminals, cargo and maintenance areas, car parks and navigational instrumentation capable of facilitating the safe and efficient movement of up to 10 million passengers per year. While the proposed Stage 1 development does not currently include a rail service, planning for the proposed airport preserves flexibility for several possible rail alignments including a potential express service. A final alignment will be determined in consultation with the New South Wales Government, with any enabling work required during Stage 1 subject to a separate approval and environmental assessment process.

In the longer term, approximately 40 years after operations commence and in accordance with relevant planning processes, the airport development could include parallel runways and additional passenger and transport facilities for around 82 million passenger movements per year. To maximise the potential of the site, the airport is proposed to operate on a 24 hour basis. Consistent with the practice at all federally leased airports, non-aeronautical commercial uses could be permitted on the airport site.

On 23 December 2014, the Australian Government Minister for the Environment determined that the construction and operation of the airport would require assessment in accordance with the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act). Guidelines for the content of an environmental impact statement (EIS) were issued in January 2015. Approval for the construction and operation of the proposed airport will be controlled by the Airports Act 1996 (Cth) (Airports Act). The Airports Act provides for the preparation of an Airport Plan which will serve as the authorisation for the development of the proposed airport.

The Australian Government Department of Infrastructure and Regional Development is undertaking detailed planning and investigations for the proposed airport, including the development of an Airport Plan. The draft Airport Plan is the primary source of reference for, and companion document to, the EIS. The draft Airport Plan identifies a staged development of the proposed airport. It provides details of the initial development being authorised, referred to as Stage 1, as well as a long-term vision of the airport's development. This enables preliminary consideration of the implications of longer term airport operations. Any stages of airport development beyond Stage 1 would be managed in accordance with the existing process in the Airports Act. This includes a requirement that for major developments (as defined in the Airports Act), a major development plan be approved by the Australian Government Minister for Infrastructure and Regional Development following a referral under the EPBC Act.

The Airport Plan will be required to include any conditions notified by the Environment Minister following this EIS. Any subsequent approvals for future stages of the development will form part of the airport lessee company's responsibilities in accordance with the relevant legislation.

1.2 Scope of works

This report has been prepared as part of the proposed Western Sydney Airport draft EIS, in accordance with Section 10 of the EIS Guidelines issued in January 2015 by the Department of the Environment. Section 10 of the Guidelines sets out the following requirements:

- The economic and social impacts of the action, both positive and negative, must be analysed. Matters of interest may include:
    - Details of any public consultation activities undertaken, and their outcomes
    - Details of any consultation with Indigenous stakeholders
    - Projected economic costs and benefits of the project, including the basis for their estimation through cost/benefit analysis or similar studies
    - Employment opportunities expected to be generated by the project (including construction and operational phases).
- The economic and social impacts must include impacts at the local, regional and national level.
- Details of the relevant cost and benefits of alternative options to the proposed action, as identified in section 3, should also be included.

This document specifically provides an assessment of economic and employment impacts of the project for construction of Stage 1, as well as operations of the proposed airport in the short term (2031) and the longer term (2063). Economic and employment impacts have included consideration of how impacts are distributed at the local, regional and national level.

Specifically the Draft Economic Analysis includes the following:

- **Airport construction land use impact assessment** – Considers the potential impacts of the construction of the proposed Stage 1 airport on employment in Western Sydney / Greater Sydney, as well as the value added implications of this investment
- **Operations land use impact assessment** –This considers how the proposed WSA development could potentially deliver jobs to Western Sydney in the form of direct employment, on-site business park employment, as well as off-site employment (due to flow-on impacts)
- **Computable General Equilibrium (CGE) economic impact assessment** – This considers the distribution of the economic benefits identified for the WSA project – in terms of household incomes, gross value added, jobs, etc.

This report has been prepared to detail the methodology and findings of each of the above and acts as a Technical Report to the draft EIS that has been prepared. This report should not be considered in isolation from the draft EIS.

1.3 Approach

In accordance with the study brief and accepted 'best practice' in the development of major transport project economic analyses, this analysis has been prepared to conform to the EIS guidelines.

More details on the approach to each of the three components of the Draft Economic Analysis is outlined in the relevant sections of this report.

1.4 Sources of data

A number of data sources have been utilised to undertake this analysis:

- **Aviation demand forecasts** – The changes in travel patterns as a result of an operational WSA. This analysis was undertaken by LEK Consulting

- **Airport proposed design** – The Reference Design of the proposed WSA development which informs the costs of the project as well as the scale of demand which can be accommodated.
- **Capital and maintenance costs** – WT Partnership have estimated the costs of construction (and maintenance costs) of the proposed airport and off-site supporting infrastructure.
- **Commercial analysis** – Revenues and operating costs have been estimated by LEK Consulting.
- **Ground transport demand** – An assessment of the change in ground transport demand (road and public transport) that will result from WSA – including workers and passengers to the airport and business park was developed by Transport for NSW's Bureau of Transport Statistics (BTS)[1]
- **Population, demographics and employment forecasts** – Long-term forecasts of population, demographics and employment in the Greater Metropolitan Area of Sydney have been provided by SGS Economics and Planning (SGS).

1.5 Assumptions

A number of assumptions were made to undertake this analysis:

- All value terms throughout this report are presented in real 2015 dollar terms unless clearly expressed otherwise
- All analysis of changes in employment as a result of the development of the proposed WSA assumes a net zero gain in employment across NSW. That is, the development of the proposed WSA is assumed to not change total employment in NSW, but to re-distribute it towards areas of increased activity (i.e. Western Sydney). This is a standard assumption in the economic appraisal of proposed transport infrastructure investments and is conservative
- As part of the land use impact assessment of the operations of the proposed airport, the employment impacts of a possible future business park has been included. The proposed development of a business park at the proposed airport site is consistent with the draft Airport Plan but outside of the scope of the Stage 1 airport development and would be subject to a future separate environmental assessment and approval regime under the Airports Act 1996.
- Results for 2031and 2063 have been presented. The year 2031 is used due to the traffic model outputs that have been provided by the NSW Bureau of Transport Statistics. The year 2063 is consistent with the definition of the long term scenario used for the purposes of the draft EIS
- All the data and calculations presented in this analysis are based on the concept design presented in the draft Airport Plan and may change following detailed design of the proposed airport.

Assumptions specific to each of the three components of the Draft Economic Analysis has been outlined in the remainder of the report.

1.6 Limitations of the analysis

The findings across the three components of the Draft Economic Analysis are subject to the following cross-cutting limitations:

- This work has not been prepared to inform decision making processes. Its sole purpose is to present potential employment and economic outcomes as a result of the development of the proposed WSA. Therefore, sensitivity testing around the results of the analysis has not been conducted
- Assumptions, forecasts and estimates underpinning the analysis are subject to further change and refinement (i.e. as part of the Final EIS process)

[1] Note that for the purposes of the evaluation, workers at WSA and their changing travel patterns are included as an externality impact of the airport

- Assumptions used to develop the forecasts may not be realised and unanticipated events and circumstances may occur. Therefore, there are likely to be differences between the forecast and the actual results, and these differences may be material

- This economic analysis is an input to the draft EIS for the WSA project only. Consequential infrastructure in the surrounding area (for example, new road links to the airport) is expected to be assessed by the NSW Government in separate decision making processes

- BTS traffic modelling is one of the inputs used to identify the scale of benefits from the WSA development to consumers of air services and the wider community. The BTS model is based on a planning horizon which is shorter than the long term planning period.[2] As a result, traffic modelling inputs from BTS (including travel times and generalised costs of access) were not provided for the full evaluation period, and therefore were assumed to remain constant for the remainder of the evaluation period.

Limitations specific to each of the three components of the Draft Economic Analysis has been outlined in the remainder of the report.

1.7 Structure of the report

The report is structured as follows:

Table 1: Structure of the report

Section	Contents
Section A – Introduction	Chapter 1 – Introduction
Section B – Construction footprint	Chapter 2 – Construction footprint
Section C – Land use impacts of operations	Chapter 3 – Employment at WSA Chapter 4 - Land use impacts of operations
Section D – Economic impacts of operations	Chapter 5 - Spatial CGE modelling

Source: EY

[2] The BTS planning horizon is for the following 25 years, as opposed to the definition of the long term scenario used for the purposes of the Draft EIS (i.e. 2063)

Section B
Construction footprint



2. Construction footprint

2.1 Introduction

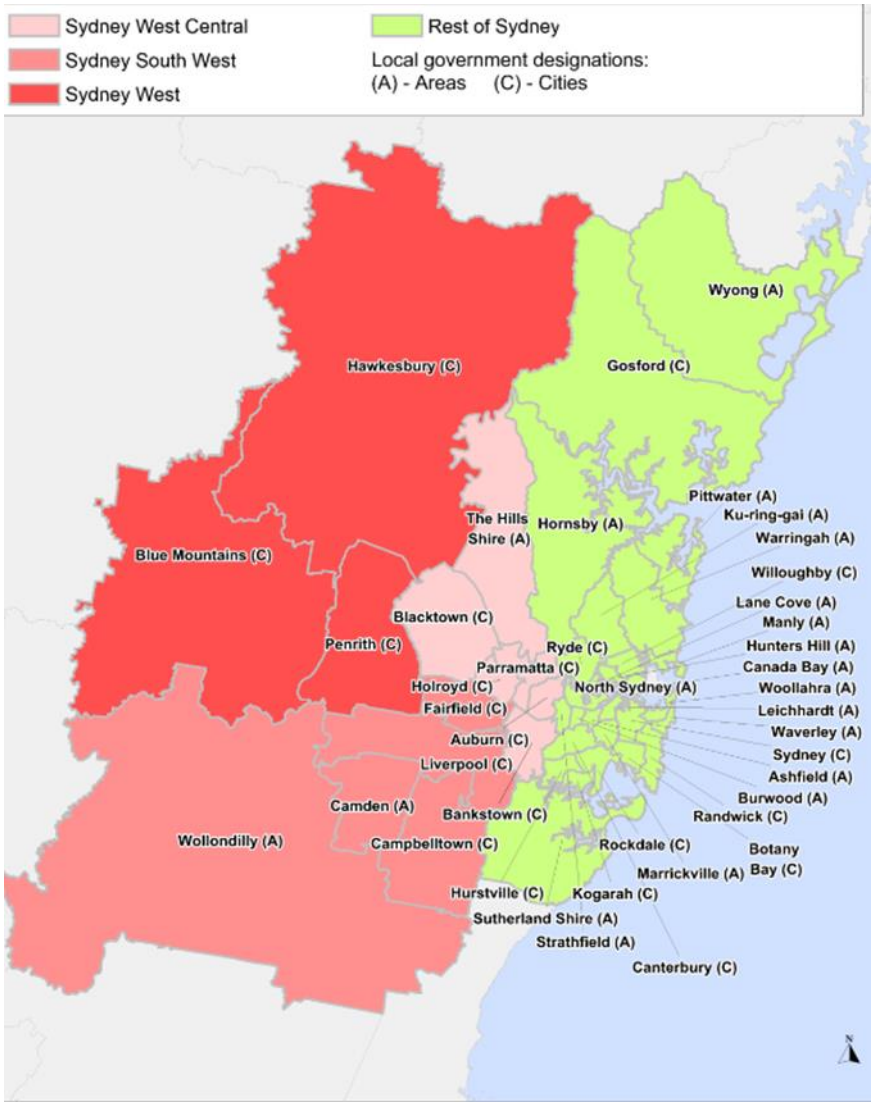
This section of the report presents results of an analysis of economic impacts of the construction of Stage 1 of the proposed Western Sydney Airport (the airport). Specifically, the analysis presents an economic contribution analysis covering the economic footprint of the construction phase of the Stage 1 development.

The results are presented for Western Sydney and 'Rest of Sydney'. Western Sydney comprises three subregions as defined by the NSW Government, with each subregion containing the following Local Government Areas (LGAs):

- **Sydney South West** - Liverpool, Fairfield, Camden, Campbelltown and Wollondilly LGAs
- **Sydney West** - Penrith, Hawkesbury and Blue Mountains LGAs
- **Sydney West Central** - Auburn, Bankstown, Blacktown, Holroyd, Parramatta and The Hills Shire LGAs

'Rest of Sydney' refers to the areas identified in Figure 1 not contained within the three Western Sydney subregions. The spatial areas are shown in the following map.

Figure 1: Spatial areas for reporting with Local Government Areas identified



2.2 Economic footprint of construction

The following section outlines:

- Direct and flow-on economic contributions
- Our approach to measuring economic contribution
- Economic footprint – employment
- Economic footprint – value-add

2.2.1 Direct and flow-on economic contributions

The direct and flow-on economic contributions presented in this report are based upon the following construction activities:

- Non-residential building construction
- Heavy and civil engineering construction
- Construction services

The analysis firstly identifies the direct jobs and the value-add of the proposed airport development in the above sectors. It then measures the flow-on impacts on jobs and value-add in other sectors along the supply chain, as well as consumption impacts through additional household expenditure.

The following definitions apply for the economic contribution analysis:

- Value-add: for each industry this is the value of production outputs (both direct and flow-on) less the value of inputs sourced from other sectors. The sum of value-add across all industry sectors in a specific region is known as the Gross Regional Product (GRP)
- "Direct" jobs and value-add: this is the number of jobs and amount of value-add directly related to the construction activities on-site. It includes the construction and fitting out of the airport, terminal buildings, the business park and associated infrastructure.
- "Flow-on" jobs and value-add: this is the number of jobs and amount of value-add generated in the supply chain of the on-site activities. This includes two components: the industrial effect and the consumption effect. The industrial effect is the impact on industries supplying the goods and services being used by the on-site activities. The consumption effect is the impact on sectors supplying goods and services being bought by households with the labour income they earned from the on-site activities.

For the purposes of the analysis, 'person years' has been used to express results. This term refers to the number of people employed, multiplied by the number of years that they are employed for. Therefore, 10 people employed for one year, or 1 person employed for 10 years, are both equivalent to 10 person years of employment. For the purposes of this economic contribution analysis, all employment totals over the construction period (i.e. from 2016 to 2024) are expressed in person years.

2.2.2 Approach to measuring economic contribution

In order to measure economic contribution, a two-step process was implemented:

- Initial inputs (sourced from GHD and REMPLAN) were collated; and

- Input-output modelling of direct and flow-on contributions was performed by EY (using GHD employment estimates and REMPLAN multipliers for the Western Sydney and Greater Sydney[3] regional economies).[4]

Employment assumptions

Table 2 presents the number of Full Time Equivalent (FTE) jobs involved in the construction sector by type of activity for each financial year during the construction phase of Stage 1 of the Project, based on GHD estimates.

Table 2: Construction FTE employment by category

GHD Category	REMPLAN Category	2017	2018	2019	2020	2021	2022	2023	2024	Total
Aviation Infrastr - Labour (Building)	Non-Residential Building Constr	-	-	-	74	124	256	217	82	**754**
Aviation Infrastr - Labour (Civil)	Heavy & Civil Engineering Constr	-	-	27	159	128	114	74	104	**605**
Aviation Infrastr - Superv and mangnt	Construction Services	-	-	4	55	135	157	148	84	**583**
Site Prep - Labour (civil)	Heavy & Civil Engineering Constr	52	141	103	15	26	61	28	-	**427**
Site Prep - Supervisory and mangnt	Construction Services	16	48	78	80	73	44	7	-	**346**
Aviation Infrastructure - Contract Admin	Construction Services	-	-	3	40	97	113	107	60	**419**
Site Prep - Contract	Construction Services	4	14	22	23	21	12	2	-	**97**
Total		**72**	**203**	**236**	**446**	**605**	**758**	**583**	**330**	**3,231**

Note: Construction is expected to end in FY2024, with development approval processes being required before the airport commences operations in July 2025.
Source: GHD

The number of jobs by type of work is mapped to the REMPLAN categories below, as shown in the above table:

- Non-Residential Building Construction – construction of non-residential buildings such as hotels, motels, hostels, hospitals, prisons or other buildings
- Heavy & Civil Engineering Construction – construction or general repair of roads, bridges, aerodrome runways or parking lots
- Construction Services – a range of services provided as part of construction activities, including installation, finishing, management, etc.

2.2.3 Economic footprint – Employment

This has been estimated for:

Western Sydney

Table 3 summarises the footprint of the construction activities on the Western Sydney economy in each financial year in terms of FTE jobs, based on REMPLAN multipliers and GHD job estimates for the project.

Table 3: Western Sydney FTE employment footprint (FTE)

Effects/Year	2017	2018	2019	2020	2021	2022	2023	2024	Total
Direct Effect	72	203	236	446	605	758	583	330	3,231
Industrial Effect	117	331	386	729	988	1,238	953	540	5,281
Consumption Effect	63	178	207	391	530	664	511	290	2,834
Total	251	712	828	1,565	2,123	2,660	2,047	1,160	11,346

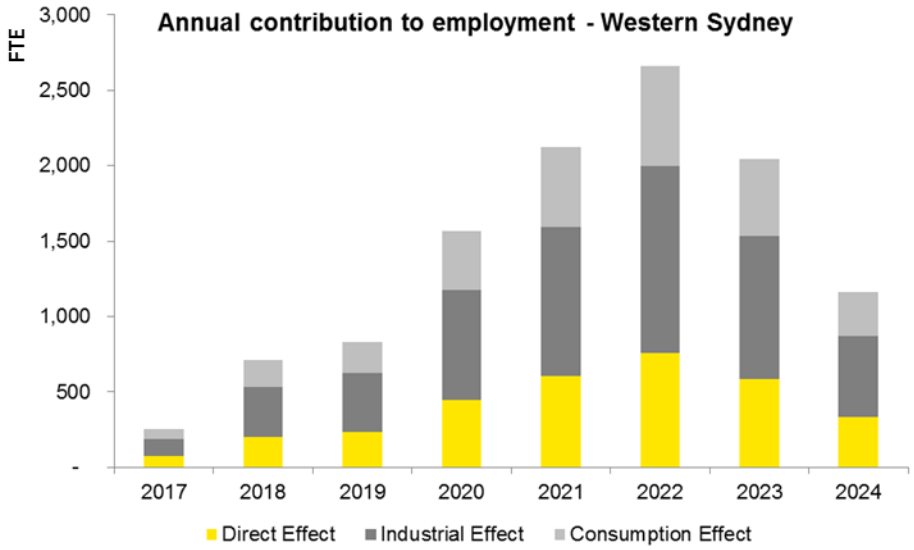
Source: REMPLAN, EY analysis

[3] This includes Western Sydney plus the rest of Sydney

[4] REMPLAN is an economic input-output model of regional economies which traces the revenue and expenditure 'multipliers' that link industries and workers within and outside economic regions based on ABS data.

Figure 2 shows the annual contribution to employment over time for Western Sydney:

Figure 2: Western Sydney FTE employment footprint



Source: REMPLAN, EY analysis

Direct on-site jobs reach 750 by 2022, generating a footprint that furthermore includes 1,200 jobs in the supply chain and a further 660 jobs through consumption effects. The total Western Sydney employment footprint reaches 2,700 jobs in 2022 and a total of 11,300 person-years over the construction period.

Greater Sydney

Table 4 summarises the footprint on the Greater Sydney economy in each financial year in terms of jobs, based on REMPLAN multipliers and GHD job estimates for the project.

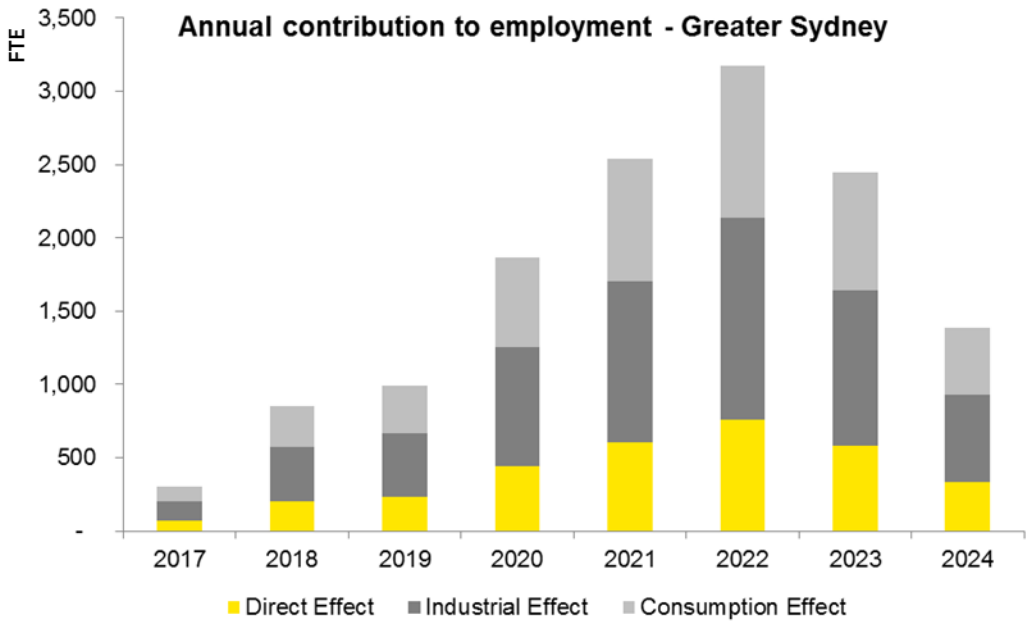
Table 4: Greater Sydney employment footprint (FTE)

Effects/Year	2017	2018	2019	2020	2021	2022	2023	2024	Total
Direct Effect	72	203	236	446	605	758	583	330	3,231
Industrial Effect	130	369	429	810	1,099	1,377	1,060	600	5,874
Consumption Effect	99	279	325	614	833	1,043	803	455	4,451
Total	300	850	990	1,870	2,537	3,178	2,446	1,386	13,556

Source: REMPLAN, EY analysis
Note that the Greater Sydney results outlined above are equal to Western Sydney plus the rest of Sydney

Figure 3 shows the annual contribution to employment over time for Greater Sydney:

Figure 3: Greater Sydney FTE employment footprint



Source: REMPLAN, EY analysis
Note that the Greater Sydney results outlined above are equal to Western Sydney plus the rest of Sydney

The Greater Sydney employment footprint is slightly larger, as a more of the flow-on impacts are captured within this larger geographical area. The Greater Sydney employment footprint reaches 3,200 jobs in 2022, and 13,600 person-years in total.

2.2.4 Economic contribution – Value-add

This has been estimated for:

Western Sydney

Table 5 summarises the economic footprint of the construction activities on the Western Sydney economy in each financial year in terms of value-add (in millions of dollars), based on REMPLAN multipliers and GHD job estimates for the project.

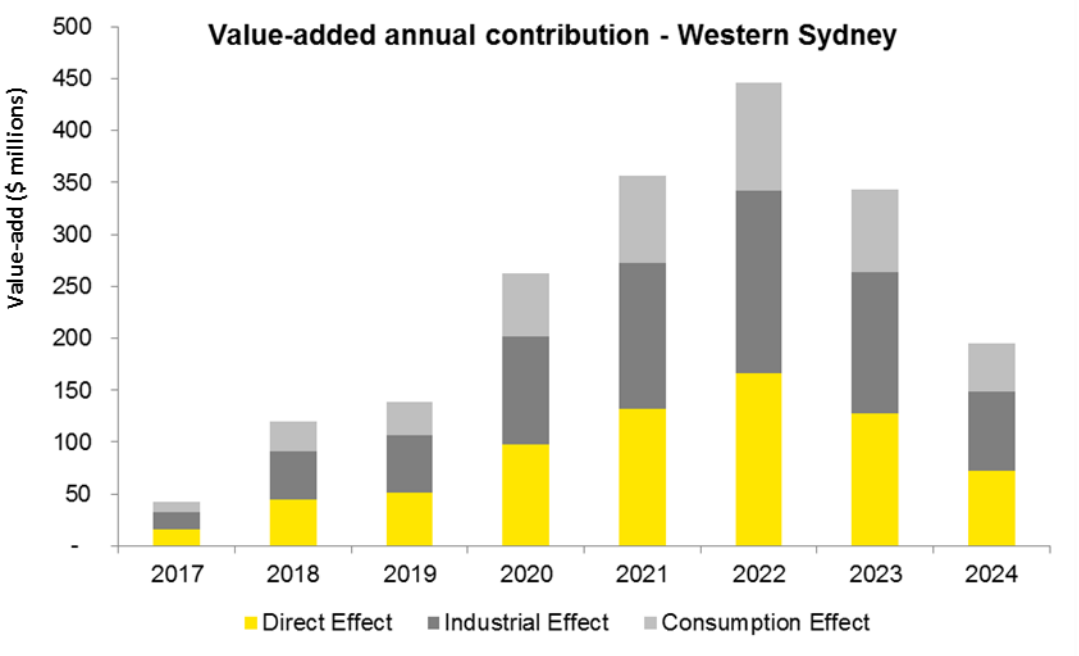
Table 5: Western Sydney value-add footprint ($ millions)

Effects/Year	2017	2018	2019	2020	2021	2022	2023	2024	Total
Direct Effect	16	44	52	98	132	166	128	72	707
Industrial Effect	17	47	55	104	141	176	136	77	751
Consumption Effect	10	28	33	62	84	105	81	46	446
Total	42	119	139	263	356	446	344	195	1,904

Source: REMPLAN, EY analysis

Figure 4 shows the annual contribution to value-add over time for Western Sydney:

Figure 4: Western Sydney value-add footprint



Source: REMPLAN, EY analysis

Direct on-site value-add reaches $170m by 2022, generating another $175m and $105m indirectly (through industrial and consumption effects). The total Western Sydney value-add footprint reaches $450m in 2022, summing up to $1,900m over the construction period (undiscounted).

Greater Sydney

The table below summarises the economic footprint on the Greater Sydney economy in each financial year in terms of value-add (in millions of dollar), based on REMPLAN multipliers and GHD job estimates for the project.

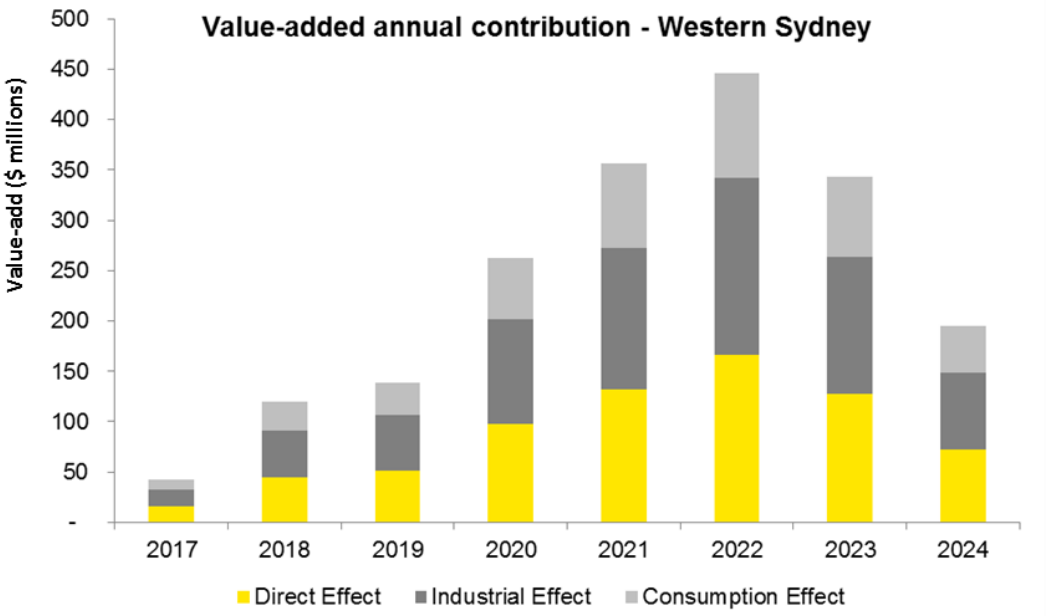
Table 6: Greater Sydney value-add footprint ($ millions)

Effects/Year	2017	2018	2019	2020	2021	2022	2023	2024	Total
Direct Effect	16	44	52	98	132	166	128	72	707
Industrial Effect	19	55	64	121	165	206	159	90	880
Consumption Effect	16	45	52	99	134	168	129	73	716
Total	51	145	168	318	431	540	416	235	2,304

Source: REMPLAN, EY analysis
Note that the Greater Sydney results outlined above are equal to Western Sydney plus the rest of Sydney

Figure 5 shows the annual contribution to value-add over time for Greater Sydney:

Figure 5: Greater Sydney value-add footprint



Source: REMPLAN, EY analysis
Note that the Greater Sydney results outlined above are equal to Western Sydney plus the rest of Sydney

As with employment impacts, the Greater Sydney value-add footprint is greater in magnitude than for Western Sydney, reaching $540m in 2022 and $2,300m over the construction period.

Limitations to this section

The findings that have been presented in this section are subject to the following limitations:

- The main limitation of economic contribution analysis is that it uses gross values rather than net values. This means it expresses the amount of economic activity that is directly and indirectly dependent on a project or an industry, but it does not explain whether the economic activity would be lost had the project not gone ahead or had the industry not existed. To understand the net impacts of a project, its economic contribution would have to be compared to that of an alternative use of resources.
- Furthermore, economic contribution analysis does not support conclusions as to whether the delivery of the project is 'better' for the economy than another project.
- Inputs have been sourced from GHD, BTS and a range of other organisations. EY has not undertaken any independent verification of the accuracy of any of these inputs.
- Assumptions, forecasts and estimates underpinning the analysis are subject to further change and refinement.
- Assumptions used to develop the forecasts may not be realised and unanticipated events and circumstances may occur. Therefore, there are likely to be differences between the forecast and the actual results, and these differences may be material.
- The results should be interpreted as being 'on average' estimates, and all else being equal. They should not be taken to reflect 'exact' and final impacts on population, employment, value-add or any other variable.
- The assessments focus on the economic outcomes resulting from the introduction of the airport. They do not consider any implications arising from any other policy changes or impacts, including how the airport is funded.
- The models do not explicitly take into account time, nor how preferences may change over time (between now and 2031 for example). Estimates should be thought of as a point in time cross sectional estimate for each of the modelled years.

Section C
Land use impacts of operations



3. Employment at WSA

Airports provide a mix of direct and indirect employment opportunities for communities, cities and regions.

3.1 Introduction

For the purposes of the technical report, the potential employment impacts that the operations of the proposed WSA can have on the Western Sydney (and wider) region has been considered in three categories:

- **Direct airport employment** (see Section 3.2) - Direct employment includes those persons that are employed at the airport to assist in the provision of its services. Direct employment at an airport typically includes administration and airport management staff, baggage handlers, airline staff, freight processing, retail operators, government operators, security and other services provided to customers
- **On-site business park employment** (see Section 3.3) – The airport site is expected to contain a business park, which can attract services directly supporting the operations of the airport (e.g. flight kitchens), services for airport employees and passengers (e.g. hotels, restaurants, tourism, car rental), as well as freight, high technology, manufacturing and finance / business related services
- **Off-site (flow-on) employment effects** (see Section 4) – The development of the proposed WSA is likely to have distributional effects on population and employment decisions in Sydney (and NSW), as businesses locate closer to the operating airport and people locate closer to employment opportunities.

3.2 Direct employment

Direct employment includes those persons that are employed at the airport to assist in the provision of its services.

In relation to direct employment, the three broad categories of employees in airports are: airline operation/service (such as ground handling, airline staff, fuel staff, freight operations staff and all maintenance staff), administration (such as airport company, police, immigration and customs employees) and commercial (such as duty free retail, restaurants and car hire companies).[5]

This section considers the approach used to estimate the total direct employees at the WSA site, and presents the results to the approach, and how they should be interpreted.

3.2.1 Approach

To identify the total number of direct airport jobs which could be supported by the proposed airport development, a benchmarking exercise was used to determine the relationship between the passenger throughput at domestic and international airports and the number of direct employees at each airport.

Table 7 presents the findings from this benchmarking exercise:

Table 7: Results from the benchmarking exercise

Airport	FTE's	pax in '000	FTE per MAP
London Airport	73000	76000	961
Schiphol Airport	60000	48000	1250
JFK NY	37000	53300	694
EWR NJ	21000	35600	590

[5] York Aviation (2004), The social and economic impact of airports in Europe

Airport	FTE's	pax in '000	FTE per MAP
LGA NY	12000	27000	444
Atlanta	58000	96000	604
Orlando	18000	34000	529
Hong Kong	40000	54000	741
Sydney	36882	32346	1140
Brisbane	14700	20300	724
Melbourne	12542	24448	513
Canberra	4900	3200	1531
Perth	5960	9359	637
Adelaide	5070	6784	747
Darwin	1641	1539	1066
Wellington	1361	5021	271
Sunshine Coast	900	917	981
Newcastle	383	1173	327
Launceston	319	1127	283
Hobart	250	1869	134
Total	403908	531983	759

Source: Publically available sources

The average employees per million annual passengers are a function of the airports considered in the analysis. Characteristics such as an airports scale (and resulting efficiencies), operating model and surrounding community can each have a significant effect on the direct employees required to service one million passenger movements.

In light of this the results in the table above demonstrate that there is a wide range of variability in the number of employees per million annual passengers – results range from 134 FTE per million annual passengers at Hobart Airport, to 1,250 FTE per million passengers at Schiphol Airport (Amsterdam, Netherlands).

Recognising the high degree of variability in the analysis, it was found that the average results are broadly consistent with:

- The findings in A study of Wilton and RAAF Base Richmond for civil aviation operations (released in 2013) – 749 FTE per million annual passengers
- The technical advice provided by LEK Consulting (the demand modelling team) – 750 FTE per million annual passengers.

Therefore a ratio of 750 employees to one million annual passengers was applied to passenger demand forecasts to calculate expected direct employees at WSA.

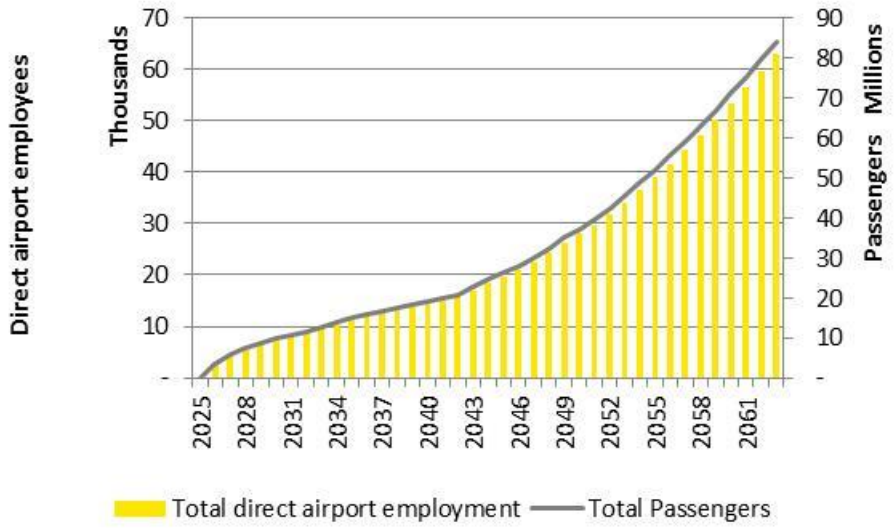
3.2.2 Results and interpretation

Given the findings presented above and the draft demand forecasts delivered by LEK Consulting, the expected direct employees at the proposed WSA are:

- In 2031 – 8,730 direct employees
- In 2063 – 62,860 direct employees

Figure 6 highlights how employee numbers are expected to grow over the course of the demand modelling period (i.e. to 2075).

Figure 6: Direct employees at WSA to 2075



Source: EY

When interpreting these results it is important to note that:

- These are estimates of the gross contribution of employment to Western Sydney as a result of the delivery of the proposed WSA. It is not a net measure (i.e. it does not consider substitution effects; i.e. the likelihood that some people who will be employed by the airport may have already been employed in a different job in Western Sydney
- It is assumed that the airport does not deliver any new population or jobs to NSW (i.e. beyond that which is currently forecast by state planning etc.). Therefore, in 2031, 8,730 jobs have been re-distributed from the remainder of NSW – i.e. 8,730 people have moved from a previous job to work at the airport.

3.3 On-site business park employment

The Land Use Plan contained within the draft Airport Plan permits commercial and other activities to take place in other areas of the airport site. As part of this report, the employment impacts of a possible business park have been assessed. However, these developments are outside of the scope of the Stage 1 development and would be subject to a separate environmental assessment and approval regime under the Airports Act 1996.

As informed by our design consultant's Landrum & Brown, it is possible that an on-site business park at WSA will be delivered in stages alongside the airport development to 2063. The business park could potentially contain the following land uses:[6]

- Industrial
- Office
- Hotels
- Petrol station and food outlets
- Regional shopping centre

[6] It is important to note that for the purposes of the draft EIS, the impacts of the following land uses have not been considered.

- Bulky goods.

This section considers the approach used to estimate the total on-site business park employees at the WSA site, and presents the results of the approach, and how they should be interpreted.

3.3.1 Approach

The approach used to estimate the total number of on-site business park employees is based on the approach that was used to conduct the same analysis as part of the Wilton and Richmond Study released in 2013. This involved three stages of work:

1. Estimate the scale of the business park

The potential scale and land use at the proposed business park was a key driver of the expected number of employees. As part of the drafting process for the draft Airport Plan, the land envelope available for the on-site business park was identified. A market sounding and work from the EY Real Estate team then identified how the identified business park envelope could be divided between different land uses.

Table 8 provides the assumed allocation of land to different land uses to 2063, as of May 2015:

Table 8: Proposed land use at the on-site business park (all units in m2)

	2031	2063
Industrial	350,000	845,000
Office	10,000	100,000
Hotels	20,000	50,000
Petrol Station and Food Outlets	15,000	40,000
Regional shopping centre	-	200,000
Bulky goods	153,000	561,000
Total	548,000	1,796,000

Source: L&B / EY Real Estate Advisory

Therefore, the on-site business park was expected to grow from 548,000 m^2 in 2031 to 1,796,000 m^2 in 2063, with the largest portion of land being set aside for industrial use and bulky goods.

2. Apply floor space to site ratio

A floor space ratio is the ratio of a buildings total floor area (gross floor area) to the gross area of the plot of land on which it is constructed.

Different land uses have standard floor space to site ratios. These were provided by the EY Real Estate Advisory team and used to identify the total floor space available given the land use expectation outlined in the previous step of the approach.

Table 9 provides the ratios applied:

Table 9: Floor space to site ratios

Land use	Floor space to site ratio
Industrial	50%
Office	125%
Hotels	40%
Petrol Station and Food Outlets	40%
Regional shopping centre	100%
Bulky goods	50%

Source: EY Real Estate Advisory

3. Apply a m^2 per employee

Having identified the total floor space available for each land use, standards (defined by industry) which outline the number of employees per square metre of floor space were then applied to identify total employees at the proposed business park.

The square metres per employee, by land use are outlined in below.

Table 10: Square metres per employee, by land use[7]

Land use	M2 per employee
Industrial	50
Office	10
Hotels	54
Petrol Station and Food Outlets	20
Regional shopping centre	90
Bulky goods	100

Source: EY Real Estate Advisory

3.3.2 Results and interpretation

Using the approach outlined above, it was estimated that the on-site business park will support:

- In 2031 – 4,440 employees
- In 2063 – 27,150 employees.

Table 11 provides a breakdown of these employment estimates by land use:

Table 11: Business park employees

	2031	2063
Industrial	3,500	8,450
Office[8]	-	12,500
Hotels	74	370
Petrol Station and Food Outlets	200	800
Regional Shopping Centre	-	2,222
Bulky Goods	665	2,805
TOTAL	4,439	27,148

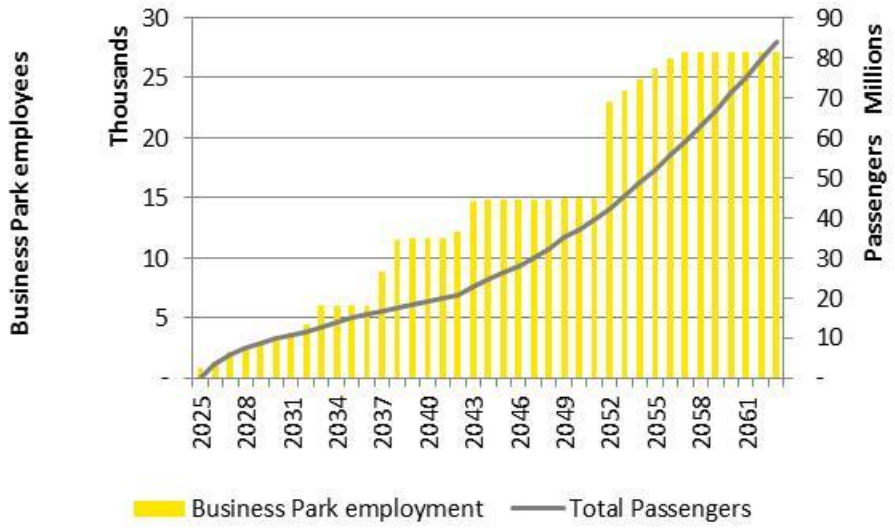
Source: EY
As noted previously, the business park development was not considered as part of the draft EIS process

Figure 7 illustrates expected growth in on-site business park employees (relative to total passenger growth):

[7] It should be noted that the square metres per hotel employee were not provided, and therefore, this was estimated as an average of the other land uses

[8] It is assumed that employees are hired one year after land is released. Therefore, while there are 10,000 m^2 of office space available in the business park in 2031, it has only just been released that year, and therefore, there is no employment expected

Figure 7: Business park employees to 2075



Source: EY

When interpreting these results it is important to note that:

- These are estimates of the gross contribution of employment to Western Sydney as a result of the delivery of the proposed WSA. It is not a net measure (i.e. it does not consider substitution effects: i.e. the likelihood that some people who will be employed by the airport may have already been employed in a different job in Western Sydney
- It is assumed that the airport does not deliver any new population or jobs to NSW (i.e. beyond that which is currently forecast by state planning etc.). Therefore, in 2031, 4,440 jobs have been re-distributed from the remainder of NSW – i.e. 4,440 people have moved from a previous job to work at the airport.

3.4 Conclusions

The combined direct employee and on-site business park employee estimates represent the total on-site employment anticipated over the planning horizon (i.e. to 2063) of the proposed WSA development.

Table 12 outlines the total employment that is expected to be redistributed to the WSA site.

Table 12: Total on-site employment

	2031	2063
Direct employees	8,730	62,860
On-site business park employees	4,439	27,148
TOTAL	13,169	90,008

Source: EY

Therefore, total on-site employment is anticipated to grow from approximately 13,000 in 2031, to approximately 90,000 in 2063.

These first distributional effects will have subsequent flow-on impacts onto the population growth and employment growth in the areas surrounding the proposed WSA. The next section considers these flow-on impacts in greater detail.

Limitations of this section

When considering the numbers that have been outlined in this section it is important to note that:

- The direct employment estimates that are presented are draft estimates. These are a function of the demand modelling which has been undertaken by LEK in February 2015 and are in the process of being updated. This will have direct impacts on the scale of the direct employment estimates identified for WSA
- The land use plans that have informed the on-site business park employee estimates was developed in May 2015 and has since been updated as part of the ongoing planning and design work for the Western Sydney Airport. Therefore the on-site business park employment results will be updated for the purposes of the Final EIS
- The employment estimates have been prepared for the purposes of the draft EIS, and will be prepared in line with updated demand and land use forecasts for the purposes of the final EIS process
- These numbers do not represent jobs which have been created in Western Sydney, but rather, these estimates represent the possible redistribution of existing employment to Western Sydney, which may be driven by the proposed WSA development. Therefore, the analysis assumes that no employment is created in NSW in the Project Case relative to the Base Case as a result of the WSA development. This is a standard assumption for economic analyses of transport infrastructure projects and we accept it is conservative.

4. Land use econometric model

WSA has the potential to impact jobs and population growth spatially throughout NSW, influencing where people will live and work. In particular, WSA is expected to significantly contribute to employment growth in and around the airport, which will provide improved job opportunities for residents in Western Sydney. In this way, WSA is a city-shaping investment that will contribute to a more balanced and sustainable growth for Sydney.

This section considers the econometric land use analysis of the Sydney economy which was used to predict, at a high level, the change in population and employment density as a result of WSA.

4.1 Land use econometric model

A project such as WSA has the potential to impact jobs and population growth in Sydney. In particular, WSA would be expected to redistribute population and employment towards Western Sydney, away from other parts of Sydney.

4.1.1 Accessibility and land use changes

To capture changes in land use (i.e. employment and population distributions) in surrounding areas due to the implementation of WSA, a land use econometric model was developed. This model was designed to measure the change in population and employment density as a result of a change in accessibility – driven by the delivery of an airport and its surrounding infrastructure. This includes:

Employment accessibility

One of many drivers of people's choice of where to live is the accessibility different locations provide to jobs and other attractions. WSA has the potential to improve accessibility to employment in Sydney's west which would be expected to attract people into the area from outside.

Population and firm accessibility

Similarly, one of many drivers of firms' location choice is the accessibility of different locations to workers and to other firms. WSA has the potential to improve accessibility for employers to both workers and other firms in Sydney's west which would be expected to attract more employers into the area from outside.

Airport

Airports themselves, independent of accessibility, also have an impact on population and employment density. In the case of population density, people may consider the distance they live from an airport. This includes:

- Effect of being within a 'threshold' distance whereby noise has an distinguishable negative impact
- Effect of distance from an airport outside of the threshold

Similarly, airports themselves also have an effect on where firms choose to locate. The effects on employment density include:

- Effect of being within an immediate airport zone – employment density within the zones that an airport is located
- Effect of distance from an airport
    i) within a 'threshold' distance (5km) which is attractive for firms in selected industries
    ii) the effect of distance outside of this threshold

4.1.2 Land use model

In order to measure the effect of accessibility on land use, both observed population and employment density is used in the econometric regression model. The model is therefore split into two parts:

- Model 1: Population density
- Model 2: Employment density

Model 1 builds a causal relationship between observed population density and accessibility to jobs in each area of Sydney to estimate the extent to which accessibility drives residential density. It does this by isolating accessibility to jobs from a number of other factors, such as distance or accessibility to other attractions or the physical characteristics of the area.

Model 2 builds a causal relationship between observed employment density and accessibility to population and other firms in each area of Sydney to estimate the extent to which accessibility drives employment density. It does this by isolating accessibility to people and firms from a number of other factors, such as proximity to other enabling pieces of infrastructure such as a port or an airport.

Outputs from the population density model (Model 1) are used as an input for population accessibility in Model 2. In this way, Model 1 and Model 2 are iterative.

Econometric techniques are used to correct for a number of confounding relationships that often prevents robust causal relationships from being identified. One such relationship is 'reverse causality'. Reverse causality occur if we estimate the impact of accessibility on density and there is a simultaneous causal impact of density on accessibility – which would be the case if transport investment and services tend to be provided in locations where density is already high.

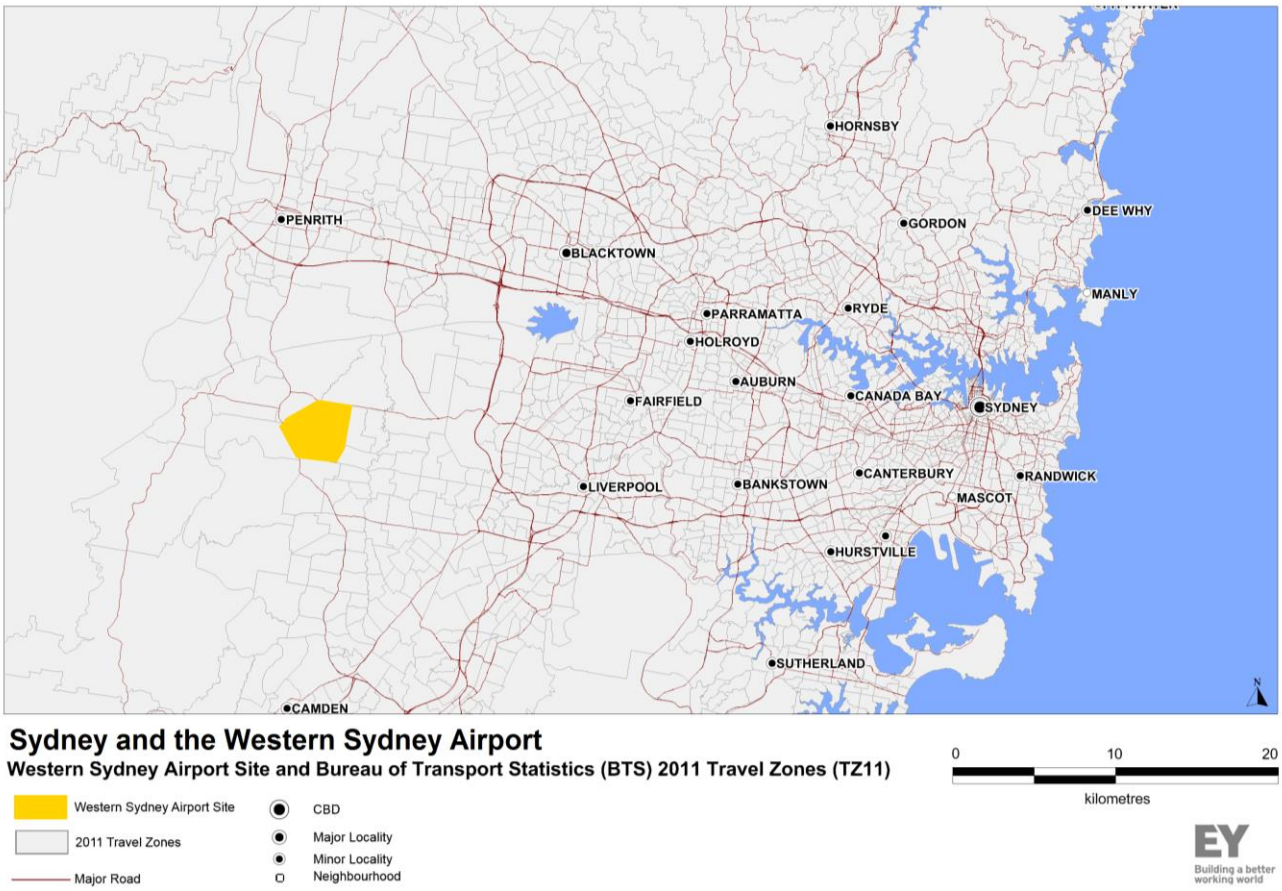
The models developed for WSA explicitly account and correct for reverse causality using techniques that are discussed the methodology below.

4.2 Land use model methodology

4.2.1 Geography

Data for density, accessibility and all of the other explanatory variables in the model was obtained for each TZ11 zone in the Sydney Greater Metropolitan Area (GMA). Figure 8 depicts the TZ11s zones and the WSA Airport site.

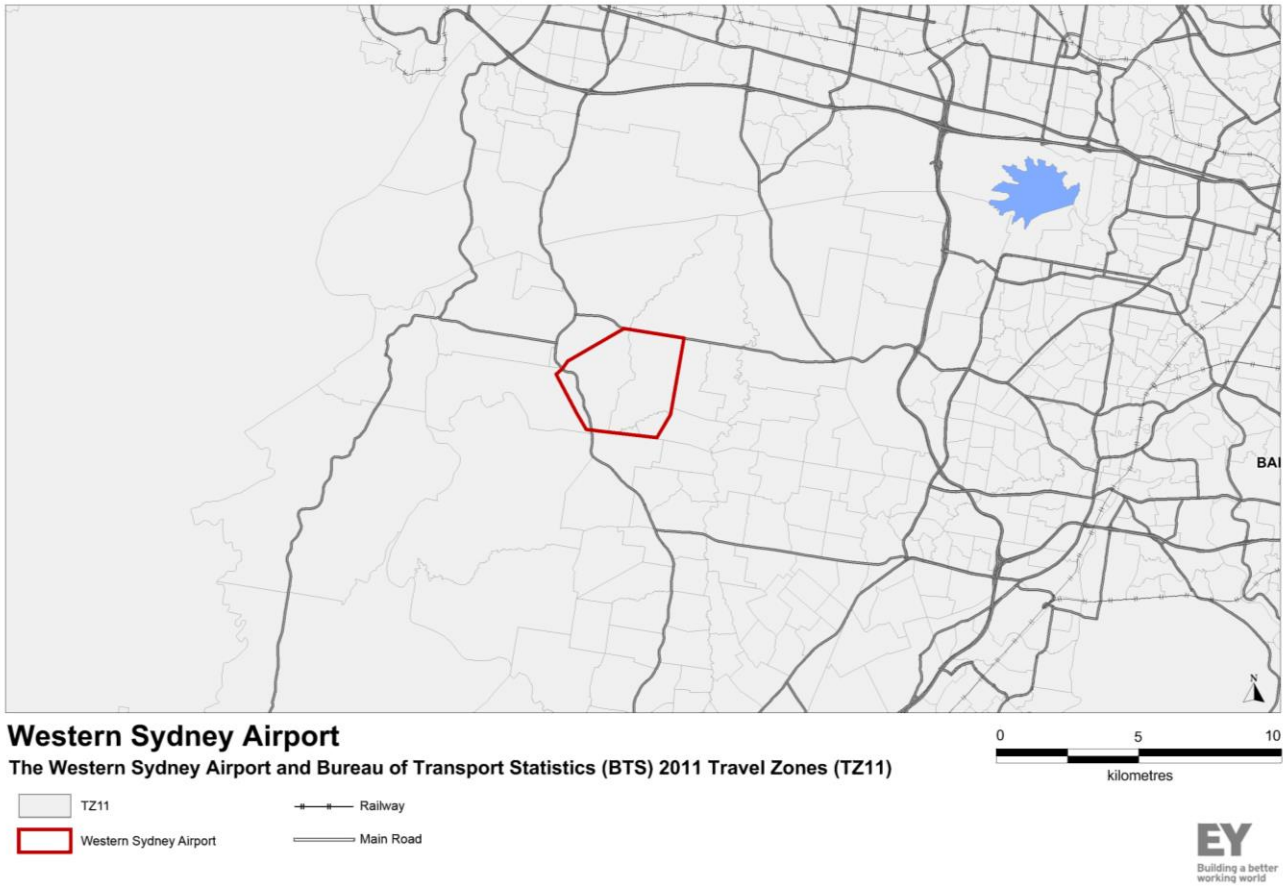
Figure 8: TZ11s and the Western Sydney Airport[9]



Travel zones are defined by NSW Bureau of Transport Statistics

[9] Note that the site marked is not the same as the proposed airport site

Figure 9: Western Sydney Airport and its immediate surrounds[10]



Travel zones are defined by NSW Bureau of Transport Statistics

4.2.2 Dependent Variable

Population model - Population density

The dependent variable in the population density model is residential density. Residential density is defined as the number of residents per hectare in each TZ11, i:

$$Pop\ density_i = Total\ pop_i / ha_i$$

Employment model - Employment density

The dependent variable in the employment density model is work-place based employment density. Employment density is defined as the number of jobs per hectare in each TZ11.

$$Emp\ density_i = Total\ emp_i / ha_i$$

4.2.3 Accessibility Variable

Population model – residents' accessibility to jobs

Accessibility for residents to jobs is measured by car, bus and rail. Job accessibility for residents in each TZ11 is the number of jobs in that TZ11 plus the number of jobs in every other TZ11 divided by the average cost of getting to these TZ11s:

[10] Note that the site marked is not the same as the proposed airport site

$$Access_i^J = \sum_{i=1}^{N} \frac{jobs_i}{avg\ cost_i^J}$$

Where the average cost of accessing jobs in the TZ11; avg cost_i^J, is across all available modes (i.e. car, bus and rail).

Average journey costs to jobs in the TZ11 where people live have been set to zero.

Employment model – employers' accessibility to workers and firms

Firms' access to workers and to other firms is measured in a similar way. Worker accessibility for each TZ11 is the number of workers living in that TZ11 plus the sum of the workers in every other of the TZ11s divided by the cost of access to these TZ11. The same logic applies to access to other firms:

$$Access_i^W = \sum_{i=1}^{N} \frac{workers_i}{avg\ cost_i^W}$$

$$Access_i^F = \sum_{i=1}^{N} \frac{firms_i}{avg\ cost_i^F}$$

Where:

- The average cost of accessing workers, avg cost_i^W, uses average journey costs across public transport modes.
- The average cost of accessing firms, avg cost_i^F, uses car journey costs.

The reason for using different modes as a basis for the two different access calculations is to avoid multicollinearity – that two explanatory variables that both have causal impact have too similar variability, prevents both of them from being identified at the same time.

The cost of accessing workers and firms in the TZ11 where employers are located is zero.

4.2.4 Regression Model

Building a regression found that there was a clear log relationship between job accessibility and population density. This relationship helps determine the specification for the regression model.

Other explanatory variables

A number of variables were collected in order to test and determine whether they had a statistically significant effect on population and employment density. These included accessibility (as outlined above), attractiveness factors, location quality, population and employment characteristics and 'control variables'. These variables were included to be able to isolate the effect of accessibility from all other factors influencing density.

A number of factors were tested for the **population model**:

- 15 attractiveness factors including distance to the nearest primary school, distance to nearest beach and distance to nearest shopping centre
- 10 control variables including distance to the nearest 'peak' elevation and distance to the nearest rail station.

A number of factors were tested for the **employment model**:

- 12 attractiveness factors including distance to major hospital, distance to nearest intermodal terminal and distance to nearest motorway access
- 2 employment and employment characteristics including the share of employment in 'higher density' occupations (i.e. jobs that are based amongst agglomeration, like financial services)
- 8 control variables including distance to the sea.

4.3 Population model results

Results for the population regression can be seen below. A number of variables are significant at the 1%, 5% and 10% statistical significance level, making them useful explanatory variables for describing population density. Statistical significance at the 5% level means that there is less than a 5% probability of the explanatory variable having a coefficient of zero (and therefore not found to affect density) given the observed coefficient.

4.3.1 Population impacts

The relevant elasticities that are estimated in the population model are used to find the change in population (and therefore population density) by travel zone. That is:

- Employment accessibility elasticity is applied to the change in employment accessibility as a result of the implementation of WSA
- The elasticity on the distance to nearest airport is applied to those travel zones that are now closer to a major airport with the introduction of WSA
- The effect of being within 5km of the airport is applied to those travel zones that will lie within 5km of the new WSA airport

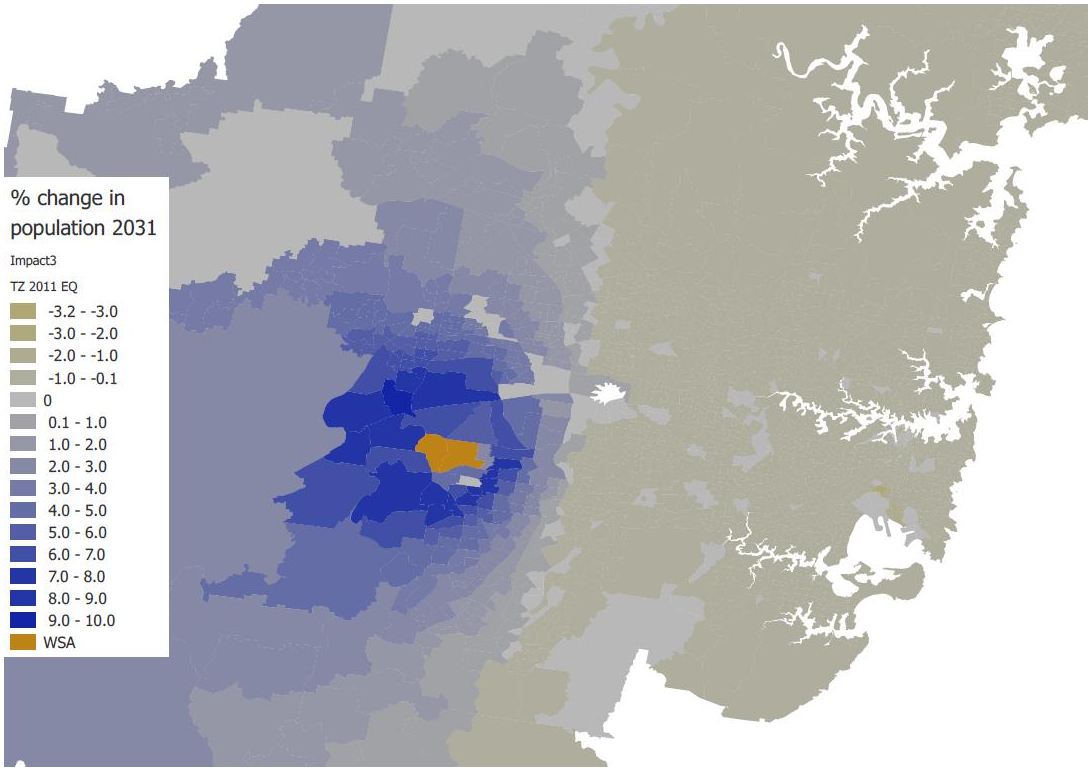
For the purposes of this land use analysis, it is assumed that there will be no net new population in Sydney as a result of WSA. Instead, population is redistributed across Sydney after the implementation of WSA and the associated changes in accessibility. The estimated change in population is incremental on the Base Case of no WSA, therefore areas that see a reduction in population in the analysis do not necessarily decline in absolute terms, rather they do not grow by as much as they otherwise would have without WSA.

4.3.2 Change in population density

By applying the job accessibility elasticity found above, to the change in job accessibility in 2031 and 2063 that results from the introduction of the WSA, the change in population density in each TZ11 is found. This can be seen visually, for 2031, in Figure 10.[11]

[11] Note that the orange area illustrates the two TZ11 which best correspond to the location of the airport. The actual airport area is different.

Figure 10: Population redistribution in 2031



Source: EY analysis

4.3.3 Change in population

The analysis found that by 2031 WSA will result in an additional population of 17,800 in Western Sydney. Figure 11 shows the areas in which population growth to 2031 will be higher and lower with WSA. The WSA site occupies the two travel zones coloured orange.

Table 13 provides a summary of the effects of the WSA on population in Western Sydney. As can be seen, Sydney West is anticipated to see the largest increase in population in Western Sydney in 2031 and beyond. Sydney South West is also anticipated to experience strong growth relative to the Base Case, particularly in 2063. This population will be redistributed away from the Rest of Sydney, the Rest of NSW and Sydney West Central.

Table 13: Population changes in Western Sydney as a result of WSA

Region	2031	2063
Sydney South West	4,900	31,100
Sydney West	16,200	63,400
Sydney West Central	-3,200	-18,200
Rest of Sydney	-14,000	-59,500
Rest of NSW	-3,900	-16,800

Source: EY

When considering the results outlined above, it is important to note that while Rest of Sydney and Rest of NSW have a negative result over the course of the planning period, this is not to say that the population of these areas will decrease. Rather, the populations of these areas will continue to grow; however, this growth will be slower relative to a case where the proposed WSA had not been developed.

In Western Sydney, the strongest growth is estimated to occur in the following LGAs:

- Penrith
- The Blue Mountains.
- Blacktown
- Wollondilly
- Camden

Growth in these LGAs is expected to be supported by slowing growth in other LGAs further from the proposed WSA development.

Table 14 outlines how the population of each LGA is expected to change in 2031 and 2063 relative to a case where there was no airport development. Table 14 also presents the expected percentage change in population, by LGA, relative to a scenario without the proposed WSA development (in 2031).

Table 14: Population change by LGA Region

LGA – population change	2031	2063	2031 %
Wollondilly	1,063	4,033	1.9%
Camden	4,152	22,474	2.6%
Penrith	12,176	48,777	4.7%
Blacktown	1,734	5,443	0.4%
Blue Mountains	3,277	12,232	3.4%

Source: EY analysis

4.4 Employment model results

A number of variables are significant at the 10% statistical significance level in the employment density model, making them useful explanatory variables for describing employment density.

4.4.1 Employment impacts

The relevant estimated elasticities and coefficients in the employment model regression are used to find the change in employment (and therefore employment density) by travel zone. That is:

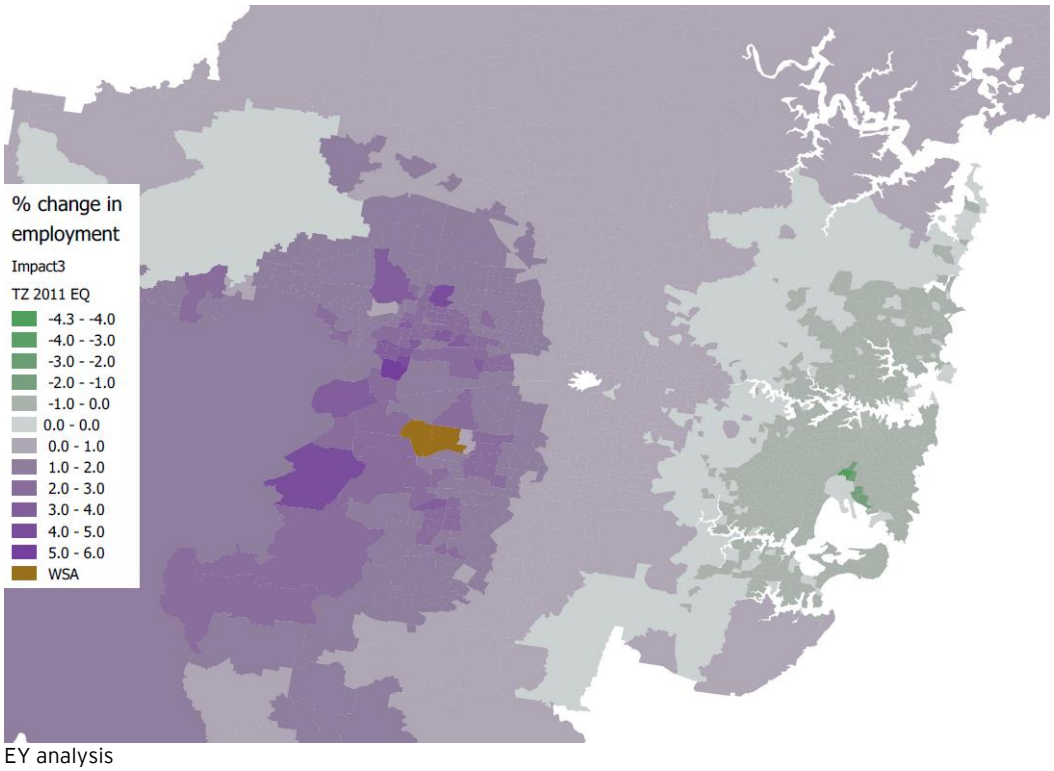
- Employment (firm) accessibility elasticity is applied to the change in employment accessibility resulting from the implementation of WSA
- Population (worker) accessibility elasticity is applied to the change in population accessibility resulting from the implementation of WSA
- The effect of being within an airport zone is applied to those travel zones containing the WSA
- The effect of being within 5km of the airport is applied to those travel zones that are to be within 5km of the new WSA airport.

Just like in the population model, for the purposes of this land use analysis it is assumed that there is no net new employment in Sydney as a result of WSA. Instead, employment is redistributed across Sydney after the implementation of WSA and the associated changes in accessibility. The estimated change in employment is incremental on the Base Case of no WSA, therefore areas that see a reduction in employment in the analysis do not necessarily decline in absolute terms, rather they do not grow by as much as they otherwise would have without WSA.

4.4.2 Change in employment density

By applying the population and employment accessibility elasticities found above, to the change in job accessibility in 2031 and 2063 that results from the introduction of the WSA, the change in employment density in each TZ11 is found. This can be seen visually, for 2031, in Figure 11.[12]

Figure 11: Employment density change as a result of WSA[13]



EY analysis

4.4.3 Change in employment

The analysis found that by 2031 WSA will enable an additional job growth of 6,930 in Western Sydney.

Table 15 provides a summary of the effects of the WSA on employment in Western Sydney. As can be seen, the Sydney West region is anticipated to see the largest increase in population in Western Sydney in 2031 and beyond. Sydney South West will see a large increase, particularly in 2063. These jobs will be distributed away from the Rest of Sydney.

[12] Note that the orange area illustrates the two TZ11 which best correspond to the location of the airport. The actual airport area is different.

[13] Note that the site marked is not the proposed airport site – the area marked is the travel zones that the proposed Badgerys Creek site falls within

Table 15: Change in Western Sydney employment in 2031 as a result of WSA[14]

Region	2031	2063
Sydney South West	2,000	10,600
Sydney West	3,000	14,300
Sydney West Central	1,900	4,300
Rest of Sydney	-7,200	-29,800
Rest of NSW	300	600

Source: EY

When considering the results outlined above, it is important to note that while Rest of Sydney and Rest of NSW have a negative result over the course of the planning period, this is not to say that the employment of these areas will decrease. Rather, the employment of these areas will continue to grow; however, this growth will be slower relative to a case where the proposed WSA had not been developed.

In Western Sydney, the strongest growth is estimated to occur in the following LGAs:

- Penrith
- The Blue Mountains.
- Wollondilly.

Growth in these LGAs is expected to be supported by slowing growth in other LGAs further from the proposed WSA development.

Table 16 outlines how the employment of each LGA is expected to change in 2031 and 2063 relative to a case where there was no airport development. Table 16 also presents the expected percentage change in employment, by LGA, relative to a scenario without the proposed WSA development (in 2031).

Table 16: Employment change by LGA Region as a result of WSA

LGA – employment change	2031	2063	2031 %
Wollondilly	244	1,080	1.6%
Penrith	2,345	11,672	2.0%
Blue Mountains	373	1,539	1.5%

EY analysis

4.5 Conclusions

As anticipated, the building of the new WSA airport will have a significant impact on both worker and job accessibility in Sydney which will lead to changes in population and employment density in the future, relative to if WSA were not built.

WSA will make it more attractive for people to live in Western Sydney by virtue of people having a greater access to jobs and wanting to be closer to an airport. This will lead to a relatively higher population density in areas like Penrith, the Blue Mountains, Blacktown, Wollondilly and Camden. These people would otherwise have continued living in the rest of Sydney, in places like Randwick, Hornsby and Canterbury, and also other parts of Sydney West Central such as Parramatta and Bankstown.

WSA will also make it more attractive for firms to set up in Western Sydney as they will have access to a greater number of workers and also be closer to other firms, enabling knowledge spill-over. Therefore,

[14] Note that this does not include the employment that will be taken up directly on-site at WSA

relative to natural 'Base Case' growth (i.e. without WSA), there will be relatively higher employment densities in Western Sydney, particularly in areas like Penrith and Blacktown, but also in Liverpool, Fairfield and Camden and across the rest of Sydney's West.

4.5.1 Value of working closer to home in Western Sydney

While Western Sydney has almost half (47 per cent) of Sydney's residents, the region has just over one third (36 per cent) of the city's jobs. This means that many Western Sydney residents must travel outside the region for work, particularly for well-paid professional and tertiary level jobs.

Around 30 per cent of the resident workforce travel to other parts of the city to get to work,[15] underscoring the importance of creating more jobs in the city's west. This dispersed employment has placed significant pressure on Sydney's transport infrastructure and generated many economic costs, including those associated with traffic congestion and disruption.[16]

The majority of employment growth in the next 20 years is expected to occur in the Sydney central business district, away from the majority of Sydney's population growth in Western Sydney. As a result, the region's job shortage ('job deficit') is expected to grow to 300,000 by 2036, with an estimated 450,000 extra jobs needed in the next 25 years to prevent the job deficit worsening.

Increased employment in the region as a result of the proposed WSA would reduce the need for residents to travel outside Western Sydney for work. In turn, this has the potential to reduce the costs of travel incurred by Western Sydney residents, increase the accessibility and efficiency of the wider transport network, and reduce unemployment in the region. This in turn can deliver a series of benefits:

- **Potentially reducing commuter times for individuals** and thereby reducing energy use, cutting carbon emissions, raising the overall productivity of the workforce and increasing people's quality of life
- **Generating higher levels of social cohesion and a greater sense of community**, with new and diverse employment opportunities offering psychological benefits associated with having a job and additional career choices, without the need to relocate. This feeds into other social benefits including increased social inclusion, good mental health and greater life satisfaction.

[15] Bureau of Transport Statistics, *2011 Journey to Work datasets,* NSW Government, Sydney, 2013

[16] Dispersed employment also contributes to residents in Western Sydney being more dependent on their cars for transport than other parts of the city. For example, the average vehicle kilometres travelled per person in Campbelltown and Liverpool is twice that of residents in inner Sydney or the eastern suburbs, while just four per cent of Camden's workforce travels to work by bus or train, compared to 20 per cent in Burwood.

Limitations

A number of limitations apply to the numbers that have been presented in this section. Furthermore, a number of simplifying assumptions were made to undertake the analysis.

- The estimates outlined in the land use analysis assume a net zero gain to employment across NSW. Therefore, all jobs that are redistributed to Western Sydney as a result of the proposed WSA would have existed elsewhere in NSW had WSA not been developed. Therefore, the land use assessment considers the relocation of population and employment, and holds total employment and population in NSW fixed whether WSA is developed or not

- This work is demand driven (i.e. where people want to move to) and does not consider existing or potential future plans for land use in NSW. For example, there is currently no intention from the NSW Government to have the Western Sydney Employment Area support any of the employment impacts of Stage 1. However, this has not been taken into consideration as part of the land use modelling

- The land use modelling is undertaken to provide a richer picture of how the WSA project impacts on firms and residents across Sydney. It represents a simplified model of the drivers of land use and is designed to provide an understanding of the general impacts on densities caused by these drivers. The model is not designed to provide an accurate prediction of impacts at a detailed level.

- The elasticity estimates produced by the land use models should be interpreted as being an 'on average' estimate, and all else being equal. They should not be taken to be 'exact' population and employment density responses to accessibility.

- The model does not take into account time and how preferences may change over time (between now and 2063). Estimates should be thought of as a point in time cross sectional estimate.

- The model only estimates population and employment redistribution as a result of a change in accessibility. Results should therefore be treated as separate from CGE results, which takes into account a number of additional changes as a result of WSA, such as travel time savings and productivity.

Section D
Economic impacts of operations



5. CGE analysis

WSA will deliver significant economic benefits. This section considers the final incidence of the economic gains, both in terms of the 'who' and 'where' of the benefits.

5.1 Data Sources

Raw data inputs underpinning the economy, such as output, consumption, labour, capital, imports and exports are sourced from REMPLAN Economy 2015 Input-Output tables. Input-Output tables are used for the four areas making up the model – Western Sydney, Rest of Sydney, Rest of NSW and Rest of Australia.

Elasticity parameters used in the model, such as for the household utility function and the firm production function, are sourced externally, but where necessary are adjusted to reflect the Australian economy.

5.2 CGE Models

CGE models are used to measure the full set of impacts of a change in economic conditions in an economy. These changes can include Government or consumer spending, population, workforce, industry (such as an increase/decrease in wages), the building of infrastructure, or any other policy change. These changes will all flow through the economy subject to the inter-relationships between various agents that participate in it. These inter-relationships exist for any number of spatial units (regions) in the economy. For example, if the economy is made up of four regions, each region would contain its own set of flows between agents, whilst it would import/export to each of the other regions making up the economy.

The purpose of the CGE modelling for the proposed WSA development is to provide a richer picture of how the proposed WSA will affect individuals and business across Sydney, NSW and Australia. The CGE model applied is a high-level model with significant simplifying assumptions and results should be interpreted with this in mind.

5.2.1 Flows and relationships between agents in the economy

Inter-relationships between economic agents, which result in the various flows of output, capital and labour in the economy, include:

Demand-side

- Households maximise utility from consumption subject to their budget constraint
- Government - Government demands and consumes output produced by firms across all industries
- The 'rest of the world' – The 'rest of the world' demands and consumes output produced by firms across all industries.
- Firms – firms demand output for use as intermediate inputs in their own production

Supply-side

- Firms – Firms across a number of industries produce output that is demanded in the economy by combining intermediate inputs produced by other firms and adding their own value-add
- Households – households provide the capital and labour that is needed by firms to produce value-add
- The 'rest of the world' – The 'rest of the world' supplies the output that is demanded by the economy that is not sourced domestically.

5.2.2 General equilibrium

Given the set of inter-relationships and flows as outlined above, an economy is said to be in 'general equilibrium' when a set of conditions are met. These are:

- Demand equals supply of output in all industries
- Labour supply equals labour demand
- Capital supply equals capital demand
- Income in any industry equals its expenditure (this implies that the economy is perfectly competitive, i.e. no supernormal profits).

Because of the interconnectedness of the economy and the set of flows between agents, any change that affects an agent in the economy is going to shift the economy out of general equilibrium. In order to move back into equilibrium, a series of 'indirect' changes, or effects, take place through the economy. CGE models find the new equilibrium, thereby capturing the direct and indirect effects of the initial change in the economy. General equilibrium is reached through a series of behavioural relationships on both the production and consumption sides of the economy.

5.2.3 How general equilibrium is reached - behavioural relationships of firms and households

In order to measure the total impact as a result of a direct change to the economy, agent behaviour must be modelled. CGE models therefore incorporate a series of behavioural rules which govern how these various agents act and respond to changes in the conditions they face.

Firms

- Firms choose production so as to maximise profits subject to their budget constraint
- Once a level of production has been chosen, firms decide how to produce it. This can be thought of as comprising six steps:
    - Determine the share of production sourced from intermediate inputs and value-add (e.g. how much of production is sourced externally and how much is produced in-house)
    - Determine the share of value-add from labour and capital (e.g. whether to invest in more machines to reduce labour need)
    - Of the labour share, determine the optimal mix of labour type (across various occupations)
    - Of the capital share, determine the optimal mix between physical capital (e.g. machines, plant equipment) and land
    - Determine the optimal intermediate input mix (across the various industries/ products available in the economy) (e.g. whether to purchase raw materials directly from the agricultural sector or processed materials from the wholesale sector)
    - Determine the share of the intermediate inputs sourced from own region (termed 'domestic region') vs. imports from each of the other modelled areas (inter-region or international imports).

These firm decisions are governed by firm technology as well as relative prices of intermediate inputs, capital and labour (domestic, inter region and international).

Households

- Households maximise utility from consumption subject to their budget constraint
- Given the total budget available, households decide the optimal consumption mix in two steps:
    - Determine the consumption mix across the products available in the economy (e.g. to consume more leisure services at the expense of housing)
    - Determine the share of consumption sourced domestically vs. imports

These household decisions are governed by household preferences as well as the relative prices of products (domestic, inter region and international).

Labour Supply

Households in each modelled area supply labour to firms in each of the model areas:

- Households supply different types of labour ranging from labourers to managers (there are eight types of occupations offered, subject to ABS OCCP 1 digit level)
- Households supply this labour subject to relative real perceived wages (i.e. higher real wages in a location increases labour supply to that location).
- Relative perceived wages are a function of salaries and also commuting travel time (e.g. lower commuting costs from A to B increases the 'perceived' relative wage in location B for residents in A)

5.2.4 What CGE models capture

CGE models are able to capture and report a series of macroeconomic and social indicators for each region that makes up the economy, before and after the exogenous change runs through it. These include:

- Value-add for every modelled industry in the economy
- Productivity for every industry in the economy
- Employment and labour income in the economy
- Business profits
- Net imports/exports

This therefore makes CGE models a good tool for capturing the economy-wide spatial impacts of a change in infrastructure. By translating some of the benefits / impacts that can accrue to users and producers of an infrastructure asset, CGE makes them identifiable from a macro perspective which demonstrates how new infrastructure can improve the economy in an aggregate sense.

5.2.5 Approach to this assessment - Spatial general equilibrium model

To develop evidence on these flow-on impacts of WSA on the wider economy, a spatial economic impact model (i.e. a Spatial General Equilibrium Model, SCGE) was used. A SCGE can assist in the translation of the potential benefits from an infrastructure investment into real economic impacts accrued to people 'on the ground'. In other words, an SCGE translates potential time and cost savings to individuals and businesses and accessibility gains (as a result of the new airport development) into area-specific changes in wages, productivity, incomes, value add and prices.

Again, it is important to note that the CGE model that has been prepared to consider the proposed WSA development is not intended to be a macro-economic exercise to understand the net outcomes of the

proposed WSA development, operations and financing. Instead it considers the final incidence of potential benefits of the proposed development amongst businesses, workers and individuals.

Metrics to describe the impact of the WSA through use of the SCGE include (all in real values):

- **Increased value add** – value add is the value of output produced less the cost of intermediate inputs used in the production of that output and expresses the net wealth generated by the activity. WSA will result in higher value-add per year by supporting productivity and growth, delivering benefits to businesses and workers alike.
- **Gross business profits** – the share of an increase in value-add that is retained as real returns to owners, investors and others who finance businesses.
- **Gross household labour incomes** – the share of an increase in value-add that is enjoyed by households through an increase in real wages.
- **Enhanced productivity per worker** – this is change in real value-add per worker per year. WSA enables workers in Western Sydney, and indeed the Rest of Sydney to be more productive due to a reduction in the cost of aviation services.
- **Net imports** – the balance of the real value of exports and imports in a region, representing both domestic, inter-regional trade and international trade.

5.3 WSA CGE methodology

5.3.1 Geography

The WSA SCGE model is set up to represent transactions taking place between individuals, businesses and governments, in terms of consumption, labour, capital, real estate and trade. Households provide labour and capital to firms and use the income to purchase goods and services. Firms use inputs sourced from other firms, as well as labour and capital, to produce goods and services, which are in turn sold to households and to other firms. These transactions are represented for four spatial areas (termed 'regions', which are:

- Western Sydney (WS) = r_1
- Rest of Sydney (RoS) = r_2
- Rest of NSW (RoNSW) = r_3
- Rest of Australia (RoAus) = r_4
- Rest of world (ROW) = e

Transactions happen both within regions and between them – that is, all parties can decide to purchase goods, services, labour and capital either from within a region or 'import' from any of the other regions.

Western Sydney

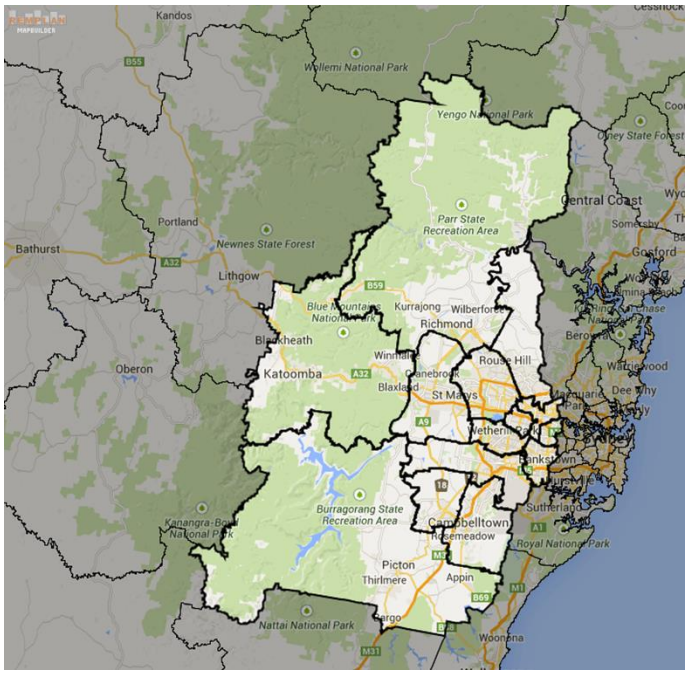
Western Sydney is made up of the following LGA areas:

- Parramatta (C)
- Bankstown (C)
- Liverpool (C)
- Fairfield (C)
- Holroyd (C)
- Penrith (C)
- Blacktown (C)
- Campbelltown (C)
- Camden (A)
- Hawkesbury (C)
- Wollondilly (A)

- The Hills Shire (A)
- Blue Mountains (C)
- Auburn (C)

Figure 12 illustrates how Western Sydney has been defined.

Figure 12: Western Sydney



Rest of Sydney

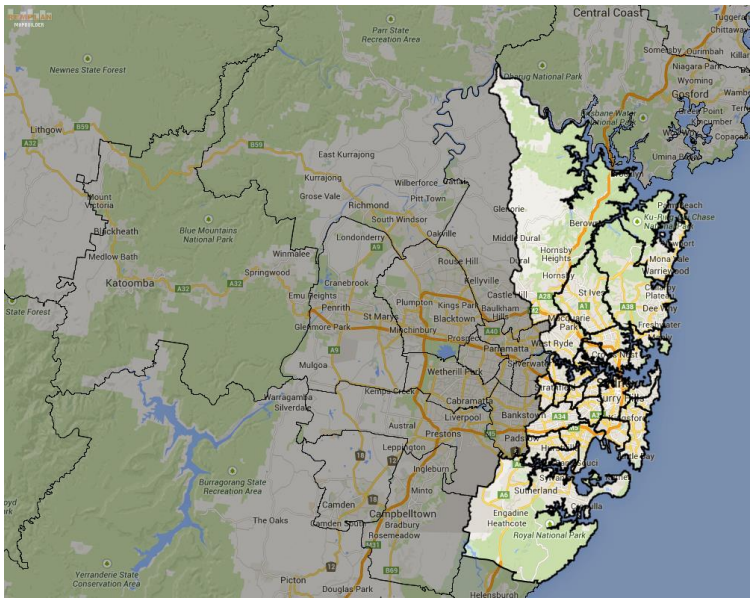
The 'Rest of Sydney' is made up of the following LGA areas:

- Sydney (C)
- Botany Bay (C)
- Rockdale (C)
- Marrickville (A)
- Canterbury (C)
- Strathfield (A)
- Burwood (A)
- Canada Bay (A)
- Ashfield (A)
- Leichhardt (A)
- Woollahra (A)
- Waverley (A)
- Randwick (C)
- Manly (A)
- Kogarah (C)
- Hurstville (C)
- North Sydney (A)
- Mosman (A)
- Willoughby (C)
- Lane Cove (A)
- Hunters Hill (A)
- Ryde (C)
- Ku-ring-gai (A)
- Hornsby (A)

- Sutherland Shire (A)
- Warringah (A)
- Pittwater (A)

Figure 13 shows how Rest of Sydney region is defined.

Figure 13: Rest of Sydney



Other spatial areas

The two other spatial areas informing the model are Rest of NSW and Rest of Australia.

The model is calibrated based on observed patterns of transactions, including intra and interregional trade and commuting.

5.3.2 Industries

Each region contains 9 industries. These are produced by grouping the REMPLAN transactions table data for each region into the following industries:

- Primary
- Manufacturing and Construction
- Utilities
- Food and trade
- Transport
- Technology
- Financial and Advisory
- Public and Social
- Other Services

5.4 Consumption

5.4.1 Households

Each of the locations in the model includes a representative household which demands and consumes goods.

Each good can be thought of as a generic good produced by each of the 9 industries. Households must first choose their consumption good mix which forms the first stage of the household consumption decision.

After choosing the consumption good mix, households must then decide from what region to source these goods.

5.4.2 Government

In the model, it is assumed that the Government acts as a consumer in much the same way as a typical household described above. Governments must firstly determine their optimal consumption good mix, before deciding where to source this consumption mix from. In this way, the Government is just another consumer.

5.4.3 Exports for consumption

While the 'rest of world' also imports products from the modelled regions, it is not explicitly modelled. The 'rest of world' is therefore represented as another consumer purchasing goods from each of the modelled regions and treated in the same fashion as households and Government (i.e. with the use of a CES utility function).

The addition of household and Government consumption as well as inter-region and rest of world consumption of a region's goods gives total consumption demand in that region.

5.5 Production

Output in the economy is produced by a representative firm in each of the 9 industries, and each of the four regions. Of this output, a proportion is made up of intermediate inputs sourced from other industries (or its own), with the remainder generated as value-add.

To create the value-add, a combination of primary inputs (in this model labour and capital) are used. Labour and capital is provided by households. While overall labour supply is relatively inelastic, it can be sourced from any of the four regions in the economy (see below). Capital supply, on the other hand, is elastic.

Once firms choose the amount of labour they need, they then choose what type of labour they need. They choose between eight different occupations. Similarly, firms must choose what type of capital they need in production – either physical capital (such as machinery or plant equipment) or land.

The intermediate inputs used in production are chosen by each firm and made up of a combination of each of the other industry's output. For each of these inputs, a proportion is sourced locally and a proportion is sourced from other regions and the rest of the world.

Choosing the mix of labour and capital

After determining the level of value-add to be produced, firms then decide the optimal combination of labour and capital to produce that value-add.

5.6 Labour

5.6.1 Choosing the occupation mix

Firms choose the occupational mix of labour which optimises the labour component of the value-add of their production.

The different occupations that firms are able to choose in their production are:

- Managers
- Professionals
- Technicians and Trades Workers

- Community and Personal Service Workers
- Clerical and Administrative Workers
- Sales Workers
- Machinery Operators and Drivers
- Labourers

5.6.2 Journey to work

Regardless of where workers in households live, workers may decide to commute to work in any of the regions.

The decision on where to work is a function of the relative wage of workers (perceived wage in region of residence versus perceived wage in region of work) and travel time to get to work. A higher wage at home relative to the other regions makes it more attractive for workers to not travel out of the region; likewise a higher travel time also makes it less attractive to workers to travel outside their region of residence to work.

Perceived Salary

The perceived salary faced by workers in a region is a function of the wage in that region and the commuting time to reach that region.

Labour Supply

The labour supply in any origin-destination pair is a function of the ratio of perceived wage to the average perceived wage faced by workers living in a certain origin and the elasticity of labour supply. The labour supply elasticity represents the responsiveness (or willingness) of labour to move into different regions to work as the relative perceived wage in that region changes (holding place of residence constant). A labour supply of 0.15 has been selected for the model.[17]

Migration

One of the effects of WSA can be to attract residents into Western Sydney and the Rest of Sydney. Household's location decisions are determined based on relative real perceived wage levels between locations. If workers living in a certain location see lower prices, higher wages or lower cost of accessing jobs, there will be an inflow of residents to that location.

5.7 The Australian economy – initial sectoral structure

Before introducing the effects of WSA on the four region Australian economy, the model is in its initial equilibrium. That is, all of the conditions previously outlined (labour demand = labour supply etc.) are true. Prices of goods, capital and labour are normalized and taken to be 1.

For all regions, the labour, capital and goods market all clear:

- Wages are such that the labour market clears
- Capital rents are such that the capital market clears
- The price of output is such that the goods market clears

[17] Fullerton, Shoven and Whalley - Dynamic General Equilibrium Impacts of Replacing the US Income Tax with a Progressive Consumption Tax

5.8 The Implementation of Western Sydney Airport

The potential benefits that result from the construction of WSA can be translated into impacts on the macro economy in Sydney. The SCGE model is able to take potential benefits and use them as 'shocks' or exogenous changes to the Australian economy.

Specific benefits which have been considered as 'shocks' to the economy in the SCGE model are:

- Willingness to pay benefits accruing to consumers
- Producer surplus benefits accruing to airlines.

This means that, as previously identified, the SCGE model that has been prepared to consider the proposed WSA development is not intended to be a macro-economic exercise to understand the net outcomes of the proposed WSA development, operations and financing. Instead it considers the final incidence of potential benefits of the proposed development amongst businesses, workers and individuals.

Willingness to pay benefits to consumers

WSA will result in a set of benefits to aviation users, including the reduced costs of accessing aviation services and reduced passenger delays. It will also result in benefits accruing to new passengers who otherwise would not access aviation services from Sydney. These savings enter the labour production function in the form of labour productivity, representing an increase in productivity of each type of occupation and in each sector for that particular region.

Therefore the higher the willingness to pay benefits, the higher is the increase in productivity per worker and value-add that is attributed to labour. By helping workers become more productive, WSA is helping increase the level of value-add per unit of labour, increasing wages and overall value-add in the Sydney and NSW economies.

Producer surplus accruing to airlines

The introduction of WSA will also result in an increase in total factor productivity in the aviation sector. This is attributed to the operational savings (producer surplus) that will be made to airlines. In the CGE model, this increase in total factor productivity is captured in the firm's value-add production process.

By enabling a total factor productivity gain, WSA is increasing the amount of value-add that results from a given level of capital and labour in the aviation sector.

5.9 Results

The increase in labour and total factor productivity results in increased efficiency and, initially, a reduction in the prices businesses charge for their products. This increases demand for these products, through increased consumption and increased demand for each region's product from other regions and from overseas.

As these impacts ripple through the economy, households and firms keep responding until prices adjust to ensure demand equals supply in all markets. The difference between the new 'equilibrium' outcome and the initial situation represent the changes caused by the introduction of WSA.

It should be noted that summing changes in labour income and business profits will not add up to change in total value-add due to these using different price indexes to bring the figures into 'real' terms. Business profits and labour income are converted using CPI, whereas total value-add is converted into real terms using an RPI (retail price index).

Table 17 reports selected outputs from the model. These include changes in value-add ($m), productivity ($/worker), business profits ($m), household income ($/worker) and exports ($m).

Table 17: Summary results – 2031 – change on Base Case as a result of WSA

Revised Label	Unit	Western Sydney	Rest of Sydney	Rest of NSW	Rest of Australia	Total
value add	$	$77m	$145m	$23m	-$39m	$205m
Business profits	$	$27m	$42m	$11m	-$8m	$73m
productivity per worker	$	$90	$95	$20	-$4	$17
Labour income	$	$44m	$50m	$15m	$32m	$140m
Net imports	$	$23m	-$36m	$5m	$55m	$47m

Source: EY CGE model

The project generates an additional $205m in value-add per year across Australia, the majority of which in Sydney. There is a reduction in value-add in the Rest of Australia (outside NSW), reflecting economic activity that is attracted to Sydney / NSW. The increase in value-add is supported by increases in productivity per worker, averaging $23 across the country, but reaching $90 per worker in Western Sydney and $95 per worker in Rest of Sydney.

$73m is earned annually as additional profits by businesses, again with the majority of the benefits accruing to Sydney. There are smaller positive benefits to the Rest of NSW and a negative impact on the Rest of Australia, again reflecting activity that is diverted to Sydney.

The impact on household incomes is $140m per year. Here significant regional spillovers are apparent, with a substantial share of the total gains falling to Rest of Australia, mainly through lower prices on imports from NSW. In this way it can be seen how WSA will also have a positive impact on households outside of NSW. Still, the largest benefit also here accrues to residents in Sydney.

Patterns of trade differ between the regions. There are two main opposing effects - additional incomes results in an increase in imports, while impact of lower prices mean improved competitiveness generates an increase in exports. For Western Sydney and the Rest of Australia the balance favours additional imports. For Rest of Sydney, the increased competitiveness dominates. The reason for these differences is primarily the sectoral composition – Rest of Sydney includes the Sydney CBD which contains a significant amount of export oriented service sectors.

Table 18 show the same set of impacts in 2063. The patterns are very similar, although the impacts are much larger, reflecting the larger productivity gains in those years.

Table 18: Summary results – 2063 – change on Base Case as a result of WSA

Revised Label	Unit	Western Sydney	Rest of Sydney	Rest of NSW	Rest of Australia	Total
value add	$	$1507m	$4640m	$506m	-$815m	$5838m
Business profits	$	$541m	$1372m	$248m	-$138m	$2023m
productivity per worker	$	$941	$1613	$225	-$42	$252
Labour income	$	$869m	$1580m	$333m	$670m	$3452m
Net imports	$	$660m	-$1015m	$372m	$1389m	$1406m

Source: EY CGE model

By 2063, WSA is expected to increase value-add in the Australian economy by $5.8bn, of which the majority is enjoyed by the Rest of Sydney. About $800m of value-add is diverted from Rest of Australia to NSW.

Worker productivity increases significantly, by $940 per worker in Western Sydney and $1,600 in Rest of Sydney. A smaller negative impact to Rest of Australia is caused by a compositional impact – as the activity that is attracted to NSW is on balance of higher-than-average productivity per worker.

Business profits increase by $2bn per year, the vast majority to NSW. Household incomes increase across all the regions, from $333m per year in Rest of NSW to $1.6bn per year in Rest of Sydney. All regions also now see an increase in net imports.

5.10 Conclusion

The economic modelling in this section investigates the final incidence of these gains after they have rippled through the Australian economy. The modelling finds that in response to the introduction of WSA, Sydney is better able to attract economic activity away from the Rest of Australia, leading to increased business profits reaching $2bn per year by 2063. Household incomes, however, increase across Australia, with $2.5bn enjoyed by Sydney residents and a further $1bn shared between Rest of NSW and the Rest of Australia. On average, Australian value-add per worker increases by $250 per year.

Limitations of the analysis

A number of limitations were identified to the scope of the analysis presented above. Furthermore, a number of simplifying assumptions were made to undertake the analysis.

- The purpose of the CGE modelling is to provide a richer picture of how the proposed WSA will affect individuals and business across Sydney, NSW and Australia. The CGE model applied is a high-level model with significant simplifying assumptions and results should be interpreted with this in mind.
- The CGE model, although built on accepted microeconomic foundations, presents a simplified and highly aggregated version of the Australian economy. All industries and households are assumed to be homogenous in that the same production and utility function represents all agents. In reality, individual preferences and firm structures are going to differ across various agents.
- The CGE model captures increases in household expenditure and gross value add in the economy as a result of the proposed WSA. However, it is important to note that the CGE model that has been prepared to consider the proposed WSA development is not intended to be a macro-economic exercise to understand the net outcomes of the proposed WSA development, operations and financing. Instead it considers the final incidence of potential benefits of the proposed development amongst businesses, workers and individuals.
- It is assumed that the economy achieves Pareto optimality, that is, no individual can become better off without another becoming worse off. In reality, it would be expected that there are inefficiencies in the economy that can be overcome to make some agents better off without making other agents worse off.
- It is assumed that there is perfect competition amongst firms in the economy. In reality there are sectors in the economy that are not perfectly competitive, where firms are able to earn a supernormal profit. In this way the CGE model of the Australian economy presents a simplified market structure which is not fully representative of the economy.
- The Constant elasticity of substitution function was assumed for firms and households in the model. Elasticities underpinning these functions were sourced from external sources or based on economic theory. They were not estimated using econometric methods.

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